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Открытые семантические технологии проектирования интеллектуальных систем

Open Semantic Technologies for Intelligent Systems

МАТЕРИАЛЫ
МЕЖДУНАРОДНОЙ
НАУЧНО-ТЕХНИЧЕСКОЙ КОНФЕРЕНЦИИ

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Kureychik V.	d. of t.s., RF proff.
Kuznetsov O.	d. of t.s., RF proff.
Lande D.	d. of t.s., Ukraine
Lobanov B.	d. of t.s., RB proff.
Loukachevitch N.	c. of ph.-m.s., RF
Massel L.	d. of t.s., RF proff.
Nevzorova O.	c. of t.s., RF ass. Proff.
Osipov G.	d. of ph.-m.s., RF proff.
Palyukh B.	d. of t.s., RF proff.
Petrovsky A.	d. of t.s., RB proff.
Petrovsky A.	c. of t.s., d. of t.s., RF proff.
Plesniewicz G.	c. of ph.-m.s., RF
Robert I.	Academician of REA, d. of teach.s., RF proff.
Rybina G.V.	d. of t.s., RF proff.
Sharipbay A.	d. of t.s., Kazakhstan proff.
Sidorkina I.	d. of t.s., RF proff.
Smirnov S.	d. of t.s., RF proff.
Soloviev S.	d. of ph.-m.s., RF proff.
Sosnin P.	d. of t.s., RF proff.
Stefanuk V.	d. of t.s., RF proff.
Suleymanov D.	AS Tatarstan academician, KF
Tarasov V.	c. of t.s., RF ass. Proff.
Telnov Yu.	d. of e.s., RF proff.
Tuzikov A.	d. of ph.-m.s., RB proff.
Vasilyev S.	academician of RAS, d. of ph.-m.s., RB proff.
Walkman Yu.R.	d. of t.s., Ukraine proff.
Yarushkina N.G.	d. of t.s., RF proff.
Yankovskaya A.E.	d. of t.s., RF proff.
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ПРЕДИСЛОВИЕ

Основным практическим результатом исследований в области искусственного интеллекта является разработка не только интеллектуальных систем, но и технологий, обеспечивающих быстрое и качественное построение таких систем. Создание указанных технологий требует решения следующих задач:

- чёткого выделения логико-семантического уровня интеллектуальных систем, который абстрагируется от всевозможных вариантов технической реализации этих систем (в том числе и от использования принципиально новых компьютеров, ориентированных на аппаратную поддержку интеллектуальных систем);
- разработки онтологии проектирования интеллектуальных систем и унификации описания логико-семантических моделей интеллектуальных систем;
- обеспечения платформенно независимого характера логического проектирования интеллектуальных систем, результатом которого является унифицированное описание логико-семантических моделей проектируемых интеллектуальных систем;
- использования методики компонентного проектирования интеллектуальных систем, в основе которой лежит постоянно пополняемая библиотека многократно используемых компонентов интеллектуальных систем (многократно используемых подсистем, компонентов баз знаний, агентов обработки знаний, компонентов пользовательских интерфейсов);
- обеспечения семантической совместимости многократно используемых компонентов интеллектуальных систем и семантической совместимости самих интеллектуальных систем и технологий их проектирования.

Основной целью ежегодных международных научно-технических конференций OSTIS (Open Semantic Technology for Intelligent Systems) является создание условий для расширения сотрудничества различных научных школ, вузов и коммерческих организаций, направленного на разработку и применение массовых и постоянно совершенствуемых технологий компонентного проектирования интеллектуальных систем.

Основной темой VII конференции OSTIS является онтологическое проектирование интеллектуальных систем и их компонентов.

VII конференция OSTIS посвящается памяти Аркадия Николаевича Борисова – профессора Рижского Технического университета, доктора технических наук, хабилитированного доктора компьютерных наук.

Председатель Программного комитета конференции OSTIS-2017
Председатель Совета Российской ассоциации искусственного интеллекта
Кузнецов Олег Петрович

FOREWORD

Development of not only intelligent systems but also technologies that ensure fast and efficient construction of intelligent systems is the main practical result of research in the artificial intelligence. Development of these technologies requires the following tasks solution:

- precise separation of logical-semantic level of intelligent systems, which is abstracted from various variants of the technical implementation of these systems (including the use of innovative computer-based hardware support for intelligent Systems);
- development of the ontology of intelligent systems design and unification of intelligent systems logical-semantic models description;
- providing of a platform independent nature of the logical design of intelligent systems, which result is a unified description of logical-semantic models of intelligent systems;
- use of a component design methodology of intelligent systems, which is based on permanently expanding library of reusable components of intelligent systems (reusable subsystems, knowledge bases components, knowledge processing agents, user interfaces components);
- ensuring of semantic compatibility of reusable components of intelligent systems and semantic compatibility of these intelligent systems and technologies of such systems design.

Creating the conditions for the expansion of cooperation between different scientific schools, universities and business organizations, aimed on the development and using of mass and continuously improved component design technologies for intelligent systems is the main purpose of annual international scientific and technical conferences OSTIS (Open Semantic Technology for Intelligent Systems).

The main topic of the VII OSTIS Conference is an ontology-based design of intelligent systems and their components.

VII OSTIS Conference is dedicated to the memory of Arkady Nikolaevich Borisov - professor of Riga Technical university, doctor of technical sciences, habilitated doctor of computer science.

Programme Committee Chair.
Chairman of the Council of the Russian Association for Artificial Intelligence
Kuznetsov Oleg Petrovich

Памяти Аркадия Николаевича Борисова

Аркадий Николаевич Борисов
(3 февраля 1938 г. – 14 мая 2016 г.)

14 мая 2016 г. на 79-ом году ушёл из жизни Аркадий Николаевич Борисов – профессор Рижского Технического университета, доктор технических наук, хабилитированный доктор компьютерных наук, создатель Латвийской научной школы по теории принятия решений, методам обработки нечёткой информации и интеллектуальным компьютерным технологиям.

Аркадий Николаевич родился 3 февраля 1938 года в Киеве. В 1964 году окончил Рижский политехнический институт (ныне Рижский технический университет, РТУ), а в 1970 г. защитил кандидатскую диссертацию, в которой предложил обучающиеся алгоритмы диагностики систем с нечёткими классами состояний, а также использование теней нечётких множеств для распознавания образов. В том же году активно участвовал в создании кафедры автоматизированных систем управления (АСУ) Рижского политехнического института и стал её первым и многолетним заведующим. Коллектив кафедры под руководством А.Н. Борисова добился серьезных успехов в подготовке специалистов в области системного анализа и решения задач в сфере информационных технологий, а также в научно-исследовательской работе.

В 1986 году А.Н. Борисов защитил диссертацию на соискание ученой степени доктора технических наук по методам и алгоритмам принятия решений в условиях многокритериальности и нечёткой исходной информации. Впоследствии получил учёное звание профессора по кафедре АСУ. В 1997 году в качестве директора возглавил профильный институт интеллектуальных компьютерных технологий РТУ. С 2003 года работал профессором кафедры моделирования и имитации РТУ и руководил группой систем поддержки принятия решений.

Профессор А. Борисов был настоящим энтузиастом в науке, он посвятил Рижскому Техническому университету более 50 лет творческой научной и преподавательской жизни.

Говоря о начале своей научной работы, проф. Борисов вспоминал, что слово «кибернетика» появилось во время учёбы на старших курсах РПИ. Оно звучало как новый призыв. Значение этого термина уже было известно. В то время все зачитывались книгами Н.Винера «Кибернетика» и «Я – математик. Слушая теоретический курс «Теория автоматического управления» и выполняя затем лабораторные работы, студенты понимали, что постигают технические аспекты кибернетики. Затем А. Борисов получил свою задачу и самостоятельную область исследований, и впоследствии вспоминал: «Мне нравилась эта работа, и возможности технической кибернетики тогда казались безграничными».

В 1960-х годах тематика научной работы Аркадия Николаевича базировалась на новой теории американского ученого Л. Заде – теории нечётких множеств. С основными положениями этой теории научный руководитель аспиранта Борисова профессор Я.Я. Осис познакомился во время стажировки в университете Беркли, США и привез идею для своих аспирантов. Именно Я.Я. Осис и А.Н. Борисов были авторами первых в Советском Союзе публикаций по нечетким системам распознавания образов и нечетким системам принятия решений, вышедших в свет в 1967-68 годах.

Уже в 1970-х годах Аркадий Николаевич Борисов стал основателем и признанным главой знаменитой рижской школы в области нечетких систем и бывшей одной из первых не только в бывшем СССР, но и во всем мире.

Научным работникам известна важность общения с единомышленниками, с которыми можно обсудить проблемы, идеи и результаты исследований в рамках семинаров и конференций. Профессор А.Н. Борисов хорошо это понимал – научная школа под его руководством активно проводила внутренние семинары, организовала несколько международных научных конференций. По его инициативе на протяжении двух десятилетий в Риге проходили все основные конференции в области теории и приложений нечетких множеств, в частности, такие крупные форумы как «Модели выбора альтернатив в нечеткой среде», «Модели принятия решений в условиях неопределенности», «Лингвистические модели принятия решений» и др. В 1973 году А.Н. Борисов организовал в Рижском Политехническом институте ежегодный выпуск сборника научных статей под названием «Управление сложными системами» (позднее – «Методы и системы принятия решений») и являлся его научном редактором до 1993 года. Статьи, публикуемые в этом сборнике, высоко ценились многими научными школами.

А.Н. Борисов обладал чрезвычайной энергией, он был неутомимым ученым, способным исследовать и оценивать огромные объёмы научной литературы и в конечном результате безошибочно определять, какие направления исследования, темы, методы будут наиболее предпочтительными и перспективными. Коллеги профессора продолжают восхищаться его дальновидностью и талантом предвидения.

В 1980-е годы профессор Борисов вместе со своими учениками подготовил серию замечательных книг: «Модели принятия решений на основе лингвистической переменной», «Обработка нечеткой информации в системах принятия решений», «Принятие решений на основе нечетких моделей: Примеры использования» и другие, которые даже спустя 35 лет достаточно часто цитируются.

При написании монографий, профессор Борисов был очень требовательным руководителем своей созданной команды соавторов. На самом деле он старался завершить каждую более или менее пространную тему исследования, в которой были получены теоретические или практические результаты, подготовкой и публикацией монографии. Круг научных интересов профессора Борисова был чрезвычайно широк. Наряду с развитием математических методов обоснования принимаемых решений и обработки нечёткой информации, он плодотворно работал и в других областях, в том числе в области распознавания образов, применения гибридных интеллектуальных систем для автоматизации проектирования технических объектов, генетических алгоритмов, методов представления знаний в информационных системах.

В 1990-2000 годы научные интересы А.Н. Борисова сместились в область искусственного интеллекта и мягких вычислений. Под его руководством проводились работы в области генетических алгоритмов, искусственных нейронных сетей, вывода на Байесовских сетях, онтологического моделирования, результаты которых были опубликованы в ведущих европейских научных журналах и получили широкое международное признание.

Профессор А.Н. Борисов руководил выполнением многих исследовательских проектов, представлявшихся на международных научных конференциях, а также ряда прикладных проектов, результаты которых были внедрены на практике. Одним из последних был латвийско-белорусский проект по разработке интеллектуальных методов и алгоритмов обработки медико-биологической информации для диагностики онкологических заболеваний.

Профессор А.Н. Борисов был всемирно признанным экспертом в области нечетких множеств и мягких вычислений. Он был вице-президентом Российской ассоциации нечётких систем, президентом Балтийского общества исследования операций. Он являлся членом ряда международных научных организаций: Европейской рабочей группы международной ассоциации по нечётким системам IFSA, инициативной группы Беркли по мягким вычислениям (BISC), Латвийской национальной организация автоматики, Балканского общества нечётких систем и искусственного интеллекта, научного консультативного совета нечеткой инициативы земли Северный Рейн-Вестфалия, почетным членом Российской ассоциации нечётких систем и мягких вычислений, а также членом программных и научных комитетов многих международных конференций.

Аркадий Николаевич был также членом редколлегий и рецензентом нескольких международных научных журналов, включая научный журнал Российской ассоциации нечётких систем и мягких вычислений «Нечёткие системы и мягкие вычисления», международного журнала «Автоматика и вычислительная техника», или «Automatic Control and Computer Sciences», Балтийского журнала по устойчивости «Technological and Economic Development of Economy. Baltic Journal on Sustainability» и др.

Многочисленные научные труды А.Н. Борисова (10 монографий и 5 учебников, написанных с соавторами, и свыше 230 научных статей) хорошо известны специалистам в Латвии и за рубежом.

Аркадий Николаевич был замечательным организатором исследовательской и педагогической работы, отличался умением увидеть в человеке способность к научной работе, и помочь добиться результатов в

выбранном направлении исследований. За многие годы плодотворной работы он создал свою научную школу, воспитал и подготовил к самостоятельной работе много квалифицированных специалистов, научив их нестандартно думать, ставить и решать теоретические и практические задачи, работать и добиваться результатов в коллективе единомышленников, доброжелательно относиться к другим людям. В работе научной школы профессора царила атмосфера поиска новых идей, увлечённости своим делом, взаимоуважения и взаимопомощи её участников. Ещё за день до своей кончины он обсуждал с участниками своей школы задачи и направления научной работы.

Профессор А.Н. Борисов подготовил 25 кандидатов и докторов наук, более 20 магистров, которые работают в университетах, ведущих ИТ–компаниях, в банках и госучреждениях, частных компаниях Латвии, Великобритании, Германии, России и Франции.

Ниже приведенная диаграмма визуально иллюстрирует стабильную, планомерную и однородную динамику работы профессора по подготовке специалистов высшей квалификации по годам.

Сегодня, восемь бывших аспирантов и докторантов профессора Аркадия Николаевича Борисова, подготовихших и защитивших свои диссертации под его руководством, успешно продолжают работать преподавателями и исследователями на кафедре моделирования и имитации Рижского Технического университета, развивая научные идеи и поддерживая принципы своего Учителя.

Аркадий Николаевич был жизнерадостным, доброжелательным и внимательным человеком. Его интересы сосредотачивались не только на его работе. Он обладал потрясающим талантом чувствовать красоту в природе, искусстве и музыке. Профессору было присуще хорошее знание архитектуры, особенно архитектуры югендстиля, который занял особое место в его сердце. Он любил джаз и мог увидеть интересное и захватывающее в повседневных вещах. Аркадий Николаевич Борисов запомнился нам своей целеустремлённостью и умением увлечь коллег и учеников новыми идеями.

Он обладал замечательной способностью привлечь в свою группу увлеченных исследователей, объединить аналогично мыслящих людей в команду и организовать их успешное сотрудничество. Коллеги школы профессора с благодарностью вспоминают свою работу в команде, и по сей день гордятся достигнутыми в то время результатами.

Все, кому посчастливилось работать с профессором Аркадием Николаевичем Борисовым и знать его лично, будут помнить его с большой благодарностью как выдающегося ученого, умного, целеустремленного и широко образованного человека, организатора и талантливого Учителя.

Грабуст Петерис Станиславович
Ужга-Ребров Олег Иванович

Аркадий Николаевич Борисов: страницы биографии и научное наследие

Поспелов Д.А., Аверкин А.Н., Батыршин И.З.,
Тарасов В.Б., Язенин А.В.

Посвящается 50-летию исследований по нечетким множествам и их приложениям в СССР

Аннотация—Работа посвящена изложению страниц научной биографии и анализу научного наследия выдающегося советского и латвийского ученого в области нечетких систем и мягких вычислений, доктора технических наук, профессора ***Аркадия Николаевича Борисова*** – пионера исследований по нечетким множествам и их приложениям в СССР, автора первых русскоязычных статей по нечетким моделям распознавания, классификации и технической диагностики, организатора первых научных семинаров и конференций по нечетким моделям принятия решений и управления, основателя знаменитой Рижской школы принятия решений в условиях неопределенности, автора ряда классических монографий по лингвистическим и нечетким моделям принятия решений.

Ключевые слова—искусственный интеллект; нечеткое множество; лингвистическая переменная; принятие решений; распознавание; диагностика; мягкие вычисления; онтологии.

14 мая 2016 г. на 79-м году ушел из жизни **Аркадий Николаевич Борисов** – профессор, доктор технических наук, выдающийся советский и латвийский ученый в области нечетких систем и мягких вычислений, один из первопроходцев исследований по нечетким множествам и их приложениям в СССР, известный специалист по интеллектуальным системам и онтологическому моделированию, основатель знаменитой рижской школы принятия решений в условиях риска и неопределенности, распознавания и обработки нечеткой информации, интеллектуализации компьютерных технологий, член программного комитета конференций OSTIS.

Аркадий Борисов родился в Киеве 3 февраля 1938 года. В 1964 году он окончил Рижский политехнический институт (РПИ), ныне Рижский технический университет, а в 1970 году защитил кандидатскую диссертацию, в которой предложил обучающиеся алгоритмы диагностики систем с нечёткими классами состояний,а также применение теней нечётких множеств для распознавания образов. В том же году создал и стал первым заведующим новой кафедры РПИ – Кафедры АСУ. Главным достижением коллектива этой кафедры стали серьезные научные результаты в сфере нечетких множеств, моделей принятия решений, систем и технологий, которые в 1970-1980-е годы выдвинули его на ведущие позиции не только в СССР, но и во всем мире.

В 1986 году А.Н. Борисов защитил докторскую диссертацию по методам и алгоритмам принятия решений в условиях многокритериальности и нечёткой исходной информации. Затем возглавил Институт интеллектуальных компьютерных технологий Рижского технического университета (РТУ). С 2003 года работал профессором кафедры моделирования и имитации РТУ.

Профессор А.Н.Борисов на родной кафедре

Аркадием Николаевичем Борисовым написано 10 монографий и около 250 научных статей, хорошо известных специалистам в Латвии, России и многих других странах. Круг научных интересов профессора А.Н. Борисова был весьма широк: он простирался от теории нечетких множеств до нечетких экспертных систем и гибридных интеллектуальных технологий, от нечетких и лингвистических моделей распознавания, классификации, диагностики до систем ситуационного управления, проектирования и принятия решений в условиях неопределенности. В последние годы жизни он активно занимался проблематикой онтологического моделирования и интеграции знаний.

В этом году исполняется 50 лет с начала в СССР научных исследований и разработок в области теории нечетких множеств и ее приложений. «Отец нечеткой логики» Л.А.Заде опубликовал на английском языке свою основополагающую статью «Fuzzy Sets» в 1965г. [Zadeh, 1965], его первая работа на русском языке «Тени нечетких множеств» вышла (в переводе

В.Л.Стефанюка) в 1966г., а уже в 1967г. в РПИ были начаты исследования Аркадия Борисова, посвященные нечетким моделям технической диагностики, вопросам распознавания и классификации нечетких образов.

Результаты его работ нашли отражение в первых оригинальных публикациях на русском языке в этой области: «Распознавание образов, представленных нечеткими множествами [Борисов, 1968],«Поиск наибольшей разделимости размытых множеств» [Борисов и др., 1969а], «Разделимость отображений размытых множеств» [Борисов и др.,1969б], и пр. (см., например, краткий обзор [Борисов, 1993]).

Аркадий Николаевич был выдающимся организатором научно-исследовательской и педагогической работы. За долгие годы его плодотворной деятельности в РПИ он создал свою научную школу. Среди его учеников – 25 кандидатов и докторов наук и более 20 магистров, которые работают в ведущих ИТ-компаниях не только в Латвии, но и далеко за её пределами.

Важнейшими достижениями А.Н.Борисова и его школы стали научные монографии и статьи по теории нечетких множеств и ее приложениям. В 1980-1990-е годы А.Н.Борисов опубликовал вместе со своими учениками целую серию замечательных книг по моделям принятия решений – как классическим, так и неклассическим, основанным на лингвистических переменных и нечетких множествах: «Модели принятия решений на основе лингвистической переменной» [Борисов и др., 1982а], «Методы интерактивной оценки решений» [Борисов и др., 1982б], «Диалоговые системы принятия решений на базе мини-ЭВМ: информационное, математическое и программное обеспечение» [Борисов и др., 1986], «Обработка нечеткой информации в системах принятия решений» [Борисов и др., 1989], «Принятие решений на основе нечетких моделей. Примеры использования» [Борисов и др., 1990], «Интеллектуальные системы принятия проектных решений» [Борисов и др., 1997]. Из этих работ особенно следует отметить монографию [Борисов и др.,1982а], ставшей наряду с [Орловский, 1981] одной из первых книг на русском языке по теории и приложениям нечетких множеств в задачах принятия решений, а также изданный в центральной печати капитальный труд [Борисов и др., 1989]. Эти книги были настольной литературой для нескольких поколений специалистов и разработчиков систем принятия решений в условиях неопределенности.

По инициативе А.Н.Борисова в течение многих лет в Риге проходили почти все основные научные мероприятия по теории и приложениям нечетких множеств в СССР. Самые первые семинары были посвящены нечетким моделям ***ситуационного управления сложными системами*** – предложенного Д.А.Поспеловым направления на стыке искусственного интеллекта, теории управления и моделирования неопределенности. Первые два Рижских семинара «Применение теории нечетких множеств в задачах управления сложными системами» прошли в 1977 и 1978 гг., а третий Рижский семинар под названием «Проблемы разработки и применения теории нечетких множеств в системах искусственного интеллекта и управления» состоялся в 1979г.

Именно с этих семинаров и началось плодотворное сотрудничество специалистов в области искусственного интеллекта во главе с Д.А.Поспеловым с их рижскими коллегами, занимавшимися вопросами теории нечетких множеств и ее приложений. Затем центр тяжести прикладных исследований в РПИ сместился в область принятия решений, и А.Н.Борисовым был организован в Риге ряд крупных мероприятий по данной проблематике: три межреспубликанские конференции «Модели выбора альтернатив в нечеткой среде» (1980, 1984, 1990 гг.), семинары «Лингвистические модели принятия решений», «Модели принятия решений в условиях неопределенности», и др. Мы хорошо помним замечательные дискуссии, присущие этим научным форумам, которые разворачивались в Риге, а затем продолжались на даче гостеприимного хозяина в Саулкрасте.

В конце 1970-х – начале 1980-х годов весьма остро встал вопрос об открытии специальных изданий, посвященных проблемам теории и приложений нечетких множеств. И конечно, именно в РПИ под редакцией А.Н.Борисова стали впервые издаваться ежегодные межвузовские сборники трудов по методам и системам принятия решений в нечеткой среде: «Методы и системы принятия решений» (1979г.); «Методы принятия решений в условиях неопределенности» (1980г.); «Методы и модели анализа решений» (1981г.); «Принятие решений в условиях нестатистической неопределенности» (1982г.); «Прикладные задачи анализа решений в организационно-технических системах (1983г.) и т.д. Начиная с 1987г. на первый план стали выходить вопросы интеллектуализации систем принятия решений и автоматизированного проектирования: «Интеллектуальные системы принятия решений» (1987г.); «Вопросы создания экспертных систем» (1988г.); «Экспертные системы в автоматизированном проектировании» (1990 г.); «Системы поддержки процессов проектирования на основе знаний» (1991г.).

Отбор публикаций был весьма принципиальным и жестким. Далеко не всякий аспирант, даже если его руководитель был другом А.Н.Борисова, мог опубликовать в Рижском сборнике свою статью. Но если такая публикация появлялась, то появлялся прямой путь к защите. Статьи в Борисовских сборниках ценились в свое время больше, чем теперь работы в изданиях, включенных в РИНЦ и Scopus.

Аркадий Николаевич Борисов принял активное участие в создании в январе 1990г. Советской ассоциации нечетких систем, САНС (с 1993 г. по 1996 г. Ассоциации нечетких систем) и в течение ряда лет был ее вице-президентом. В 1990-м году он провел научную конференцию и съезд САНС в Риге. В 2005г. профессор А.Н.Борисов был избран почетным членом Российской ассоциации нечетких систем и мягких вычислений.

А.Н. Борисов был членом ряда международных научных организаций: Европейской рабочей группы международной ассоциации по нечётким системам, Балтийского общества исследования операций, Латвийской национальной организации по автоматике, Балканского общества нечётких систем и искусственного интеллекта, а также членом редколлегий нескольких международных журналов, в том числе научного журнала Российской ассоциации нечетких систем и мягких вычислений «Нечеткие системы и мягкие вычисления».

В 2010-е годы Аркадий Николаевич уже редко выезжал на конференции, но всегда стремился побывать у ближайших соседей: у В.В.Голенкова на OSTIS в Минске и А.В.Колесникова в Светлогорске на конференции «Гибридные и синергетические системы в искусственном интеллекте». И на них он со свойственной ему прямотой отстаивал «чистоту науки», не стесняясь проверить уровень компетентности ее творцов.

Дискуссия между А.Н.Борисовым и С.В.Микони: что такое лингвистическая лотерея?

В мае 2013г. на VII-й международной научно-практической конференции «Интегрированные модели и мягкие вычисления в искусственном интеллекте» в Коломне было проведено специальное заседание, посвященное 75-летнему юбилею А.Н.Борисова и его вкладу в создание и развитие нечетких систем принятия решений и управления. На нем с докладами о научных достижениях юбиляра выступили его давние друзья, ученики и коллеги из Российской ассоциации искусственного интеллекта и Российской ассоциации нечетких систем и мягких вычислений.

Сам юбиляр, как всегда моложавый и подтянутый, выступил с лекцией об основных итогах развития нечетких моделей и систем принятия решений в Рижском техническом университете. Затем были путешествие на теплоходе по Оке и банкет в гостинице «Коломна» Никто из присутствующих не подозревал, что эта встреча с Аркадием Николаевичем станет последней.

3 февраля 2016г. мы поздравили Аркадия Николаевича с днем рождения. Он пообещал прислать свою новую книгу «Методы нечеткой классификации и кластеризации» [Алексеева и др., 2014], в которой уже на новом уровне вернулся к своим ранним работам по распознаванию и классификации. Как всегда, обещание было им выполнено: через три с лишним месяца почтового путешествия книги из Риги в Москву мы читали автограф автора. Собрались от всей души его тепло поблагодарить, но нас опередило печальное известие. . .

Светлая Вам память, дорогой Аркадий Николаевич!

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Два профессора, два друга из Прибалтики в Коломне:
А.Н.Борисов и А.В.Колесников

Экскурсия на теплоходе по Оке:
А.Н. Борисов и А.Н.Аверкин

Участники Учредительного съезда Советской ассоциации нечетких систем в Казани
(январь1990г., второй справа в среднем ряду – А.Н.Борисов)

ARKADY NIKOLAYEVICH BORISOV: BIOGRAPHICAL PAGE AND SCIENTIFIC HERITAGE

Pospelov D.A., Averkin A.N., Batyrshin I.Z., Tarassov V.B., Yazenin A.V.

The paper is devoted to an outstanding Soviet and Latvian scientist in the field of fuzzy sets and soft computing – Prof., Gr. D-r Arkady N. Borisov – a pioneer of investigations on fuzzy sets and their applications in the USSR, author of the first Russian papers on fuzzy recognition, classification and diagnostics models, organizer of the first scientific events on fuzzy control and decision-making, founder of well-known Riga scientific school on decision-making under uncertainty, author of classical books on linguistic and fuzzy decision-making models.

Professor Arkady Borisov

In 2017 we celebrate 50 years from the beginning of investigations on fuzzy sets theory and applications in the former USSR. «The Father of Fuzzy Logic» L.A.Zadeh published his pioneering paper «Fuzzy Sets» in 1965, the first Russian translation of his paper «Shadows of Fuzzy Sets» appeared in 1966, and already in 1967 Arkady Borisov in Riga Polytechnic Institute started to work in the field of fuzzy sets, fuzzy models in technical diagnostics, fuzzy pattern recognition and classification. As a result, his original papers were published by the end of sixties, in particular, «Recognition of Patterns Represented by Fuzzy Sets», «Separability of Fuzzy Set Mappings», «Optimal Separation of Fuzzy Patterns».

Arkady Borisov was born on February 3, 1938 in Kiev. Graduated from Riga Polytechnic Institute, RPI (now Riga Technical University, RTU) in 1964 he obtained his PhD from RPI in 1970. The topic of his PhD thesis was related to learning algorithms to make diagnostics of systems with fuzzy states, as well as using shadows of fuzzy sets in pattern recognition. At once in 1970 he organized the department of Automatic Control Systems at RPI. During a few years a brilliant research and education team was formed headed by A.N.Borisov. This team obtained some important results in fuzzy sets and systems and theirs applications that put it into leading positions both in the USSR fuzzy community and all over the world.

In 1986 Arkady Borisov obtained the Great Doctor degree in Computer Science. The subject of his second thesis was «Multi-criteria decision-making methods and algorithms under fuzziness».

Arkady Borisov authored 10 monographs and about 250 papers. His scientific interests were rather wide: they extended from fuzzy set theory and linguistic variables to fuzzy expert systems, soft computing and hybrid intelligent technologies, from fuzzy recognition and classification models to situational control systems and decision-making under uncertainty. He also contributed to ontological engineering and knowledge management.

In 1980-1990's A.N.Borisov together with his colleagues and students published several important books in decision-making models – both classical and fuzzy. In particular such books as «Decision-Making Models on the Basis of Linguistic Variable» (1982), «Fuzzy Information Processing in Decision-Making Systems (1989), «Decision-Making Based on Fuzzy Models. Application Examples» (1990) are worth mentioning. Arkady Borisov was also organizer of the first Soviet workshops and conferences on fuzzy control and decision-making in a fuzzy environment, chief editor of the first Soviet inter-university volumes «Methods and Models of Decision-Making». Many years he was the director of the Institute of Intelligent Computer Technologies at RTU. From 2003 Arkady Borisov worked as professor of RTU Simulation Department; he also headed the research group on decision support. Professor A.N.Borisov died on May 14, 2016.

Ontology-based Design of Intelligent Systems

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***Abstract*—The main subject of this paper is the consideration of technology of designing intelligent systems, based on the *ontologies*, i.e. ontological treatment of this technology. Ontological approach to design of any complex system classes (including intelligent systems) makes it possible to decompose clearly and hierarchically a process of *designing* any system of specified class into such *design actions*, many of which can be executed in parallel and each of which can be executed locally, i.e. within the specific ontologies. Within the paper basic principles of such an approach are given.**

Keywords*—ontology, subject domain, ontology-based design, intelligent system, Ontology of intelligent systems, Ontology of designing intelligent systems, language for sense knowledge representation, formal ontological model of intelligent system.

I. Introduction

A. Objective and Relevance of the Work

The purpose of this paper is to make more precise definition for concept of ***formal model of intelligent system***, and also to consider methodology and tools for ***designing intelligent systems***. The aggregate of such models, methodologies and tools is nothing but ***the technology of designing intelligent systems***. Relevance of creating such technologies is due to expansion of ***intelligent systems*** applying area and, as a consequence, due to the necessity to decrease essentially the work content for its development.

The feature of this paper is consideration of technology of designing intelligent systems on the base of ***ontologies***, i.e. ontological treatment of this technology [6], [7], [27], [28], [22], [19], [20]. Ontological approach to designing any complex system classes (including intelligent systems) makes it possible to decompose clear and hierarchically a process of ***designing*** any system of specified class into such ***design actions*** many of which can be executed in parallel and each of which can be executed locally, i.e. within the framework of specific ontologies.

Thus hierarchical system of design actions is put in correspondence with hierarchical structure of ontology within a framework of which such design actions can be carried out. It is clear that such an approach speeds up essentially design activity by means of multisequencing and localization of an area of searching a solution while executing each design action.

B. Problems to be Solved to Succeed

- To improve effectiveness of designing intelligent systems it is necessary to have a ***general*** (complex, integrated, holistic) ***technology of designing intelligent systems***. Within such technology all the necessary partial technology should be harmonized, i.e. it **should be ensured compatibility of design solutions** which can be resulted within partial technologies.
  Compatibility of such design solutions means compatibility of different kinds of ***intelligent system components*** which, in general, can be the products of developing by different and independent developer teams. Among other factors it is necessary to ensure compatibility of different kinds of ***knowledge*** within knowledge base, different ***models for problem solving*** which are used by intellectual problem solver, compatibility of different ***models of understanding external information*** received by intelligent system on different channels, in different formats and on different languages.
- To create a general integrated technology of intelligent system design it is necessary to create a **general formal theory of intelligent system** [1].
- Intelligent system design technology should decrease work content not only while initial development but also while **permanent improvement** process (modernization, re-engineering) during the operation. In other words **intelligent systems** based on such technology **should be flexible**, easy modified, reconfigurable.
- Formal *models of intelligent systems* which are results of these systems design should be **simple as much as possible** and understandable not only by ***interpreters*** used for its implementation on different platforms but also by all the developers of such models.
- As different *intelligent systems* have, in general, different ***knowledge representation models*** and ***knowledge processing models*** the main problem of developing such models is creating a unified universal principle, a "skeleton", which makes it possible to build **hierarchical multilevel models of knowledge representation and processing with any configuration**.
  For *knowledge representation models* – this is move from *knowledge* to ***meta-knowledge***, from meta-knowledge to meta-meta-knowledge and so on, and, in particular, from description of actions (both internal and external) to description of actions on arbitrary higher level.
  For *knowledge processing models* – this is move from *agents* capable to execute one level actions to ***collective agents*** executing ***actions*** on arbitrary higher level.
  On the highest level internal activity of intelligent system represents balanced dialog of agents-optimists and agents-pessimists:
  - optimist generates ideas and hypothesis, looks for way out of various situations (contradictions) and for way of various problem solution;
  - pessimist always questions everything, always is searching for reasons and ideally – for proofs or retractions.

C. Analysis of Existing Approaches to Solving Specified Problems

Today there are a number of technologies for designing intelligent systems. Analysis of such technologies and corresponding tools is given in several works [25], [26]. Some of them have a significant impact on our research:

- Technology of designing real time expert systems on the base of instrumental system G2 [2];
- AT-Technology [25], [26];
- Technology of developing cloud intelligent services on the base of IACPaaS platform - Intelligent Application, Control and Platform as a Service [13];
- Technology of developing science portals [15];
- Technology of developing engineering knowledge portals which provide with complex engineering computations [9].

Today there are already a lot of modern technologies of designing intelligent systems. But they can solve not all problems mentioned above. Recently, most attention is focused on knowledge engineering and on technology of ontological engineering [8], [4] to the detriment of other equally important aspects of designing intelligent systems.

As a consequence, modern technologies of designing intelligent systems:

- are created not on the basis of **general formal theory of intelligent systems** and therefore do not consider detailed integration of "diverse" components of intelligent systems (***knowledge bases, knowledge processing machines, user interfaces***). Also modern technologies do not have a unified universal basis which allows within technology to integrate various scientific and practical results in area of artificial intelligence;
- do not provide compatibility of intelligent systems being developed and their components. This makes it difficult to organize simultaneous design of different components of the same system and the following integration of these components. Also it makes it difficult to develop ***collectives of intelligent systems***;
- do not provide **platform independence** of designing intelligent systems, i.e. clear separation of two processes: the process of development of complete *formal models of intelligent systems* and the process of development of these models interpreters on different platforms;
- do not have a formalized methodologies of complex **collective** designing intelligent systems, and in particular, do not have clearly formalized scope of full independence of simultaneously executed branches of designing and necessary points for coordination of these branches. Therefore do not provide saving both development time and labor;
- do not include ***methodology of training engineers of intelligent systems*** and, consequently, do not provide further training during development and the operation of these systems;
- do not support **their own development** including analysis and systematization of design experience.

D. The Proposed Approach to the Specified Problems

The following principles form the basis of the proposed approach to creating a *complex technology of designing intelligent systems*:

- Using ontological approach to intelligent system design, i.e. an approach based on hierarchical system of ***formal ontologies*** (on precisely specified systems of concepts which correspond to different and precisely distinguished levels of intelligent system consideration).
- Development of concepts and the corresponding ontologies for ***formal sense representation*** of any kind of knowledge, formal ontologies among them [21], [24], [29].
- Developing ***Formal ontology of intelligent systems*** which will be used as the base for unification and simplification for formal models of intelligent systems.
- Developing hierarchical system of consistent (compatible) ***formal ontologies*** for different kinds of *knowledge* and different *knowledge processing models*. It ensures integration of different kinds of knowledge and different models of knowledge processing, and also, independence from *platforms* of their interpretation. Developing ***General model of knowledge processing*** which represents a collective of agents working with common ***semantic memory***, interacting through this memory and controlled by knowledge kept in this memory. Formalizing this model as an ontology in relation to which different ontologies of specific knowledge processing models (inductive, deductive, crisp, fuzzy and so on) will be partial ontologies.
- Developing hierarchical system of consistent formal ontologies for design activity aiming not only to develop intelligent systems but also to permanently modify them during the operation. Such hierarchical system of ***formal ontologies of designing*** together with the corresponding tools should ensure a high level of improvement of intelligent systems during the operation.
- High level of flexibility of suggested technology is achieved due to the fact that this technology itself is implemented as an ***intelligent metasystem*** which ensures a complex support of intelligent system development in accordance with suggested technology and due to the fact that this technology itself is built on the same technology.
- Developing a ***formal ontology for improvement of technology of designing intelligent systems***: accumulation and systematization of design experience, replenishment of reusable component libraries and so on.
- Using ***methodology of component-based design*** on the base of permanently replenished ***library of reusable components***. This replenishment is carried out by developers of design technology as well as by developers of specific intelligent systems. Thus the proposed technology formalized as *intelligent metasystem* and implemented on the same technology has high rates of growth because it has:
  - •• effective tools for specification of design experience of engineers;
  - •• effective tools for specification of new scientific results (i.e. fundamentally new models, tools and methods for developing intelligent systems);

●● effective tools for modifying actual models, tools and methods.

- Availability of unified foundation which allows to construct **different hierarchy levels of *intelligent systems components*** on its base, i.e. to move from level to meta-level, from knowledge – to meta-knowledge, from actions, action classes and ways to perform this – to meta-actions, meta-action classes and ways to perform this, from systems to metasystems.
  With this there is an opportunity to create multilevel libraries of reusable compatible components: libraries of knowledge and meta-knowledge, libraries of action and meta-action classes, libraries of ways to perform actions and meta-actions, libraries of typical base-level subsystems and subsystems of different meta-levels.
  All of this allow to **increase** substantially **the level of *component-based design*** – computer systems will be assembled not only from "small" but from "large-scale" components of any hierarchy level.
- Proposed technology represents an open semantic technology of component platform independent development of flexible compatible intelligent systems. We called this technology ***OSTIS Technology*** (Open Semantic Technology for Intelligent Systems). More detailed about base principles of this technology see in [11], [12].

E. Introduction to Ontology-based Design of Intelligent Systems

Since design is a key human activity ***General ontology of designing*** any kind of artefact is one of ***high level ontologies*** and represents a system of concepts which is the base of design activity systematization and control.

Design is a process of developing certain ***artefact*** information model (specification) sufficient to implement this artefact.

Ontology-based design is design on the base of using different ontologies and the result of such design is an ***ontological model of artefact being developed***, i.e. the model corresponding to ***ontology*** which describes characteristic of such artefacts.

As regard the ontology ***formalization*** in memory of ***intelligent system*** - ontologies should be considered the most important kind of ***knowledge*** used by intelligent systems. At the same time it is important to consider formalization not only of ***ontologies*** themselves (their internal structure) but also formalization of different kinds of connections and correspondences between ontologies. In particular it is very important to describe implicitly decomposition and semantic hierarchy of ontologies within ***knowledge base***. Also in this context it is important to describe connections of ontologies not only among themselves but also their connections with other kinds of ***knowledge***, for example, formal models of ***subject domains*** corresponding to ontologies, ontological models of different entities (in particular, designed artefacts).

This paper will consider ontology formalization on the base of ***semantic network***. It makes it possible to analyse more constructive the structure of ontologies themselves, the structure of ***subject domains*** and also connections and correspondences between them.

When considering ***General ontology of designing*** it makes sense to talk about a system of three interconnected ontologies as a minimum:

- ***General ontology of designing***
- ***General ontology of artefacts and their models***
- ***General ontology of intelligent systems for design automation***.

The first of these describes a general methodology of designing. The second – describes ontological models of designed objects. The third – describes information and instrumental designing tools.

Components of any technology including technology of designing intelligent systems are as follows:

- Ontology of corresponding class of artefacts being developed. This ontology describes how these artefacts and their ontological models are organized;
- Ontology of designing artefacts of specified class which describes methodology of designing artefacts of specified class;
- Ontological model of tools for designing artefacts of specified class.

It is clear that in addition to *General ontology of designing* there are a number of other partial ontologies of designing which make more precise (detail) general organizing principles of design activity taking into account the particularities of specific types of designed objects and the particularities of specific design stage organization.

For example, we can talk about ***Ontology of designing intelligent systems*** and about ***Ontology of testing intelligent systems***.

Each ontology is a specification of system of concepts used it the corresponding subject domain. Connection between ontologies and subject domains is specified by ***subject domain**** relation (to be a subject domain of specified ontology).

In terms of *Ontology of designing intelligent systems* which is the main subject of this paper we should talk about a system of ontologies and their corresponding subject domains which is presented on Fig. 1.

Subject domain of designing intelligent systems is a subject domain within which objects of research are processes of designing intelligent systems. It is important to construct this domain to minimize work content of designing processes and to provide a high quality of designed intelligent systems.

Such a designing quality ("cheap but good") could be achieved not only on the base of well thought-out unified *Ontology of designing intelligent systems* but also on the base of *Ontology of intelligent systems and their models* which clarifies and unifies the structure of designed intelligent systems.

For this purpose in proposed ***OSTIS Technology*** we have made clarification and **unification** of internal structure of designed intelligent systems.

Fig. 1 introduces a concept of ***ostis-system*** – intelligent system being developed on ***OSTIS Technology,*** and also a concept of ***IMS Metasystem*** (Intelligent MetaSystem) which is the *ostis-system* for *ostis-systems* design automation.

Note also that information presented on Fig. 1 is a text on the language called ***SCg-code*** (Semantic Code Graphic) which is an universal language for visualizing ***ostis-systems knowledge bases***. The detailed description of *SCg-code* syntax and semantic see in [3].

II. Base Language for Sense Knowledge Representation

Quality of internal language for knowledge representation in memory of intelligent systems is the main factor which determines effectiveness of designed intelligent systems as well as effectiveness of design activity for developing these systems. Such language should be

- as simple as possible,
- universal,
- extensible, open.

The main problem of knowledge representation is the creation of such a language that would be convenient and easily interpretable by not only intelligent system but also by a person who can be a developer or a user of the system. That could be achieved only by one way – to get closer as much as possible to what is called ***sense knowledge representation***.

The main requirement to a ***formal language of sense knowledge representation*** is to eliminate semantic equivalence of texts within knowledge base of each intelligent system. So within knowledge base semantically equivalent texts should be transformed into the same text, i.e. such texts should not be duplicated.

So sense knowledge representation can be treated as invariant of variety of semantic forms of this knowledge representation. Note that semantically equivalent texts within knowledge base of different intelligent systems may exist but at the same time such texts should be completely structurally and semantically equivalent up to isomorphism.

Variety of syntactic forms (variants) of representation of the same information (the same knowledge) should be reduced to only one variant while creating a language of sense knowledge representation. Within this variant it would be sufficient simply to determine semantic equivalence of two texts using syntactic structure of these texts. Syntactic equivalence (isomorphism) of two texts should be the necessary condition of semantic equivalence of these texts.

The main guideline while creating a formal language of internal sense knowledge representation in intelligent system memory is to take away from language all unnecessary things unrelated to creating an internal model of external and internal "world" in which this intelligent system will solve various kinds of problems.

The essence of each language structure, its semantic power is specified (1) by a method of information encryption and (2) by a certain *ontology* which clarifies semantics of concepts used in this language. In its turn a method of information encryption is specified (1) by a method of representing signs of entities described by language texts and (2) by a method of describing connections between described entities (these connections in language texts are represented as syntactic connections between signs of specified entities).

Universal and open language of knowledge representation can be created only on the base of hierarchical system of ontologies within which the following are distinguished: a top-level base ontology and a family of ontologies which are partial in relation to this base ontology and which provide unlimited detailing for describing entities from this top-level base ontology.

As a base internal formal language for knowledge representation in memory of intelligent systems we suggest the language which is named ***SC-code*** (Semantic Computer Code).

Now consider **principles underlying SC-code** and also its features and advantages.

A. Specification of SC-code concept

Formally speaking ***SC-code*** is a set of texts (sc-texts) set-theoretical union of which represents an unlimited structure including descriptions of various entities. This unlimited structure is nothing but ***Subject domain of entities*** which contains descriptions of various entities on the initial level of their detailing. Specified subject domain is the highest level subject domain because there is no other subject domain in relation to which it would be ***partial subject domain****. As any other subject domain, *Subject domain of entities* has its own ontology corresponding to it, namely, ***Ontology of entities*** which specifies concepts used within *Subject domain of entities* and specifies SC-code semantic.

Fragments (substructures) of *Subject domain of entities* will be referred to as ***texts of SC-code*** or simply ***sc-texts***.

So <u>language as a set of in some ways organized texts about certain subject domain</u> is put in correspondence with integrated cognitive model of this subject domain.

Strictly speaking SC-code can be treated not as a language but as a universal code which provides a unified and therefore semantically compatible representation of various subject domains and their corresponding ontologies on the base of ***Subject domain and ontology of entities***.

Base nature of *Subject domains of entities* is reflected in the fact that all (!) other subject domains are not just ***partial**** in relation to it but are also its subsets, i.e. ***included**** structures. Classes of entities included in *Subject domain of entities* not just as key classes (key concepts) in different combinations within ***partial subject domains**** will serve as key concepts the sense of which is clarified within *ontologies* corresponding to these subject *domains*.

B. Concept of sc-element

All (!) syntactically elementary (atomic) fragments of SC-code texts (sc-texts) are ***signs*** of their corresponding (denoted by them) *entities*. Such elementary fragments of sc-texts we will name ***sc-elements***. It should be stressed, that:

- Elementary (atomic) character of sc-elements means that such elements do not have internal structure, i.e. do not consist of any other fragments of sc-texts as, for example,

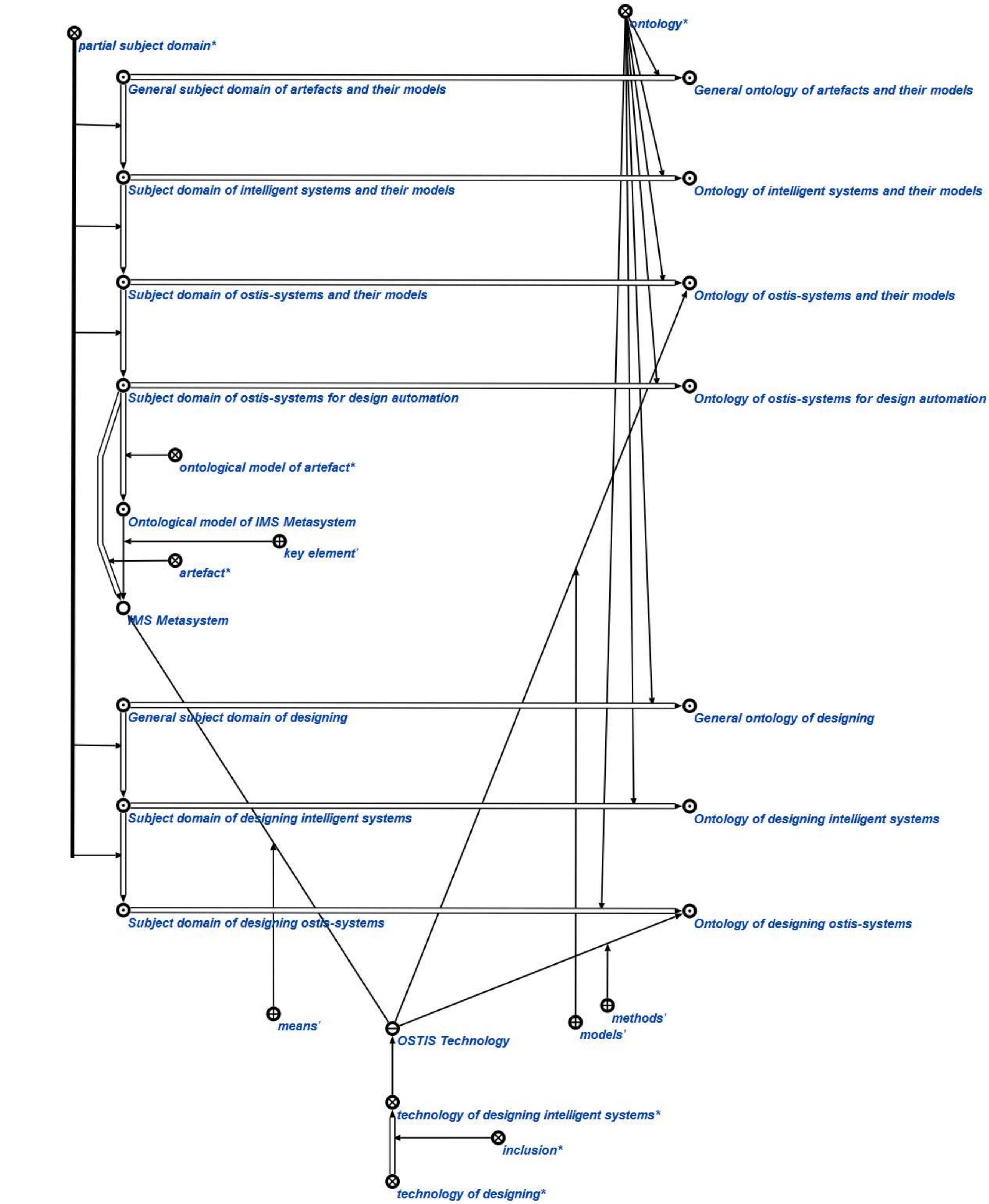

Figure 1. System of the ontologies and subject domains, connected with the Ontology of designing intelligent systems

signs of traditional languages which, in general, represent phrases and consist of words and, further, from letters;

- signs of any (!) entities can be presented by sc-elements. Thus SC-code is universal in the sense that sc-texts can describe any entities;
- sc-texts do not contain any signs beside sc-elements;

- within each sc-text, including sc-text of knowledge base of intelligent system, the following should not contained:
  - pairs of synonymic elements which denote the same entity. So sign of any described entity is contained only once in the corresponding sc-texts;
  - homonymous sc-elements, i.e. sc-elements each of which represents different entity while considering from different perspectives.
    Thus correspondence between sc-elements of given sc-text and entities which are described in this text is one-to-one correspondence.

C. Description of sc-element

Type of arbitrary considered sc-element, and consequently, type of entity denoted by this sc-element is specified within SC-code as follows:

- sc-element is introduced which denotes specified type of sc-elements, i.e. a class of those and only those sc-elements which correspond to this type;
- sc-element is introduced which denotes connection of membership of considered sc-element with that sc-element class which is denoted by sc-element introduced above.

D. Typology of sc-elements

Typology (classification) of sc-elements on the main criteria looks as follows.

On constance-variability criterion a set of sc-elements is split on:

- sc-constants (constant sc-elements);
- sc-variables (variable sc-elements).

On structure criterion (by a "place" of sc-element within sc-text structure) a set of constant sc-elements is split on:

- signs of external entities;
- signs of terminal abstract entities (i.e. abstract entities are not sets);
- signs of sets of sc-elements.

In its turn a set of signs of sets of sc-elements on structure criterion is split on:

- sc-classes – set of signs of classes of sc-elements;
- sc-links – set of signs of connections between sc-elements; each such connection is treated as a set of sc-elements connected by this connection;
- sc-structures – set of signs of structures consisting, in general, of sc-elements of various structure types.

Type of sc-variable is determined by the area of its possible values. It can be:

- variable sign of external entity if all of this variable values are signs of external entities;
- variable sc-link if all of this variable values are constant sc-links;
- and so on.

On ***temporal criterion*** set of sc-elements is split on:

- denotations of permanent entities;
- denotations of temporary entities.

E. SC-code syntax

SC-code syntax is defined as:

- collection of sc-element classes which are specified not with standard SC-code means described above but implicitly, syntactically, by means of assignment of corresponding "labels" to sc-elements. This is nothing but ***alphabet of sc-elements***;
- implicit (syntactic) representation of membership connections between signs of binary connections and components of these connections. This implicit representation of connections is specified by two incident relations of sc-elements: incident relation of signs of binary connections and sc-elements connected by these connections and incident relation of signs of binary oriented connections (sc-arcs) and its second components, i.e. those sc-elements for which these arcs are ingoing arcs.

Stress that all mentioned syntactic "techniques" of SC-code have a clear semantic interpretation – this is always implicit representation of membership connection, i.e. such a representation for which explicitly specifying this connection sc-element is not introduced. Such membership connection specifies (1) membership of sc-element to a given sc-elements class included in sc-element alphabet or (2) membership of sc-element to a given binary connection which is presented by sc-elements denoting this connection.

Thus SC-code does not have syntax in the traditional sense. SC-code syntax is:

- a special syntactic, implicit, form of distinguishing certain classes of sc-elements (syntactically distinguished classes which compose the language alphabet);
- a special syntactic, implicit, form of representation of membership connections as syntactically specified incident connections connecting sc-elements which denote binary connections with sc-elements which are components of these binary connections.

In purpose to formalize SC-code syntax within *Subject domain of entities* the following two concepts are introduced:

Syntactically specified class of elements
= such class of sc-elements membership in which for each given sc-element is specified not by membership pair but by means of addition of corresponding label to this sc-element. A set of label types and a family of syntactically specified classes of sc-elements are in one-to-one correspondence

sc-connector
= atomic binary link
= sc-element which denotes binary connection between sc-elements and for which its connection with components of this binary connection is specified syntactically by means of incidence relation
*<= partitioning**
- *sc-arc*
- *sc-edge*

The above formal text is a text of ***SCn-code*** (Semantic Code Natural) which provides with structured hypertext visualization of *SC-code* texts. Detailed description of *SCn-code* syntax and semantics see in [3].

F. Concept of a set of sc-elements

Existing unity of syntax and semantic aspects of SC-code is reflected also in the fact that sc-elements which are signs of sets can denote only such sets elements of which are sc-elements, i.e. signs of various entities. Those sets will be called ***sc-sets***. Such sets are syntactic and semantic constructions simultaneously if, certainly, some semantic criteria will be taken into account while creating those sets.

If a set consists of signs of all those and only those entities which have a common characteristic this set will be a ***class*** of signs of equivalent entities.

If a set consists of signs of all those and only those entities which are interconnected by certain connection this set will be a ***link*** of signs of interconnected entities.

If a set consists of signs of all those and only those entities (it is possible also of signs of connections between these entities) representing a certain holistic construction which are independent object of research then this set will be a holistic ***structure*** of signs.

Stress that mentioned semantic restriction on set elements does not reduce semantic power of SC-code because any set of entities can be put in one-to-one correspondence with set of signs of these entities which in fact is information model of initial set.

It is important to note that within any significant ***sc-text*** the number of secondary sc-elements denoting sc-element sets greatly exceeds the number of primary (terminal) sc-elements which are not signs of sets (such sc-elements are signs of material entities, signs of such abstract entities as geometric point, as number).

Note also that any sc-text can be treated as hierarchical system of sets based on ***membership**** relation. This relation connects sc-elements identifying sets with sc-elements which are elements of these identified sets (in doing so the signs of certain sets can be elements of other sets). Therefore SC-code can be treated as a language with base set-theoretical semantic interpretation of its texts.

G. SC-code as semantic network language

Construction of sc-text can't be linear because sign of each described entity is included in sc-text (in knowledge base also) only once and because each described entity can be connected by unlimited number of connections with other entities. In its turn this means that each sign of sc-text can have unlimited number of connections with other signs. Such non-linear constructions are called ***semantic networks*** [5], [16].

Consequently SC-code is a language of semantic networks. The whole *Subject domain of entities* is, accordingly, an infinite semantic network which has integrated into itself all various texts of SC-code.

The main advantage of semantic networks and of SC-code texts, in particular, is consolidation of syntactic and semantic aspects of knowledge representation. It reduces significantly computational complexity of knowledge processing [23].

Stress that moving from traditional (linear) texts to semantic networks can be treated as a process of getting rid of that language excessiveness which are resulted from communicative function of traditional languages but are not necessary for creation of formal sense internal model of world in which intelligent system "lives".

Getting rid of specified excessiveness includes:

- exclusion of text fragments non-interpreted semantically – letters, separators, delimiters, words which are not signs of entities. All the atomic fragments of texts become signs;
- exclusion of synonymy of signs;
- exclusion of homonymy of signs.

H. SC-code as the Base of Representation of Various Subject Domains and Ontologies

SC-code is the base for creation of formal models of various *subject domains* and for representation of other kinds of knowledge. For these purposes it is introduced (1) sub-language of SC-code which is specified by ***Subject domain of subject domains*** and by the corresponding ***Ontology of subject domains***; (2) sub-language of SC-code which is specified by ***Subject domain of ontologies*** and by the corresponding ***Ontology of ontologies***; (3) a family of other sub-languages of SC-code oriented on representation of other kinds of knowledge.

Thus SC-code results all the variety of knowledge kinds not only to a common syntactic form but also to one common high level ontology, ***Ontology of entities***, which is the basis for syntactic structure of SC-code texts as well as base semantic interpretation of these texts.

I. SC-code and the System of Specialized Languages

Formal language of internal sense knowledge representation in memory of intelligent systems represents an integrated, open and permanently developed language based on SC-code. In its entirely this language represents a hierarchical system of specialized formal languages each of which is a sub-language of SC-code and is specified (1) by subject domain ***partial**** in relation to *Subject domain of entities* and (2) by ontology which specifies a set of concepts used by this partial subject domain and which itself is ***partial**** in relation to *Ontology of entities*.

Since integrated language of internal sense knowledge representation is a hierarchical system of languages created on SC-code it is based on:

- language of formal representation of subject domains which is specified by *Subject domain and Ontology of subject domains*;
- language of formal representation of ontologies which is specified by *Subject domain and Ontology of ontologies*;
- base language SC-code itself which is specified by *Subject domain and Ontology of entities*.

III. Formal Models of Subject Domains

In this chapter the following topics will be considered:

- general principles for representation on ***SC-code*** of formal models of ***subject domains***;
- formal model of ***Subject domain of entities*** which corresponds to ***SC-code***;
- formal model of ***Subject domain of subject domains*** for which researched objects are various subject domains.

Explicit distinguishing various *subject domains* within knowledge bases of intelligent systems, and in particular, *subject domains of actions and tasks*, makes it possible to localize search for ways to solve specific problems. These problems could be solved by intelligent systems themselves or by system users with help of intelligent system.

A. Structure of Formal Models of Subject Domains

Formal model ***Subject domain*** represented on SC-code is sc-structure within which by means of special collection of ***role relations*** several key *elements* of this structure are distinguished and roles of these key elements within this structure are specified. Such role relations are subsets of *Membership relation*.

First of all key elements of subject domain are signs of *considered concepts* clarification of sense of which are essential for semantic analysis of specified subject domain. Also key elements of subject domain can be signs of those objects of research within this subject domain which have special characteristics and used for description of sense of above key concepts within this subject domain. Number 0 and number 1 are examples of such *key researched objects* within *Subject domain of numbers*.

Description of sense of such key concepts of subject domain, i.e. specification, is nothing but ***ontology*** corresponding to specified *subject domain*.

Roles of concepts contained in subject domain follow:

considered concept’
= *concept considered in given subject domain’*
= *key concept of given subject domain’*
<= *partitioning**
- *the researched concept’*
- *non-researched but considered concept’*

<= *partitioning**
- *concept introduced in given subject domain’*
- *considered concept introduced in other subject domain’*

There are four variants of clarifying roles for concepts considered in subject domains:

- concept can be researched and introduced in given subject domain;
- concept can be researched in given subject domain but introduced in other subject domain;
- concept can be non-researched but introduced in given subject domain;
- concept can be non-researched and non-introduced in given subject domain.

The above-mentioned ***role relations*** specify different correspondences between *subject domains* and ***concepts*** considered in these domains, for example, the correspondence between concepts and subject domains where these concepts are researched.

It is not hard to see that these role relations describe semantic distribution of concepts between subject domains. In general, this distribution takes into account differences in concepts usage (considering) in different subject domains, and also it takes into account that one and the same concept can be used in different subject domains.

It is clear that subject domains considering one and the same concept have a deep semantic relationship between themselves.

More detailed consideration of role relation ***the researched concept’*** taking into account a structure type of these concepts allows to specify the following sub-classes of these relations:

researched concept’
= *to be the researched concept’*
⊃ *class of primary researched objects’*
  ⊃ *the maximum class of primary researched objects’*
    = *class of primary researched objects for which there is no other class of primary researched objects that would be its subset within subject domain’*
⊃ *the researched relation’*
  = *class of researched links’*
  ⊃ *maximum researched relation’*
⊃ *class of researched structures’*
  ⊃ *maximum class of researched structures’*
⊃ *class of researched classes’*
  = *parameter (characteristic) specified on a set of researched objects’*

Set-theoretical connection between a concept considered in a subject domain and the set of elements of this subject domain is specified by the following role relations:

- *a set all of elements of which are located in given subject domain’*
- *a set not all of elements of which are located in given subject domain’*

Semantic hierarchy of subject domains is specified by the following role relations:

- *a concept which is an instance of a concept researched in other subject domain’*
- *a concept which is a subset of a concept researched in other subject domain’*
- *a concept for which in other subject domain a researched concept exists against which the first specified concept is a class of parts of its instances’*

B. Concept System of Subject Domain of Entities

Let’s consider ***Subject domain of entities*** which on the base level specifies syntax and semantic of ***SC-code*** and which is *subject domain* of the highest possible level. It follows that concepts considered in this subject domain can’t be introduced in other *subject domains* because to make that possible these other subject domains would be higher level subject domains. The highest possible level of *Subject domain of entities* means also that a lot of concepts will be only introduced in this subject domain and will be researched in other *subject domains* as ***classes of primary researched objects'*** including. Within *Subject domain of entities* ***maximum class of primary researched objects'*** is a concept of ***entity***, more precise, a concept of set of signs of various entities which is identical with ***sc-element*** within ***SC-code***.

Classification of a set of ***sc-elements*** on different criteria produces a hierarchical system of subclasses of maximum class of sc-elements. A feature of *Subject domain of entities* is the fact that signs of all the specified partial classes of sc-elements are themselves *sc-elements*, i.e. instances of ***maximum class of primary researched objects'***. Moreover within considered subject domain all the ***researched relations'***, all the ***classes of researched structures'*** and all the ***classes of researched classes'*** are also partial ***classes of primary researched objects'***.

Let's consider three general criteria of sc-elements classification:

- logical typology *of sc-elements*;
- structural typology *of sc-elements*;
- temporal typology *of sc-elements*.

sc-element
= abstract sign of certain entity for which its internal structure is not important but only its conditional connection with entity denoted by this sign is important
<= partitioning:*
- *sc-constant*
- *sc-variable*

<= partitioning:*
- *terminal sc-element*
- *sc-set*
  <= partitioning:*
  - *sc-link*
  - *sc-structure*
  - *sc-class*

<= partitioning:*
- *denotation of permanent entity*
- *denotation of temporary entity*

Let's consider more detailed classes of researched objects introduced within *Subject domain of entities*.

sc-constant
<= partitioning:*
- *terminal sc-constant*
  = sc-constant which is not a sign of set
- *constant sc-set*
  = sc-element denoting specific set of sc-elements
  <= partitioning:*
  - *constant sc-link*
  - *constant sc-structure*
  - *constant sc-class*
    <= partitioning:*
    - *constant class of terminal sc-constants*
    - *constant sc-relation*
      = constant class of constant sc-links
    - *constant class of constant sc-structures*
    - *constant class of constant sc-classes*
    - *constant class of sc-variables*

<= partitioning:*
- *constant permanent entity*
  = permanently existing constant entity
- *constant temporary entity*
  = temporarily existing constant entity

constant sc-link
<= partitioning:*
- *constant binary sc-link*
- *constant non-binary sc-link*

<= partitioning:*
- *constant non-oriented sc-link*
- *constant oriented sc-link*

<= partitioning:*
- *constant sc-multilink*
  = constant sc-link with multiple occurrence of some components
- *constant sc-link with single occurrence of all its components*

<= partitioning:*
- *constant sc-metalink*
  = constant sc-link which has some other sc-links as its components
- *constant sc-link which does not have other sc-links as its components*

constant binary sc-link
<= partitioning:*
- *constant sc-link about membership nature*
- *constant binary sc-link which is not about membership nature*

constant sc-link about membership nature
<= partitioning:*
- *constant sc-link of membership*
  = Membership relation
- *constant sc-link of non-membership*
  = Non-membership relation
- *constant sc-link of fuzzy membership*

sc-variable
= sc-element denoting arbitrary sc-element from certain set of sc-elements which are possible values of this arbitrary sc-element

Thus sc-variables as well as sc-sets can be treated as secondary sc-elements (secondary signs) because each sc-set is a sign of set of sc-element and each sc-variable "runs" certain set of sc-elements representing a set of possible values of this variable.

sc-variable
<= partitioning:*
- *sc-variable with values which are sc-elements of one logical level*
  <= partitioning:*
  - *sc-variable of the 1st level*
    = sc-variable with values which are only sc-constants

- sc-variable of the 2nd level
  = sc-variable with values which are only sc-variables of the 1st level
- sc-variables with values which are sc-elements of different logical levels
  <= partitioning*:
  - terminal sc-variable
  - variable sc-set
    = sc-variables with values which are only sc-sets
    <= partitioning*:
    - variable sc-link
    - variable sc-structure
    - variable sc-class

  <= partitioning*:
  - variable permanent entity
  - variable temporary entity

terminal sc-element
<= partitioning*:
- terminal sc-constant
- terminal sc-variable
  <= partitioning*:
  - terminal sc-variable of the 1st level
    = sc-variable with values which are only terminal sc-constants
  - terminal sc-variable of the 2nd level
    = sc-variable with values which are only terminal sc-variables of the 1st level

sc-set
<= partitioning*:
- constant sc-set
- variable sc-set
  <= partitioning*:
  - variable sc-set of the 1st level
    = sc-variable with values which are only signs of constant sc-sets
  - variable sc-set of the 2nd level

sc-link
<= partitioning*:
- constant sc-link
- variable sc-link
  <= partitioning*:
  - variable sc-link of the 1st level
  - variable sc-link of the 2nd level

<= partitioning*:
- binary sc-link
  <= partitioning*:
  - binary sc-link about membership nature
    <= partitioning*:
    - sc-link of membership
    - sc-link of non-membership
    - sc-link of fuzzy membership
  - binary sc-link which is not about membership nature

sc-structure
<= partitioning*:
- constant sc-structure
- variable sc-structure
  <= partitioning*:
  - variable sc-structure of the 1st level
  - variable sc-structure of the 2nd level

sc-class
<= partitioning*:
- constant sc-class
- variable sc-class
  <= partitioning*:
  - variable sc-class of the 1st level
  - variable sc-class of the 2nd level

denotation of permanent entity
<= partitioning*:
- constant permanent entity
- variable permanent entity
  <= partitioning*:
  - variable permanent entity of the 1st level
  - variable permanent entity of the 2nd level

denotation of temporary entity
<= partitioning*:
- constant temporary entity
- variable temporary entity
  <= partitioning*:
  - variable temporary entity of the 1st level
  - variable temporary entity of the 2nd level

1) Consider SC-code means used for description of syntax structure of SC-code texts detailing:

syntactic text structure*
= Relation connecting a sign of certain text (not necessarily sc-text) with sc-text describing its syntactic structure*

Alphabet of sc-elements
= Family of syntactically distinguished classes of sc-elements
= syntactically distinguished class of sc-elements
∋ sc-constant
  = constant sc-element
∋ sc-variable
  = variable sc-element
∋ sc-connector
  = atomic sc-link
  = sc-link connected implicitly (syntactically) with its components by means of **Incidence relation of sc-elements** and **Incidence relation of sc-arcs with its second components** (i.e. with sc-elements these sc-arcs enter in)
  = syntactically distinguished class of binary links for which connection with their components is formalized by means of syntactically implemented incidence relations
  ⊂ binary sc-link
∋ sc-node
  = sc-element which is not sc-connector
∋ sc-arc
∋ denotation of permanent entity
∋ denotation of temporary entity
∋ sc-link of membership
∋ sc-link of non-membership
∋ sc-link of fuzzy membership

Stress that each ***sc-element*** should have three labels as minimum which specify: (1) its logical type – constant or variable, (2) its structural type – sc-node or sc-connector, (3) its temporal type – permanent or temporary nature. Moreover sc-links about membership nature should have one more label specifying membership, non-membership, fuzzy membership.

Family of syntactically formalized relations on sc-elements
= *syntactically formalized relations on sc-elements*
∋ *label'*
  = *Relation which connects syntactically distinguished classes of sc-elements with instances of these classes'*
∋ *incidence of sc-connectors with their components'*
  ⊃ *incidence of sc-arcs with their second components'*
∋ *incidence of sc-arcs with their second components'*

Here is an example of how syntactic structure of *sc-texts* can be formalized with *SC-code* means and used to convert *sc-texts* to more compact unified form based on appeared in knowledge base information clarifying the sense of certain *sc-elements*. Fig. 2 demonstrates certain constant *sc-node* ***ci***. Let it became known after some time that this sc-node is a sign of *binary sc-link** and components of this link also became known (see Fig. 3). Then semantic structure of this *sc-text* can be converted to the form presented on Fig. 4 and further this *sc-text* can be represented in more compact form demonstrated on Fig. 5. SC-code text on Fig. 4 is a description of syntactic structure of *sc-text* from Fig. 5 and therefore these texts can be connected by considered above relation to be ***syntactic text structure****.

It's clear that *sc-texts* describing syntactic structure of other *sc-texts* should not be kept in knowledge base. They can appear in knowledge base only for the period of analysis and updating syntactic structure (coding way) of some knowledge base fragments to make more compact and unified the way of coding these fragments.

2) Subject domain of entities comprises a number of relations which has inter-subject nature.: In the corresponding partial subject domains various clarification of such relations (i.e. various relations which are their subsets) are introduced and researched. Examples of such inter-subject relations follows:

part*
= *to be a part**

generalized part*
= *connection of class of entities with class of certain kind of parts of these entities**

decomposition*
= *splitting a specified entity into a set of its parts (components)**
= *connection of entity with maximum (complete) family of their disjoint parts**

generalized decomposition*
= *connection of class of entities with maximum family of classes of disjoint parts of these entities**

We give examples of clarifying inter-subject relations for different subject domains.

Within *Subject domain of sets* the following clarifications of specified relations are introduced:

inclusion*
= *subset**
⊂ *part**

partitioning*
= *decomposition of a set into maximum family its pairwise disjoint subsets**
⊂ *decomposition**

Within *Subject domain of geometric points and figures* the following clarification of *decomposition** relation is introduced:

decomposition of geometric figure*
= *set-theoretical union of geometric figures each pair of which either does not intersect or intersects but only by its boundary points**
⊂ *decomposition**

Within *Subject domain of temporary entities* the following clarifications of specified relations are introduced:

temporal part*
= *period of existence of specified temporary entity**
⊂ *part**

temporal decomposition*
= *decomposition of temporary entity into family of its disjoint temporal parts**
⊂ *decomposition**

C. Concept System of Subject Domain of Subject Domains

Consider formal model of one more important subject domain – ***Subject domain of subject domains*** within which various subject domains including this domain itself are objects of research.

Key concepts within ***Subject domain of subject domains*** are the following:

- ***role relations*** connecting signs of subject domains with sc-elements which are included in these *subject domains* and, in particular, with signs of key concepts of specified subject domains. Such *role relations* have been considered above;
- concepts which denote various ***classes of subject domain***;
- relations specified on *set of subject domain*;
- family of concepts which can be defined only within *Subject domain of subject domains*.

1) Consider certain classes of subject domains: which are important for intelligent systems.

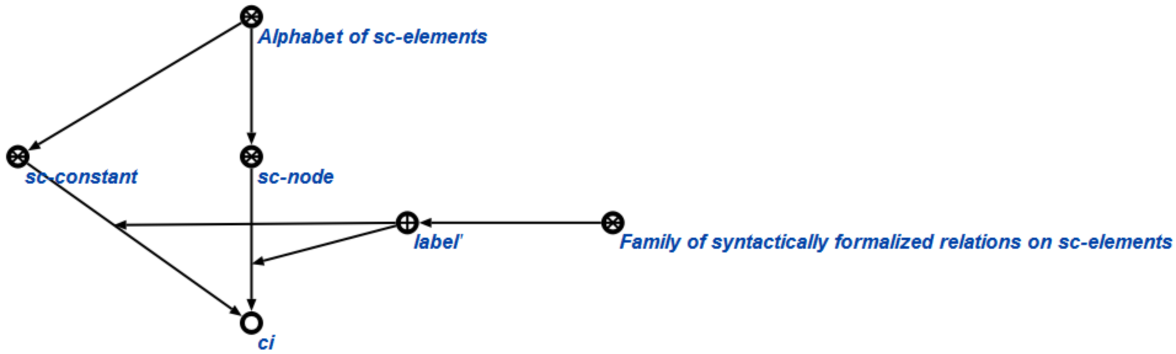

Figure 2. Specification of some constant sc-node ***ci***

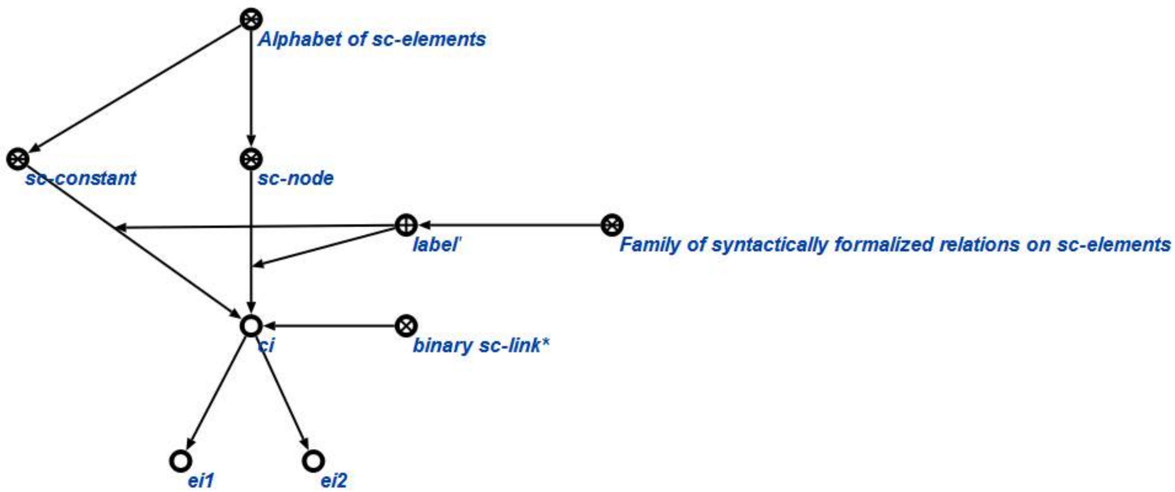

Figure 3. Adjustment of specification of sc-node ***ci***

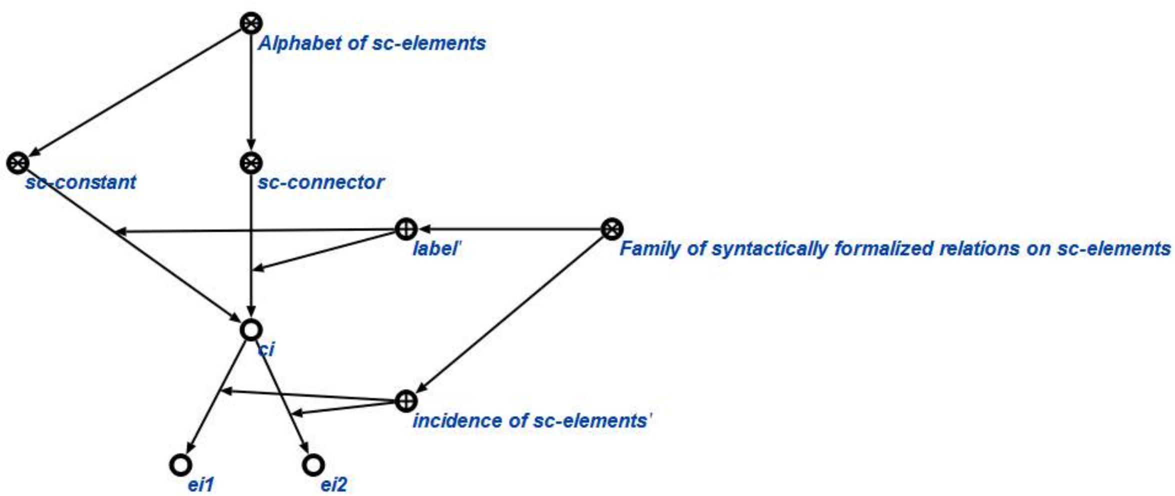

Figure 4. Change of syntax type of sc-node ***ci***

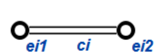

Figure 5. Transformation of sc-node ***ci*** into an sc-connector

subject domain
⊂ *sc-structure*
<= *partitioning*:*
- *static subject domain*
  ⊂ *static sc-structure*
- *dynamic subject domain*
  ⊂ *sc-process*
    = *dynamic sc-structure*
  ⊃ *subject domain of actions and tasks*

subject domain of actions and tasks
⊃ *subject domain of knowledge elicitation from specified subject domain and its ontology*
  = *subject domain of actions for knowledge elicitation from current state of kept in memory fragment of specified subject domain and its ontology*
  = *subject domain of activity during operation of specified subject domain and its ontology, i.e. generating answers to information questions within this subject domain and its ontology*
⊃ *subject domain of improvement of specified subject domain and its ontology*
  = *subject domain of design actions for improvement of current state of kept in memory fragment of specified subject domain and its ontology*
⊃ *subject domain of designing on the base of specified subject domain and ontology of corresponding class of artefacts*
  = *subject domain of design actions for creating information model (specification) of certain new artefact on the base of specified subject domain and ontology of corresponding class of artefacts*
⊃ *subject domain of external behaviour*
  = *subject domain for changing state of specified dynamic subject domain*
  ⊃ *subject domain for implementation of designed artefacts*

The main problem which is solved within *subject domain of external behaviour* and its ontology – is the problem of behaviour planning, i.e. the problem of creating plan of action to achieve the specified goal.

2) Consider certain ***relations specified on set of subject domains****:*

relation specified on set of subject domains
= *relation connecting subject domains either among themselves or with other kinds of entities*
∋ *subject domain of knowledge elicitation from subject domain and its ontology**
  = *Relation each link of which connects a subject domain with other subject domain describing actions and tasks for knowledge elicitation from kept in memory current state of the first subject domain and its ontology**
∋ *subject domain of improvement of subject domain and its ontology**
  = *Relation each link of which connects a subject domain with other subject domain describing actions and tasks for improvement of the first subject domain and its ontology**
∋ *subject domain of designing**
  = *Relation each link of which connects a dynamic subject domain describing a class of artefacts with other subject domain describing actions and tasks for developing information model of a new artefact belonging to specified class of artefacts**
∋ *subject domain of external behaviour**
  = *Relation each link of which connects a dynamic subject domain with other subject domain describing actions and tasks for changing state of the first subject domain**
∋ *subject domain of implementation of designed artefacts**
  ⊂ *subject domain of external behaviour**
  = *Relation each link of which connects a dynamic subject domain describing a class of artefacts with other subject domain describing actions and tasks for implementation (reproduction) of a new artefact belonging to specified class of artefacts**
∋ *partial subject domain**
  = *to be a subject domain a set of researched objects of which is included in a set of researched objects of other specified subject domain**
  = *subject domain of a subset of researched objects of specified subject domain**
∋ *subject domain with united set of researched objects**
  = *to be a subject domain a set of researched objects of which is a union of sets of researched objects of certain family of other specified subject domains**
∋ *subject domain of class of parts of researched objects of specified subject domain**
  = *to be a subject domain a set of researched objects of which is a class of parts of researched objects of specified subject domain* (specified parts can be either spatial or temporal)*
∋ *subject domains equivalent over a set of researched objects**
  = *subject domains which have the same researched objects but do not consider different connections of these researched objects between themselves as well as with other entities**
∋ *ontology**
  = *to be an ontology for the specified subject domain**
  = *Relation each link of which connects sign of a subject domain with sign of the corresponding ontology**

3) At the end of consideration of Subject domain of subject domains: let's give an example of concepts which can be defined only within this subject domain. In particular, such a concept is a concept of ***concept***.

concept
= *class of entities which at least within one of subject domains implements the role of researched class (the role of class of researched objects, the role of researched relation, the role of researched class of structures, the role of researched class of classes)*
⊂ *sc-class*

So far from each class of entities can have a status of ***concept***.

IV. Formal models of ontologies

This chapter addresses some aspects of formal ***ontologies*** representation using the tools of basic language of sense knowledge representation, i.e. formal ontologies representation as *sc-texts*.

Semantics of any language each of which is a set of sign constructions is specified as follows:

- on the lower level – by clarifying ***sign*** concept and by clarifying relations specified on sign language (this is SC-code level);
- on the top level – by hierarchical system of *subject domains* and the corresponding ***ontologies***. This system clarifies a variety of used in this language ***concepts*** distributing these concepts between ***subject domains*** and specifying them within the corresponding ontologies.

Explicit distinguishing ***ontologies*** in knowledge bases of intelligent systems is necessary for the following:

- to fix a coordinated current version of treatment (clarification) of all the used concepts;
- to secure a clear organization of continuous process of developing and coordinating the system of used concepts. In its turn, this requires detailed documenting (logging) all the changes in concept system.

Stress that while designing knowledge bases it is necessary on every stage to secure *semantic compatibility* of knowledge bases and their components. This is especially important when different collectives of knowledge engineers participate in the same development process and when the system of used concepts is being changed constantly and therefore ontologies also is being changed constantly. It is clear, that such compatibility could not be achieved without explicit distinguishing ontologies, without *logs of coordinated changes* of different subject domain ontologies, without explicit distinguishing *coordinated specified versions* for each of ontologies.

Each ***ontology*** is a model (specification) of a ***subject domain***, more precisely, a specification of system of concepts used within this subject domain.

Classification criteria of ontologies are the following:

- class of subject domain specified be this ontology;
- type of specification itself of subject domain.

To type of specification of subject domain could be attributed the following:

- structural specifications of subject domains – ***structural ontologies***;
- set-theoretical specifications of subject domains – ***set-theoretical ontologies***;
- logical specifications of subject domain – ***logical ontologies***;
- terminological specifications of subject domains – ***terminological ontologies***;
- ***integrated ontologies*** which unite all the specified partial types of ontologies.

At the same time if we unite all ontologies of certain type in a integrated text then this text can be treated as a subject domain comprising various ontologies of specified type.

Each ***structural ontology*** represents a fragment of ***Subject domain of subject domains***. This fragment contains all information about specified subject domain:

- role structure of subject domain,
- typology of subject domain,
- connections of subject domain with other subject domains.

Each ***set-theoretical ontology*** comprises not only specification of concepts considered in the specified subject domain but also specification of connections between relations and their definition areas, between relations and their domains, between characteristics (parameters) and a set of those entities which possess these characteristics. This ontology comprises also description of other set-theoretical connections between concepts included in specified subject domain.

All ***set-theoretical ontologies*** can be put in correspondence with ***Subject domain of sets*** researched objects of which are various sets including concepts comprised by specified subject domains.

Each ***logical ontology*** comprises:

- indication of not-defined concepts of specified subject domain;
- definitions of defined concepts;
- description of hierarchical system of concepts based on the facts which concepts are used in definition of each concept;
- axioms;
- theorems;
- proofs;
- description of hierarchical system of axioms and theorems indicating which axioms and theorems have been used for proving each theorem;
- description of different types of connections and analogies between definitions, axioms, theorems and proofs.

By analogy with relationship between *structural ontology* and *Subject domain of subject domains* **logical ontilogies** is put in correspondence with ***Subject domain of logical formulas*** key concepts of which are the following: ***sc-variable*** concept, concepts ***of logical formula, atomic logical formula, non-atomic formula of existence, conjunctive formula, disjunctive formula, implicative formula, formula of negation*** and other concepts.

Each ***atomic logical formula*** is treated on SC-code as a permanent *sc-scructure* among the elements of which there are both *sc-constants* and *sc-variables*. Each ***non-atomic logical formula*** is treated as *sc-link* which is attributed to the corresponding *sc-class of non-atomic logical formulas* and elements of which are signs of logical formulas which are components of given *non-atomic logical formula*.

Each t***erminological ontology*** comprises:

- description of main terms used for external representation of all the concepts considered by specified subject domain;
- description of minor terms belonging to different languages with specifying synonymy and homonymy;
- description of origin of used terms;

- description of connections of terms with authoritative documents in which these terms are used;
- description of linguistic specification of each term;
- description of rules of creating names for instances of concepts considered within a specified subject domain.

Terminological ontologies are put in correspondence with ***Subject domain of terms***, by analogy with relationship between *logical ontologies* and *Subject domain of logical formulas*.

It is clear that each considered in this chapter *subject domain* is put in correspondence with its *integrated ontology*:

- ***Ontology of entities***,
- ***Ontology of subject domains***,
- ***Ontology of sets***,
- ***Ontology of logical formulas***,
- ***Ontology of terms***.

Ontology of entities
= *Base ontology of SC-code reflecting main principles of its syntax and semantics*
= *Ontology of Subject domain of entities*
= *General ontology of entities*

V. Ontological Model of Intelligent System

A feature of designing knowledge data bases is the fact that knowledge bases are both objects and results of design because in this case information model of designed object which is the result of design and design object itself coincide, i.e. knowledge base and its information model are one and the same thing.

Knowledge bases of intelligent systems which are developed on the base of SC-code in the form of sc-models of knowledge bases and designing of those knowledge bases have a number of advantages and features.

Since SC-code is universal language of formal knowledge representation it can be used not only for representation of ontological model of knowledge base of intelligent system (sc-model of knowledge base) but also of ontological model (sc-model) of intelligent system on the whole. Clear that *sc-model of knowledge base* of intelligent system will be a part of sc-model of this intelligent system.

If we introduce the concept ***of extended knowledge base of intelligent system*** and if we consider sc-model of this intelligent system as such knowledge base we will have a lot of advantages. These advantages mainly relate to significant increasing flexibility of developed intelligent systems and of their platform independence. Flexibility level of developed intelligent systems is determined by work content for changing system maintaining its integrity. In case of collective development flexibility level is determined also work content is.

Platform independence level is determined by a number of "coordination points" between developers of sc-models of certain intelligent systems (i.e. designers of such systems) and developers of interpreters for different platforms providing interpretation of sc-models of any intelligent systems. Ontological character of sc-models of intelligent systems provides an opportunity to clear indicate "coordination points" which are concepts of the corresponding ontologies.

The structure ***of sc-model of extended knowledge base of ostis-system*** is a reflection of this ***ostis-system*** architecture because such extended knowledge base comprises:

- sc-model of ***main subsystem of ostis-system***;
- sc-model of ***subsystem of improvement of extended knowledge base*** of considered ostis-system***;***
- sc-model of ***subsystem of improvement of integrated knowledge processing machine*** of considered ostis-system. This integrated machine comprises knowledge processing machines of all subsystems of this ostis-system;
- sc-model of ***subsystem of improvement of integrated user interface*** of considered ostis-system. Such interface comprises user interfaces if all subsystems of this ostis-system.

All the specified subsystems of considered ostis-system, in their turn, comprise the following:

- ***sc-model of knowledge base*** of subsystem;
- ***sc-model of knowledge processing machine*** of subsystem;
- ***sc-model of user interface*** of subsystem.

Stress that *sc-model of user interface* of each subsystem of ostis-system and also *sc-model of integrated user interface* of the whole ostis-system consists of ***sc-model of knowledge base of user interface*** and ***sc-model of knowledge processing machine of user interface***.

sc-model of knowledge base of user interface, in its turn, comprises:

- description of syntax and semantics of all used external languages. This description should be full enough to make it possible translation of *SC-code* texts to external language and vise versa by *knowledge processing machine of user interface*;
- description of how "main window" of user interface of the subsystem of considered ostis-system is included in "main window" of *integrated user interface* of this ostis-system;
- description of interaction principles of user interface with users on the low interface level;
- interface models of users containing information about their peculiarities, possibilities and preferences. This information makes interface to be able to adapt to each user and to make more effective interaction with user.

So designing *ostis-system*, in fact, is reduced to designing its *extended knowledge base*. At the same time specific of designing *integrated knowledge processing machine of ostis-system* and its *integrated user interface* is reduced to only semantic specifics of the corresponding sc-models – of *sc-models of knowledge processing machines* and *sc-models of user interfaces* which are specified by the corresponding ontologies: ***Ontology of knowledge processing machines*** and ***Ontology of user interfaces***.

It follows that *Subject domain and ontology of sc-models of knowledge bases* coincide completely within OSTIS Technology with *Subject domain and ontology of sc-models of ostis-systems*.

Accordingly *Subject domain and ontology of designing sc-models of knowledge bases* is identified with *Subject domain and ontology of designing sc-models of ostis-systems*.

At the same time *Subject domain and ontology of sc-models of knowledge processing machines* and also *Subject domain and ontology of sc-models of user interfaces* become *partial** in relation to *Subject domain and ontology of sc-models of knowledge bases*.

Information about different kinds of activity of *ostis-system*, its subsystems and its users is also included in *sc-model of extended knowledge base of ostis-system*:

- information about work of *ostis-system users* on the low (front-end) level. This is results of monitoring and analysis of user activity on front-end level;
- information about *operation of ostis-system* includes knowledge elicitation (first of all by users) from the current state of *extended knowledge base*. Such knowledge elicitation means not only information search but also solution of problems of any level of complexity. Description of operational activity is formalized as logs of *dialogue between ostis-system and their users*. These logs (1) can be interesting for users themselves, (2) can be useful for clarifying models of information necessities of users – it is important for increasing efficiency of interconnecting with users on meaningful level, (3) can be useful for detecting errors and defects of ostis-system itself;
- information about continuous activity for *improving knowledge base of ostis-system* both in whole and within improving sc-models of its separate subsystems.

Information about improvement of knowledge base comprises:

- current coordinated state of knowledge base;
- log of changes of knowledge base;
- suggestions for improvement of knowledge base;
- current state of process of coordinating suggestions for improvement knowledge base;
- log of coordinating suggestions for improvement knowledge base.

So extended knowledge base of ostis-system reflects two viewpoints of ostis-system consideration:

- *ostis-system* architecture;
- *ostis-system* dynamics in terms of its operation and evolution (past activities and their results, current activities, future planned events).

VI. Ontological model of designing intelligent system

As it was mentioned in the previous chapter designing intelligent system using *OSTIS Technology* is reduced to design of its *extended knowledge base* which represents meaningful *sc-model* of developed intelligent system. Typology of *design actions* while designing intelligent system is determined by:

- typology of designed component of intelligent system;
- type of design action.

Depending on typology of designed component the following actions can be distinguished:

- subject-independent design actions for developing sc-models of various knowledge base fragments;
- specific actions for developing *sc-models of knowledge processing machines*;
- specific actions for developing *sc-models of user interfaces*.

Depending on type of design actions the following activities can be distinguished:

- testing of given fragment of extended knowledge base;
- elimination of contradictions and errors in knowledge base detected during testing;
- information waste removal (i.e. those sc-texts which are not needed more);
- addition of new *sc-texts* which do not change structure of any *subject domain* (i.e. its *ontology*);
- change of structure of *subject domain*. Each such change should have a clear specified transition period at the end of which all the needed corrections of this *subject domain* and its *ontology* caused by replacement of one group of concepts to another should be completed;
- whole complex of design actions for changing *subject domain* and its *ontology* in accordance with coordinated changes in system of concepts of this *subject domain*. The first step of this process is generating design action plan which is directed to knowledge base engineers. On the next step engineers of knowledge bases enter into knowledge base formal *definitions* of all new concepts and also of obsolete replaceable concepts on the base of currently used concepts. Further design actions can be completed manually or automatically;
- expertise, coordination and approval of suggestions for improvement of knowledge base.

VII. Intelligent System for Complex Automation of Designing Intelligent systems

Proposed *OSTIS Technology* is implemented as an intelligent system which created with OSTIS Technology itself. We called this system ***IMS Metasystem*** (Intelligent MetaSystem). The current version of this metasystem contains accumulated to this moment and formalized models, tools and methods of designing intelligent systems which are included in *OSTIS Technology*.

Remember that the main advantage of *OSTIS Technology* is flexibility of *ostis-systems*, i.e. systems which are developing on this technology. It is true also for *IMS Metasystem* because it is also *ostis-system*. It follows flexibility of *OSTIS Technology* itself, i.e. ensuring high level of development (improvement) of this technology. The main work content of *OSTIS Technology* development is reduced to creating a clearly working infrastructure which ensures organization of expertise, coordination and approval of various suggestions for improvement of *OSTIS Technology*. From formal point of view these suggestions represent suggestions for improvement of *extended knowledge base of IMS Metasystem*. Stress that at the same time *IMS Project* aimed to developing *IMS Metasystem* and, consequently, to developing *OSTIS Technology* is an open project. Such a project allows to anyone who wishes to get into team of *OSTIS Technology* developers following all the rules of project activity organization.

IMS Metasystem interacts not only with its developers and end-users but also with other ostis-systems which are created on OSTIS Technology and represent its *child systems**. IMS Metasystem for its child systems:

- carries out automatic assembly of *child ostis-systems* starting versions on instructions which developers of these systems direct to IMS Metasystem. This way new *child ostis-systems* are generated;
- includes in *child ostis-systems* new *reusable components* from permanently replenished *OSTIS Library*. IMS makes it on its own initiative or on request of developers;
- replaces in *child ostis-systems* obsolete versions of *reusable components* by new versions from *OSTIS Library*. IMS makes it on its own initiative or on request of developers;
- includes in *child ostis-systems* a subsystem of improvement of its extended knowledge base and, if necessary, a subsystem of improvement of its *integrated knowledge processing machine* and of *user interface*;
- automatically forms and directs to *child ostis-systems* various suggestions for improvement of these systems caused by new features of permanently improved *OSTIS Technology*. These suggestions should have its own expert examination, coordination and approval within a project of improvement of the corresponding *child ostis-system*.

Thus after child ostis-systems appeared its connection to *IMS Metasystem* is not interrupted and *IMS Metasystem* become a permanent participant of process of improvement of all *child ostis-systems*.

Note also that all published materials about *OSTIS Technology* in formalized type are included in *IMS Metasystem* knowledge base [3].

More detailed information about *IMS Metasystem* see in [10].

VIII. Conclusion

In the heart of ***ontology-based design*** lies development of a complex of interconnected *subject domains* and their corresponding *ontologies*.

The main advantage of ontological approach to design is essential **increasing of flexibility** of both developed systems and design activity because of clear differentiation of (1) those *design activities* which can be executed locally within the corresponding *subject domains* and therefore do not require any coordination with design actions within another subject domains and (2) those design actions which should be coordinated between different subject domains under clearly specified coordination procedure.

Flexibility and **clearness of decomposition** of designed systems *ontological models* are the basis for effective organization of *collective design activity*.

When *designing dynamic systems* the main object of design is not only structure of these systems but also activity of these systems (activity of knowledge processing machine, activity of users during system operations and for system improvement).

Universal language of knowledge representation within intelligent systems (***SC-code***) is an effective formal base for implementation of ontology-based design of both intelligent systems and any other technical systems. The main advantages of *SC-code* are unity of syntax and semantics and also unity of language and metalanguage.

Development of *formal knowledge models* is a key issue in designing intelligent systems because quality of knowledge processing machine, of user interface and other components of intelligent system directly depend on quality of ***knowledge base***. But development of formal knowledge models is a key issue also:

- when designing any complex technical systems because direct product of any design is an information ontological model which is complete enough for the following implementation (reproduction) of this technical system;
- when organizing collective development and coordination of any other scientific and technical information, for example when developing standards;
- when processing results of any scientific researches because in this case results should be well structured, clearly represented, verified and coordinated knowledge.

More precise definition of ***ontology-base design of intelligent systems*** offered in this paper comprises solutions of the following problems:

- creating ontology of design objects – *Ontology of intelligent systems*. Such ontology is nothing but general formal theory of intelligent systems based on unified *formal models of intelligent systems*;
- creating ontology of design actions – *Ontology of designing intelligent systems*;
- creating *ontological model of intelligent system for automation of designing intelligent systems*.

Further developing ***formal models of ostis-systems*** would require include in ostis-system architecture the following additional systems:

- *subsystem of users training ostis-system* which allows end-users and developers to get new knowledge and skills during interconnection with ostis-system;
- *subsystem of information security* of ostis-system;
- *subsystem of verbal interface with other systems* (including other ostis-systems);
- *subsystem of perception and primary analysis of non-verbal information* about external environment;
- *subsystem of non-verbal influence on external environment*.

Particular aspects of ***OSTIS Technology*** are considered in the following works:

- about *technology of designing knowledge bases* of ostis-systems see [14];
- about *technology of designing knowledge processing machines see* [30];

- *about technology of designing user interfaces* of ostis-systems see [17];
- about creating *interpreters of formal models of ostis-systems* on different platforms see [18].

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ОНТОЛОГИЧЕСКОЕ ПРОЕКТИРОВАНИЕ ИНТЕЛЛЕКТУАЛЬНЫХ СИСТЕМ

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Статья посвящена уточнению понятия формальной модели интеллектуальной системы, а также рассмотрению методик и средств проектирования интеллектуальных систем. Совокупность таких моделей, методик и средств есть не что иное, как технология проектирования интеллектуальных систем. Актуальность создания таких технологий обусловлена расширением областей применения интеллектуальных систем и, как следствие, необходимостью существенного снижения трудоемкости их разработки.

Особенностью данной статьи является рассмотрение технологии проектирования интеллектуальных систем на основе онтологий, т.е. онтологическая трактовка указанной технологии. Онтологический подход к проектированию любых классов сложных систем (в том числе и интеллектуальных систем) дает возможность четко и иерархически декомпозировать процесс проектирования любой системы заданного класса на такие проектные действия, многие из которых могут выполняться параллельно и каждое из которых может быть выполнено локально, т.е. не выходя за пределы конкретных онтологий.

Таким образом, иерархической системе проектных действий ставится в соответствие иерархическая система онтологий, в рамках которой соответствующие проектные действия могут быть выполнены. Очевидно, что это существенно ускоряет проектную деятельность путем ее распараллеливания и локализации области поиска решения при выполнении каждого проектного действия.

Проблемы, которые необходимо решить для достижения поставленной цели:

- Для повышения эффективности проектирования интеллектуальных систем необходимо иметь общую (комплексную, интегрированную, целостную) технологию проектирования интеллектуальных систем, в рамках которой были бы согласованы все необходимые частные технологии, т.е. была бы гарантирована совместимость проектных решений, которые могут быть получены в рамках различных частных технологий.
  Совместимость таких проектных решений – это совместимость различных видов компонентов интеллектуальных систем, которые могут быть продуктами разработки в общем случае различных и независимых друг от друга коллективов разработчиков. В частности, должна быть гарантирована совместимость различных видов знаний, которые входят в состав базы знаний, различных моделей решения задач, используемых интеллектуальным решателем задач, совместимость различных моделей понимания внешней информации, которая поступает в интеллектуальную систему по разным каналам, в разной форме и на разных языках.
- Чтобы создать общую интегрированную технологию проектирования интеллектуальных систем, необходимо разработать общую формальную теорию интеллектуальных систем.
- Технология проектирования интеллектуальных систем должна обеспечивать снижение трудоемкости не только при первоначальной разработке интеллектуальных систем, но и в процессе постоянного их совершенствования (модернизации, реинжиниринга) во время эксплуатации.
- Необходимо, чтобы формальные модели интеллектуальных систем, которые являются продуктами (результатами) их проектирования, были максимально просты и легко понимаемы не только интерпретаторами, которые используются для их реализации на различных платформах, но и всеми разработчиками подобных моделей.
- Так как модели представления знаний и модели обработки знаний могут различаться у разных интеллектуальных систем, основой для разработки таких моделей должен быть единый универсальный принцип, "скелет который позволяет строить иерархические многоуровневые модели представления и обработки знаний любой конфигурации.
  Для моделей представления знаний необходимо иметь возможность перехода от знаний к метазнаниям, от метазнаний к метаметазнаниям и т.д., и, в частности, от описания действий (как внутренних, так и внешних) к описанию действий сколь угодно более высокого уровня.
  Для моделей обработки знаний необходимо иметь возможность перехода от агентов, способных выполнять действия одного уровня, к коллективным агентам, способным выполнять действия сколь угодно более высокого уровня.

Несмотря на то, что уже существует достаточно много современных технологий проектирования интеллектуальных систем, они решают далеко не все указанные выше проблемы. Так в последнее время наибольшее внимание уделяется инженерии знаний и технологиям онтологического инжиниринга в ущерб другим не менее важным аспектам проектирования интеллектуальных систем.

Как следствие этого, современные технологии проектирования интеллектуальных систем:

- строятся не на основе общей формальной теории интеллектуальных систем и, следовательно, недостаточно детально рассматривают интеграцию "разнородных" компонентов интеллектуальных систем (баз знаний, машин обработки знаний, пользовательских интерфейсов), а также не имеют единой универсальной формальной основы, позволяющей в рамках технологии интегрировать самые разнообразные научные и практические результаты в области искусственного интеллекта;
- не обеспечивают совместимость разрабатываемых интеллектуальных систем и их компонентов, что затрудняет организацию одновременного проектирования разных компонентов одной системы с последующей интеграцией этих компонентов, а также разработку коллективов интеллектуальных систем;
- не обеспечивают платформенную независимость проектирования интеллектуальных систем, т.е. четкое разделение процесса разработки полных формальных моделей интеллектуальных систем и процесса разработки интерпретаторов этих моделей на различных платформах;
- не имеют формализованных методик комплексного коллективного проектирования интеллектуальных систем и, в частности, не имеют четко формализованных рамок полной независимости одновременно выполняемых ветвей проектирования и точек необходимого их согласования. Следовательно, не обеспечивают сокращение трудоемкости и сроков разработки интеллектуальных систем;

- не включают в себя методик обучения инженеров интеллектуальных систем, и, следовательно, не обеспечивают повышение их квалификации при разработке и эксплуатации этих систем;
- не поддерживают собственное развитие, в том числе, путем анализа и систематизации проектного опыта.

В основе предлагаемого подхода к созданию комплексной технологии проектирования интеллектуальных систем лежат следующие принципы:

- Использование онтологического подхода к проектированию интеллектуальных систем, т.е. подхода, основанного на иерархической системе формальных онтологий.
- Разработка принципов и соответствующих онтологий для формального смыслового представления знаний любого вида, в том числе и формальных онтологий.
- Разработка Формальной онтологии интеллектуальных систем, на основе которой выполняется унификация и упрощение формальных моделей интеллектуальных систем.
- Разработка иерархической системы согласованных (совместимых) формальных онтологий для различных видов знаний и различных моделей обработки знаний. Это обеспечивает интеграцию различных видов знаний и различных моделей обработки знаний, а также независимость от платформ их интерпретации.
- Разработка Общей модели обработки знаний, которая представляет собой коллектив агентов, работающих над общей семантической памятью, взаимодействующих через эту память и управляемых знаниями, которые хранятся в указанной памяти. Оформление этой модели в виде онтологии, частными по отношению к которой будут различные онтологии конкретных моделей обработки знаний (индуктивных, дедуктивных, четких, нечетких и т.д.).
- Разработка иерархической системы согласованных формальных онтологий проектной деятельности, направленной не только на построение интеллектуальных систем, но и на постоянную их модификацию непосредственно в процессе эксплуатации. Такая иерархическая система формальных онтологий проектирования вместе с соответствующими инструментальными должна обеспечить высокие темпы совершенствования интеллектуальных систем во время их эксплуатации.
- Обеспечение высокого уровня гибкости предлагаемой технологии благодаря тому, что технология реализуется в виде интеллектуальной метасистемы, которая обеспечивает комплексную поддержку разработки интеллектуальных систем по предлагаемой технологии и которая сама построена по этой же технологии.
- Разработка формальной онтологии совершенствования технологии проектирования интеллектуальных систем: накопление и систематизация проектного опыта, расширение библиотек многократно используемых компонентов и т.д.
- Использование методики компонентного проектирования, в основе которой лежит постоянно пополняемая библиотека многократно используемых компонентов. Это пополнение выполняют как разработчики технологии проектирования, так и разработчики конкретных интеллектуальных систем. Таким образом, предлагаемая технология, оформленная как интеллектуальная метасистема и реализованная по той же технологии, обладает высокими темпами развития, имея эффективные средства спецификации накапливаемого инженерами проектного опыта, эффективные средства спецификации новых научных результатов (т.е. принципиально новых моделей, средств и методов, предлагаемых для разработки интеллектуальных систем) и эффективные средства для внесения изменений в те модели, средства и методы, которые используются в текущий момент.
- Наличие единого фундамента, позволяющего на его основе строить различные уровни иерархии компонентов интеллектуальных систем, т.е. переходить от уровня к метауровню, от знания – к метазнанию, от действий, классов действий и способов их выполнения – к метадействиям, классам метадействий и способам их выполнения, от систем – к метасистемам. Благодаря этому появляется возможность создавать многоуровневые библиотеки многократно используемых совместимых компонентов. Все это дает возможность существенно повысить уровень компонентного проектирования, когда компьютерные системы собираются из компонентов любого уровня иерархии.
- Предлагаемая технология представляет собой открытую семантическую технологию компонентной платформенно-независимой разработки гибких совместимых интеллектуальных систем и названа нами Технологией OSTIS (Open Semantic Technology for Intelligent Systems).

В основе онтологического проектирования любых систем лежит разработка целого комплекса взаимосвязанных предметных областей и соответствующих им онтологий.

Основное достоинство онтологического подхода к проектированию – это существенное повышение гибкости как самих разрабатываемых систем, так и самой проектной деятельности благодаря четкому разделению (1) тех проектных действий, которые могут выполняться локально в рамках соответствующих предметных областей и не требовать никакого согласования с проектными действиями в других предметных областях и (2) тех проектных действий, которые должны быть согласованы между разными предметными областями, но процедура согласования которых четко определена.

Гибкость и четкость декомпозиции онтологических моделей проектируемых систем является основой для эффективной организации коллективной проектной деятельности.

Ontology-Based Knowledge Base Design

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***Abstract*—The paper deals with the application of the ontological approach to the design of knowledge bases developed by group of developers. This approach is based on the representation of the knowledge base as a hierarchal structure of interconnected subject domains and their ontologies.**

***Keywords*—knowledge base, ontology, ontological design, component-based design, collective development**

I. Introduction

A. Goal and relevance

Nowadays there is urgent problem of effective information support of various branches of human activity. Increasing of the amount of information has caused creating knowledge storages, providing structuring and systematization of stored knowledge, as well as their effective processing.

One of the most promising directions in this field is development of knowledge-based system [46]. A key component of such systems is the knowledge base. The quality of the developed system of such type is defined including by the quality of knowledge base and variety of types of knowledge, stored in it.

Developing of knowledge base is a time-consuming and lengthy process. Accordingly, there is urgent problem of reducing time of development and ensuring of effectiveness of life cycle support of knowledge bases.

There are following ways to reducing the time and decreasing the laboriousness of knowledge bases development:

- ensuring joint development of knowledge bases by distributed group of developers [12];
- automation of activity of knowledge bases developers;
- reusing of already developed knowledge bases fragments [30], [36], [1], [47], [33], [7].

However, full automation of the process of knowledge base development is impossible, because some steps, such as the formation of a concepts system, require the agreed efforts of a number of developers and experts and are subjective.

An important step of knowledge base development is structuring. Structuring of knowledge base, i.e. selection of various interconnected substructures in it is needed for a variety of reasons [3]. In particular, it is necessary for didactic purposes (for person, acquiring some knowledge, it is desirable to have a kind of contents of this knowledge, that allows to schedule its assimilation and consider it with varying degree of detail), as well as for organizing of the distribution of tasks of knowledge bases design (when various implementers are entrusted development of various fragments of knowledge bases, with enough clear boundaries).

The goal of this work is the development of a unified semantic models of knowledge bases and tools of their collective development, based on the ontological structuring of knowledge base, that allows to decrease laboriousness and time of their development and modernization.

B. Problems for achieving goal

Among problems in the field of knowledge bases development are following:

- Lack of tools of unification of all types of knowledge and models of knowledge representation in a single knowledge base.
- Lack of formal tools of structuring, enabling the knowledge base to be presented on different levels of detailing.
- Lack of a unified approach to the selection of reusable components of knowledge bases and formation of components libraries, which leads to the large number of incompatible already developed components of knowledge bases. [33]
- Laboriousness of modernization of knowledge bases and their support is high (some changes, made in knowledge base can cause the necessity of substantial changes in knowledge base structure).
- Despite there are a lot of well-developed tools for design of knowledge bases, still there are no tools to ensure complex support for the development team on the all stages of knowledge base design, which are, in its turn, enough flexible and extensible. Besides, all existing tools are generally oriented at any specific knowledge storage format, which makes complicated the transfer of already developed knowledge base on another interpretation platform.

C. The analysis of modern approaches to achieving the goal

Nowadays, there are several models of knowledge representation, however most of them can be reduced to four basic: semantic networks, frames, productional and logical model [2].

However, each of said knowledge representation models is adapted to specific kinds of knowledge representation, while creating of intelligent systems often requires representation of various kinds of knowledge in a single base, which can not be provided by any of the models above, taken individually. [15], [13] Hence there is a necessity of creation a universal model of knowledge representation, which would allow to represent any kinds of knowledge in a unified manner.

The key moment in the process of knowledge structuring is formation of system of basic concepts of subject domain. [3].

Nowadays, during the process of development of knowledge-based system, widespread use of the W3C consortium standards [43]. Its mission is the development of standards in the field of Semantic Web [43], [25]. In particular language for ontologies description OWL [39] and knowledge representation language in the form of semantic networks RDF [40] were developed by consortium. Also effective knowledge base storages based on RDF were developed ensure storage and access to data by means of the query language SPARQL [42]. To edit ontologies a large number of editors was created, which have a fairly broad functionality [38].

However, despite the development of the Semantic Web project and related means, a significant part of the resources of Web still contains no semantic markup and metadata. Semantic resources that are developed on the base of Wiki-Technologies [44] are exceptions and are becoming increasingly popular.

Wiki-technology allows to accumulate knowledge, which are presented in interoperable form, providing knowledge navigation. Using Wiki-technology is possible for projects of any scale and thematic focus (from open electronic encyclopedias, to reference systems of different companies and educational institutions) [21].

Wiki-technology provides its users tools for storage, structuring text, hypertext, files and multimedia. Wiki-technology uses MediaWiki platform as a tool [37], which allows to perform information interaction, provides access to information resources of all participants in the system development process, organize, manage and oversee the development process. [6] Among advantages of this technology can be distinguished simplicity of wiki-marking, communication capabilities, which are implemented through co-authoring pages editing as well as by electronic discussions on the wiki or other environments, such as chat or forum, project nature of the work, cooperation, formation of a single product of joint activity provide a meaningful engagement, knowledge sharing, evaluation and continuous improvement of work [21].

Influence of Semantic Web for such projects is constantly increasing, so that the engines of Wiki-sites were created, which support the ontological knowledge representation and semantic markup resources, by Semantic MediaWiki tools [41]. These tools allow to include semantic annotation to Wiki-markup in the form of OWL and RDF and to separate explicitly structured and unstructured information. [21].

Besides these advantages, Wiki, as technology, has several disadvantages: duplication of information on different pages, the impossibility of knowledge structuring due to lack of hyperlinks hierarchy and lack of unification of data representation, lack of possibility of automatic verification.

In this paper, the idea of Wiki technology has been used, but has been attempted to eliminate these problems.

To the problem of development and structuring knowledge bases the following research were focused on:

- Knowledge Base and Knowledge Management [2], [3]
- Fractal model of knowledge structuring, based on the representation of different forms (species) of knowledge as objects layered (stratified) space [19]
- Technology of development engineering knowledge source providing performance of complex engineering calculations [8]
- AT-Technology [23]
- Technology of development of intelligent cloud services based on IACPaaS platform - Intelligent Application, Control and Platform as a Service [9]
- Technology of sources development of scientific knowledge [13], [14]

Nowadays, a large number of knowledge bases on a variety of subject domains was developed [29]. However, most of them are not well-structured, consistent and compatible with each other.

D. The principles underlying the proposed approach to achieve this goal

At the proposed models are following basic principles of open semantic technology of intelligent systems design OSTIS (Open Semantic Technology for Intelligent Systems) [34]:

- using of the ontological approach to the knowledge bases design, which involves structuring of knowledge bases, based on ontologies;
- phased evolutionary knowledge bases design;
- focus on team-oriented knowledge base design in the project;
- focus on semantic knowledge base representation;
- unification of knowledge bases models of intelligent systems;
- modular design based on libraries of typical reusable components.

OSTIS technology is focused on the development of ***knowledge-driven computer systems*** - systems, each of which is based on knowledge base, presented in a unified way, which contains all the information, used by the system, in a systematic way [4]. As part of paper, knowledge-based system developed using OSTIS Technology, is called ***ostis-systems***.

E. The tasks that must be solved for implementation of the proposed approach to achieve the goal

To solve the above problems is required to solve the following tasks:

- develop a unified semantic models of representation of different types of knowledge, based on ontologies;
- develop ontological models of knowledge bases structuring;

- develop ontological models of team knowledge base design;
- develop support subsystem of team knowledge bases design, including automation of developers' activities, tools for editing of knowledge bases, tools for automation of verification of knowledge bases.

II. The ontological model of the knowledge base

In this paper it's proposed to use as a formal basis for knowledge representation method of knowledge representation in the form of semantic networks with the basic set-theoretic interpretation, allowing to describe as knowledge relating to the subject domain (including meta-knowledge and a simple transformation from knowledge to meta-knowledge), so as processing procedure. This method is the base on Open semantic technologies of intelligent systems (OSTIS). Thus it was developed a method of such semantic networks encoding - SC-code (Semantic Code). Elements of such a semantic network are called sc-nodes and sc-connectors (sc-arcs, sc-edges). Using this approach to knowledge representation due to its versatility and possibility of unlimited transformation from knowledge to meta-knowledge and number of other advantages [4], [5].

As mentioned above, one of the key principles in the design of knowledge bases using OSTIS Technology is using of the ontological approach.

Nowadays ontologies are the most effective tools of formalizing and structuring various fields of knowledge [32]. This approach is used in most modern solutions of problem of intelligent systems development and their components development. [32], [31], [35], [36], [45], [3], [7], [8], [12], [16], [18], [20], [22], [24]. The purpose of the ontology - to form the conceptual basis of the subject domain, therefore, ontologies are backbone of any knowledge base and are used for the integration of different knowledge bases and their parts.

The ontological approach to the design knowledge base includes development of:

- ontological model of developed artifact, ie, ***ontological model of the knowledge base***
- ***ontology project activities, aimed at knowledge bases development***, ie, formal description of the method of knowledge bases design.
- ***ontological model of tools for support of knowledge bases design***, ie, formal description of model of the support subsystem of knowledge bases design.

Knowledge base *of ostis-system* is finite information structure, which is a formal representation of all knowledge, sufficient for the functioning of a computer system and stored in the memory of the system. [4].

Precise separation of the design process of the formal description of the semantic model of developed knowledge base from the implementation process (interpretation) of the model on one or another platform is a basic of knowledge base development using OSTIS technology [4]. The advantage of this approach to the design of knowledge bases is independence of such an implementation from the platform, ie, developing only semantic model of knowledge base, it is possible to implement this model on different platforms without changing the model itself. Formal model of knowledge bases, presented in ***SC-code*** will be called ***sc-models of knowledge bases***.

Knowledge base of intelligent system, presented in the form of well-constructed semantic network of the specified form, eliminates duplication of information in such knowledge base.

As mentioned earlier, one of the ways to reduce labor costs in the development of knowledge bases is to organize their team design. An important task is to ensure coordinated work of the development team. In this paper, this task is also solved with use of ontological approach.

The essence of the ontological approach in knowledge base design is to consider structure of knowledge base as a hierarchical system of selected subject domains and their respective ontologies, such as ontology classes of solving tasks that allows to reduce search area of ways to a particular problem, limiting it by specific subject domain. This is true both in the case of solving tasks by system automatically, and in the case of performing design tasks by developers. In the second case, this approach helps to minimize the dependence of development process of some knowledge base components from others. In those cases, where the process of solving a problem involves concepts from different subject domains, is required coordination of these concepts. One of the problems in the formation of the structure of the specific knowledge base and set of subject domains is to minimize these kinds of cases. Besides, a significant advantage of using ontologies in knowledge bases design is the ability to reuse already developed knowledge base components, which also reduces the time of development of knowledge bases.

Thus, **the main problem of knowledge base design using the proposed approach** is to identify subject domains so that they minimally depend on each other and allow relatively independent evolution of each fragment of knowledge base that describes the relevant subject domain and its ontology.

During the development of a formal model of a subject domain it's necessary to remember that despite the fact that it is always possible to find a connection between any two entities, it is necessary to abstract from some of the connections considered the subject domain, which are not essential in the task. It is necessary to take into account the sufficiency of the conditions for solution of certain problems, without breach of integrity of knowledge base.

An explicit denotation of fragments of knowledge base for agreement with the development team, greatly reduces the effort required during the development of knowledge bases, as developer knows which it's necessary to coordinate with the others, and which parts of the knowledge base is area of responsibility of developer.

One of the distinguishing features of knowledge bases design within ***OSTIS Technology*** is the development of a knowledge base is reduced to development of its model presented in ***SC-code*** (***sc-model of knowledge base***).

Further, the model is interpreted on one of the platforms of sc-models interpretation, additional adaptation of the developed model to the features of a particular platform is not required.

Consider the structure of *sc-model of knowledge base of ostis-system*, which is researching in the ***Subject domain of sc-models of knowledge bases***:

sc-model of knowledge base
= *unified semantic model of knowledge base*
∈ *section of knowledge base*
<= *basic decomposition*:*
{
• *the subject part of the knowledge base*
• *context of subject of knowledge base of the Global Knowledge Base*
• *documentation of the computer system*
• *history and current processes of computer system operation*
• *history, current processes and computer systems development plan*
}

subject part of the knowledge base contains all the information about *subject domain* (or several related domains within the same knowledge base) [11], for which is this or that knowledge-based system (eg - Help System). Examples of such sections are *Documentation OSTIS* or *Documentation. Euclidean Geometry*

context of subject of knowledge base of the Global Knowledge Base contains a specification of the objects, which are not studied directly in the subject part of the knowledge base of the system, but have the attitude to it, that is, referred to in the description of any of concepts researching in the subject part of the knowledge base. For example, for IMS system it can be such concepts as *artificial intelligence* or *intelligent system*, for Euclidean Geometry system - historical reference of the life of Euclid, mathematics, etc.

Section ***documentation of the computer system*** contains documentation of *ostis-system*, at least, specification of its knowledge base, knowledge processing machine [26] and interface, as well as all the necessary guidance to ensure the opportunity to learn how to use the system.

history and current processes of computer system operation
<= *basic decomposition*:*
{
• *history of operating computer system*
• *current processes of computer system operation*
}

Section ***history of operating computer system*** stores the history of the system dialogue with its users, ie the specification of all the actions carried out (already become past entities) by system in order to satisfy the information needs of users, including answers to questions and the implementation of the transformation in the knowledge base including sequence of the actions and result. If necessary, a part of such descriptions can be removed, for example, after timing expiration.

There are specifications of all actions executed by ostis-system at the moment (included in the set of real entities) in ***current processes of computer system operation*** section, as well as all temporary structures generated by sc-agents during the process and has not yet been deleted. After performing the actions of their marks and specifications are transferred to the section of the ***history of operation of the computer system***.

history, current processes and computer systems development plan
<= *basic decomposition*:*
{
• *structure and organization of computer system project*
• *history of computer system development*
• *current processes of computer system development*
• *plan of computer system development*
}

Structure of the project, aimed at developing ostis-system, including its sub-projects and specified the role of developers responsible for each project describes in section ***Structure and organization of computer system project.***

Specification of project activities carried out during the development of the system (the last entity), with the obligatory indication of the performers, consistency and performance results are stored in section *of* ***history of computer system development***.

There are specifications of approved and initiated project *actions* executed by developers of the system at the moment (*real entities*), with the obligatory indication of the performers, the sequence and target of performance, as well as all the information that describes suggestions for *subject part of the knowledge base* and *history of operating computer system* editing and its discussion by administrators, managers and experts in section of ***current processes of computer system development***.

There are specifications of the project actions which have been approved to execution, but not yet executed for any reason, as well as all theinformation that describes the proposals for editing of *history, current processes and computer systems development plan* section and its discussion by administrators, managers and experts in ***plan of computer system development*** section.

III. Structuring of knowledge base

One of the most common (in terms of semantics specification) concepts for describing of properties of any object is the concept of ***structure***, considered in ***Subject domain of structures***.

Each ***structure*** is a set of *sc-elements*, removing one of which leads to breach of integrity of the set.

Concepts that describe roles of the elements in the structure have been introduced for formal representation of structures:

element of structure'
<= *partitioning*:*
{
• *non-represented set'*
• *fully represented set'*
• *partially represented set'*

• *structure element, which is not set'*
}
<= *partitioning**
{
• *maximal set'*
• *non-maximal set'*
}

A series of *correspondences** such as *homomorphism*, polymorphism*, automorphism*, isomorphism**, *structures analogy*,* etc. can be defined on the structures.

More detailed *Subject domain of structures* is considered in paper [11].

Within knowledge base will be selected semantically meaningful *structure,* which have a semantic integrity. These structures will be called ***knowledge***.

Within ***Subject domain of knowledge*** were identified following types of ***knowledge***, which are considered in [11]:

knowledge
= *sc-knowledge*
= *Set of all possible knowledge*
= *sc-knowledge or holistic fragment sc-knowledge*
⊂ *structure*
⊃ *semantic neighborhood*
⊃ *comparison*
⊃ *factual knowledge*
⊃ *section*
⊃ *subject domain*
⊃ *ontology*
⊃ *task*
⊃ *program*
⊃ *plan*
⊃ *solution*
⊃ *statement*
⊃ *definition*

Important relation, defined on the set of knowledge, is the relation to be *meta-knowledge** that describes transformation from knowledge to meta-knowledge describing their [2].

For specification of individual *entities* within knowledge base we introduce the concept of ***semantic neighborhood***, which is considered in ***Subject domain of semantic neighborhoods***.

semantic neighborhood - is *knowledge*, which is a specification (description) of *an entity* which sign is a *key element* of the knowledge. Note that each *semantic neighborhood* as opposed to other kinds of knowledge has the only one key element (the key sign, sign of described entity). Also note that a variety of types of semantic neighborhoods shows the variety of semantic kinds of descriptions of the various entities. Typology of semantic neighborhoods discussed more detail in paper [11].

As mentioned above, one of the key concepts in determining the structure of knowledge base is a ***subject domain***.

Subject domain - is the most important kind of knowledge that is part of semantic space [4]. Each subject domain focuses on the description of connections the relevant class of research objects. Each sign, which is part of the knowledge base, should belong to (be part of) at least one subject domain, performing a role in it. Each subject domain can be associated with:

- set of semantic neighborhoods, describing researching objects of this subject domain;
- family of various types of ontologies that describe properties of the concepts of this subject domain.

Subject domains are the basis for structuring of the semantic space, localization tool, focusing on the properties of the most important classes of described entities, which are classes of objects of research *in subject domains*.

Consideration of the structure of the knowledge base in relation to the subject domain allows to consider objects of research on different levels of detail. Detail of consideration of researched objects can be carried out as within original subject domain, to the independent system, but related between each other subject domains.

Following conditions are fulfilled, during the transition from subject domain to its model, presented in the form of a semantic network:

- each element of subject domain one-to-one correspondence denoting its element of semantic network;
- each signature-based element of subject domain one-to-one corresponds either indicating its key node of semantic network or indicating element of alphabet of semantic network.

For a description of the formal model of subject domain in knowledge base, let's consider the ***Subject domain of subject domains and its ontology***. The composition of ***Subject domain of subject domains*** include structural specification of the *subject domains*, included in knowledge base of *ostis-system*, including ***Subject domain of subject domains*** itself. Thus, ***Subject domain of subject domains***, at first, is a reflexive set, secondly, reflexive subject domain, that is, *subject domain*, one of the objects of research is itself.

In terms of representation in the knowledge base, there is any ***subject domain*** is a result of integration (association) partial semantic neighborhoods, describing all the investigated entity of a given class and have the same (common) subject of research (ie the same set of relations, which should include connectors, included in *integrable semantic neighborhoods*).

The concept of ***subject domain*** is the most important methodological techniques to select from the World only a certain class of the researching entities, and only a certain family of relations defined on the specified class. That is done localization, focusing only on that, abstracting from the rest of researching world [4].

Any ***subject domain*** from the formal point of view is a structure.

More detailed relations that define the role of elements in subject domain considered in papers [4], [11].

On Figure 1, the example of fragments of structural specifications of ***Subject domain of triangles***, ***Subject domain of rounds and circles*** and ***Subject domain of inscribed planar***

figure shows the principle of correlating concepts with subject domains. The figure shows that the concept of a *triangle, right-angled triangle, equilateral triangle, obtuse triangle, an isosceles triangle, the median ratio*, congruence*, bisector*, side** and the concept of the *area* are the key to the ***Subject domain of the triangles***. However, the concept of the triangle and areas are studied in other subject domains (***Subject domain inscribed planar figures*** and ***Subject domain of rounds and circles***) and performing other roles in them. Accordingly, during knowledge base process developers have to take into account the requirement of coordination concepts ***triangle*** and ***area***.

Following set-theoretic relations can be defined on the set of subject domains: *inclusion * union*, intersection*, decomposition*, homomorphism*, isomorphism **, as well as the special relations, which domain is set of *subject domains*.

particular subject domain* - binary oriented attitude, used to specify a hierarchy of domains by transforming from less detailed to more detailed consideration of the researching concepts. An example of a hierarchical structure of subject domains is shown on Figure 2 by the example of the structure of ***Subject domain of Euclidean geometry***.

Particular subject domain can be selected according by two criteria:

- ***particular subject domain by primary elements class**** - restriction of the subject domain in the class of primary elements;
- ***particular subject domain by researching relations**** - restriction of subject domain by the subject of research.

Connections of relations ***unrelated subject domains**** connects two subject domains that have common elements, but are not related by relation *particular subject domain**.

Considered above relations are special case of the relation ***meta-knowledge****.

Each ontology is a specification of subject domain, ie, specification of a system of concepts used in this subject domain. The concept of ontologies discussed in the ***Subject domain of ontologies***.

The relation between subject domain and its ontology is defined by relation *ontology**, which is a special kind of *meta-knowledge** relation.

Depending on the considered properties of concepts of subject domain, that are described in the ontology, distinguish the following types of ontologies:

- ***structural specification*** - is ontology, which describes the role of concepts included in the subject domain, as well as connections of specifiable subject domains to other subject domains
- ***set-theoretical ontology*** - is ontology that describes the set-theoretic relations between the concepts of subject domain (inclusion, partition, union, intersection, set difference, domain, domain name, function)
- ***logical ontology*** - is ontology, which is a description of the system of statements of given subject domain
- ***logical hierarchy of concepts*** - is ontology is built on the logical ontology, including the description of system of definitions of concepts for a given subject domain, indicating a set of concepts, through which is determined each defined concept of subject domain
- ***logical hierarchy of statements*** - is ontology is built on logical ontology includes description of system of the subject domain, indicating a set of statements, through which can be proved every statement
- ***terminological ontology*** - is ontology that describes the system of major and minor terms (names, external symbols) corresponding absolute concepts and relations of a given subject domain, as well as description of the rules of terms construction for entities that are members (instances) of these concepts and relations
- ***ontology of tasks and solutions*** - is ontology that describes the problem and their classes solved in the subject domain
- ***ontology of task classes and solution methods*** - is an ontology that describes ways to solve problems and their classes within the subject domain. It is built on the ontology of problems and classes of problems
- ***integrated ontology*** - is ontology, combining all ontologies of different kinds of a certain subject domain

To provide formal representation in the knowledge base of different kinds of knowledge has been selected a number of subject domains and their ontologies. Data of ontology refers to the ***top-level ontologies*** [45], because they are basics for structuring and description of all kinds of knowledge.

These subject domains include:

- *Subject domain of entities*
- *Subject domain of sets*
- *Subject domain of connections and relations*
- *Subject domain of parameters and values*
- *Subject domain of numbers and numerical structures*
- *Subject domain of logical formulas and logical ontologies*
- *etc.*

IV. The ontological model of team of knowledge bases design

In this section, we consider ***Subject domain of activities aimed at the development and evolution of the knowledge base*** and its *ontology*. Objects of research of this subject domain are the processes of *sc-models design of knowledge bases of ostis-systems*. It is important to build it in such a way as to minimize the complexity of the design process, at the same time, ensuring the high quality of the developed knowledge bases.

The process of development of *sc-model of knowledge base of ostis-system* is the formation *of* ***proposals for editing*** of a knowledge base section by *developers* and the review of these proposals by *administrators*, if necessary - by experts, as well as in individual cases by *managers* of corresponding projects.

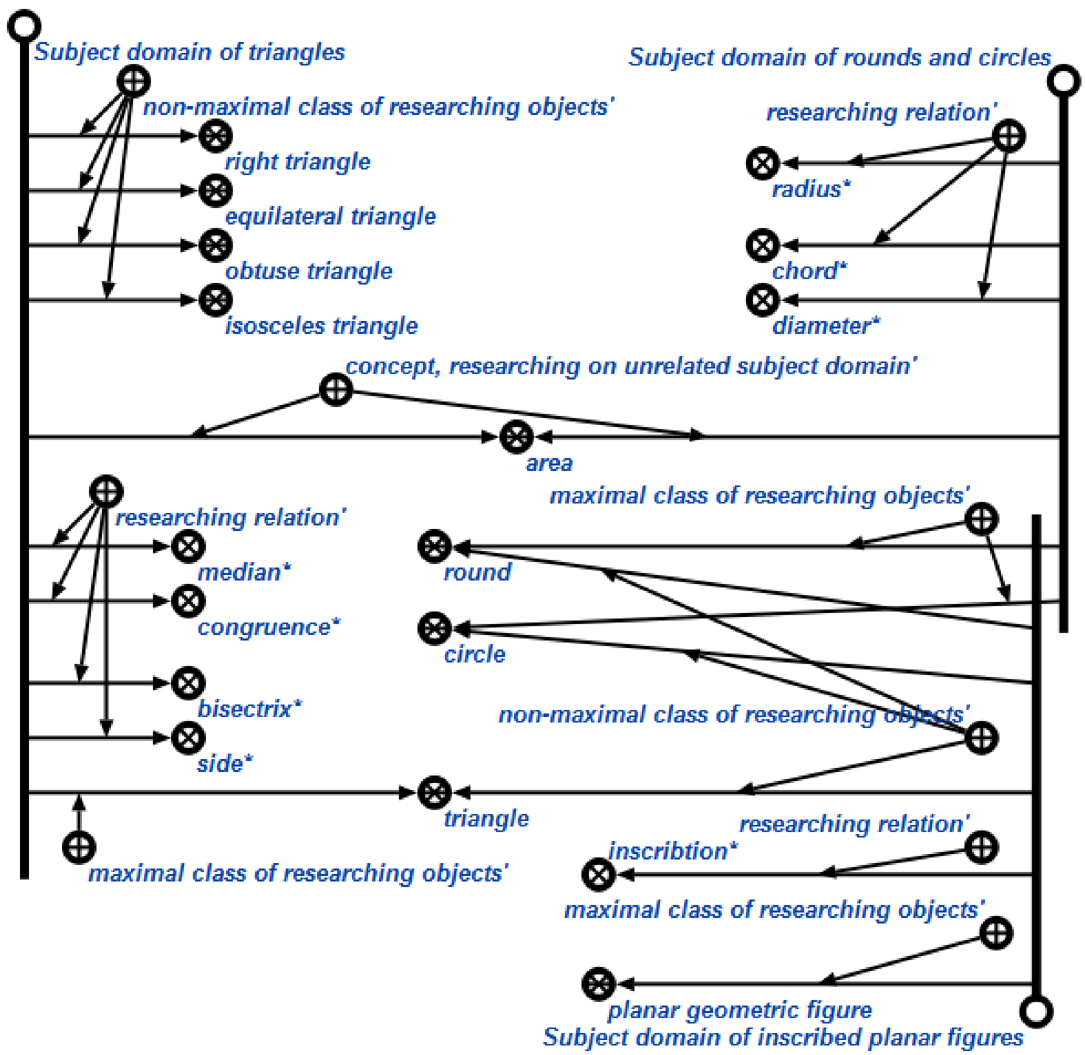

Figure 1. Specification of subject domains

A. *Typology of developer of ostis-systems*

Consider typology of users of ***ostis-system***.

All users of any ostis-systems are divided into ***registered users**** and ***unregistered users****.

user*
= *user of ostis-system**
∈ *binary relation*
∈ *non-role relation*
<= *partitioning*:*
{
• *unregistered user**
• *registered user**
}

unregistered user* - a *binary relation* which connects *ostis-system* and *sc-element* denoting *a person* who does not pass the registration process in the system.

Unregistered user has read access to the subject part of the knowledge base of *ostis-system*. This type of user can work with *ostis-system* in operation mode, ie, can only ask questions, addressed *the subject part of the knowledge base (ie the subject tasks)*.

registered user* - *a binary relation* which connects *ostis-system* and *sc-element* denoting a person that has passed the registration process in the system.

Registered user has read access to the whole knowledge base and making suggestions to the whole knowledge base, can perform the role of the finite user of *ostis-system*, ie work in the mode of operation and the role of its developer. At the same time independent of the role performed by a particular user, it may make an offer to edit any part of the knowledge base, which, depending on its level will either be accepted automatically, or will be considered separately.

Other user type is selected among the registered users - ***developer*.***

developer* - a *binary relation* that relates a *knowledge base section of ostis-system* (in the limit - the whole knowledge base) and *sc-element* denoting *a person*, which may be a

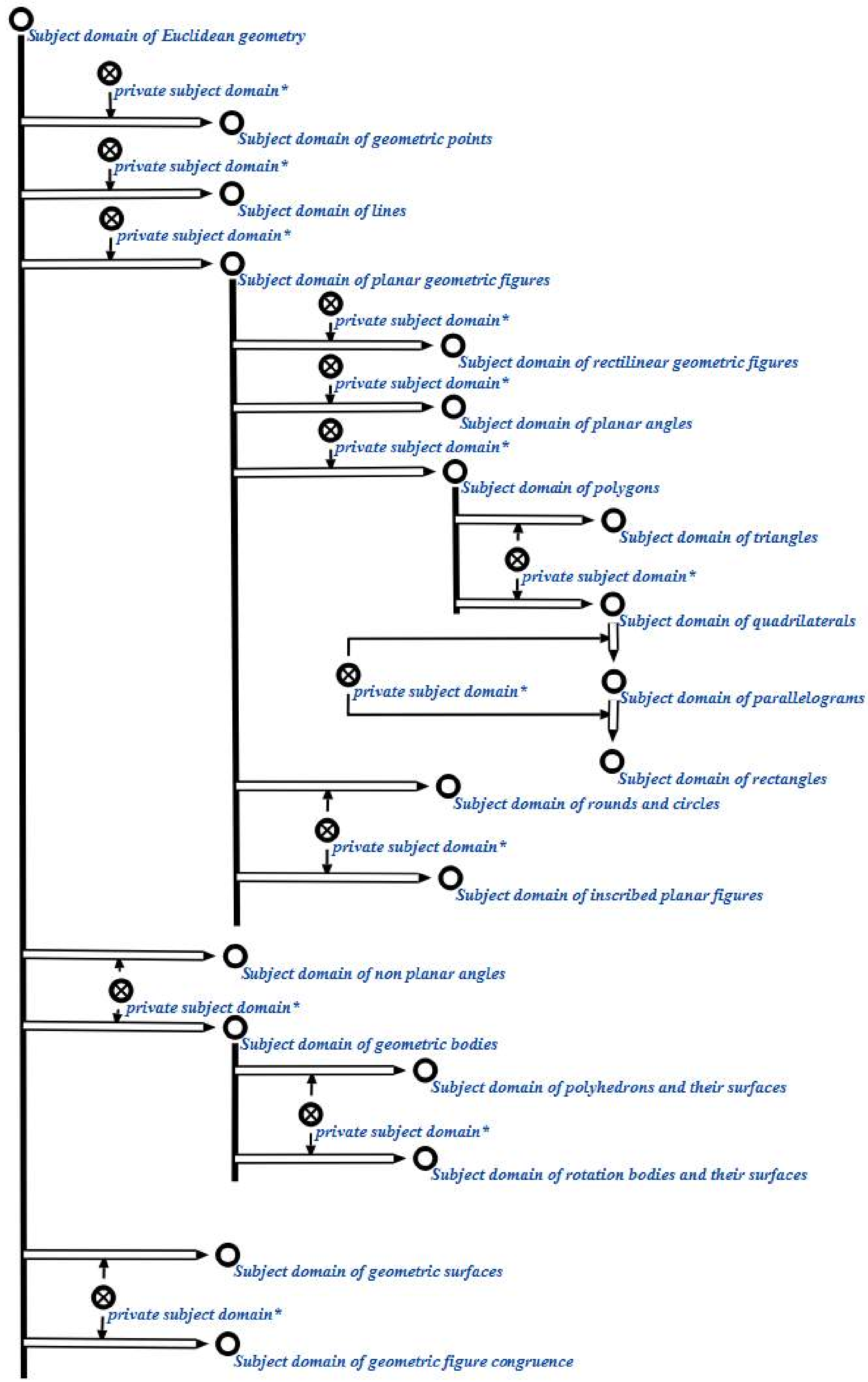

Figure 2. Hierarchical structure of Subject domain of Euclidean geometry

developer of the knowledge base section, i.e. perform design tasks under this section.

Besides *ostis-system* operation ***developer**** can make proposals for editing of any part of the knowledge base, adding comments to the proposals for editing of knowledge base. Among developers selected such roles as ***administrator****, ***manager**** and ***expert*.***

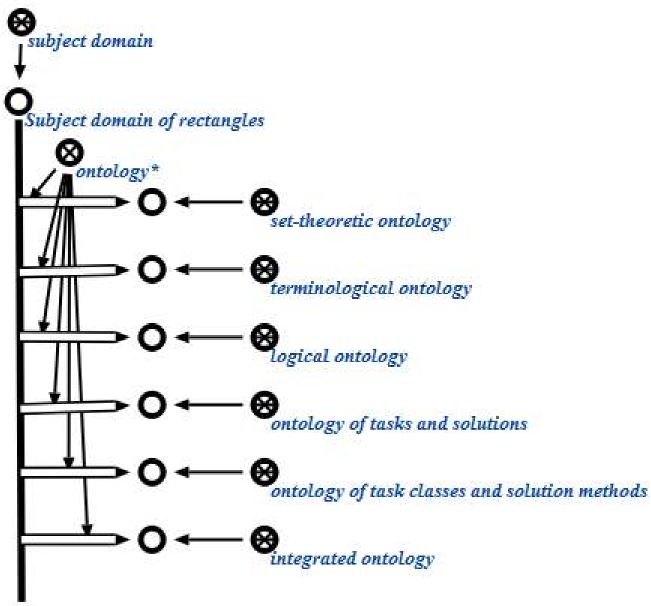

Figure 3. Ontologies of Subject domain of rectangles

developer*
=> *inclusion*:*
 • *administrator**
 • *manager**
 • *expert**

administrator* - a *binary relation* that relates a *section of knowledge base of ostis-system* (in general case - the whole knowledge base) and *sc-element* denoting the *person* who is an administrator *of the knowledge base section*.

There are tasks of ***administrator****:

- control of the integrity and consistency of the whole knowledge base;
- definition of access levels of other users;
- decision making the acceptance or rejection of proposals in different parts of the knowledge base, including, if necessary, send them for examination;
- independent making changes in different parts of the knowledge base through using editing command (in this case the changes are automatically made out as suggestions and are recorded in *history of ostis-system development*).

manager* - a *binary relation* that connects a knowledge base section of *ostis-system* (in general case - the whole knowledge base) and sc-element denoting *the person* who is the manager of *the knowledge base section*.

Tasks of ***manager**** are:

- planning of capacity of work on knowledge base design;
- detailed division of tasks into subtasks, directly formulation of project objectives, setting performers of project objectives;
- setting priorities and timing of work on design of knowledge base;
- control the timing of performing of project objectives.

manager* makes changes to the part of the section describing the project tasks, using the appropriate editing command (in this case the changes are automatically made out as suggestions and are recorded in section *project of ostis-system. History, current processes and development plan ostis-system*). Thus, the ***manager**** is *administrator** of section *history, current processes and plan of computer system development*.

expert* - a *binary relation* that relates *knowledge base section of ostis-system* (in general case - the whole knowledge base) and *sc-element* denoting *the person* who is an expert of *the knowledge base section*.

Tasks of ***expert**** are:

- verification and testing results of the implementation of project tasks;
- if necessary, an expert can add comments to any fragment of knowledge base regarding to its correctness. All comments fall into *plan of computer system development*.

B. Typology of actions of knowledge base developers

During the development process of *sc-model of knowledge base of ostis-system*, each of the users participated in design uses a specific set of commands. Each command corresponds to a certain class of *actions in sc-memory* [28]. All these actions are combined into a common *class* ***action of developer of unified semantic models of knowledge bases***, which are considered in Subject domain of activities aimed at the development and evolution of knowledge base [10].

Consider the typology of such actions:

action of developer of unified semantic models of knowledge bases
<= *inclusion*:*
 action in sc-memory
=> *inclusion*:*
 • *action of expert of knowledge base*
 • *action of administrator of knowledge base*
 • *action of manager of knowledge base*
 • *action of developer of knowledge base*

action of developer of knowledge base
=> *inclusion*:*
 • *action form project task proposal*
 • *action.form new fragment for inclusion in knowledge base*

action of developer of knowledge base* can be performed by any *registered user** *of ostis-system*, including, if necessary, administrator or manager.

action. form knowledge base editing proposal
=> *inclusion*:*
 • *action. form project task proposal*
 • *action. form project task executor proposal*

<= *inclusion*:*
action of developer of knowledge base

It is supposed that in the case of approval of the proposal, this structure will be integrated into the appropriate section of knowledge base, and, if necessary, *action* will be initiated, which signs are included in its composition. The process of formation of the *structure* can be automated using appropriate commands.

Number of classes of actions that are executed only by developers who have additional levels of responsibility, ie *administrator**, *manager** and *expert** of knowledge base is highlighted among actions of ordinary developers. It includes: ***action. approve knowledge base editing proposal*** and ***action. to reject the proposal for editing knowledge base*** that can be performed by ***expert, manager and administrator*** of the knowledge base, depending on the additional conditions.

action of administrator of knowledge base
=> *inclusion*:*
- *action. consider knowledge base editing proposal*
  => *inclusion*:*
  - *action. consider new project task*
  - *action. consider proposal verification result*
- *action. form task of proposal verification*
- *action. approve proposal verification result*
- *action. reject proposal verification result*

action of manager of knowledge base
=> *inclusion*:*
- *action. form project task proposal*
- *action. consider project task proposed executor*
  => *inclusion*:*
  action. consider new project task

action of expert of knowledge base
=> *inclusion*:*
- *action. verify given structure*
- *action. reject verifying proposal*
- *action. approve verifying proposal*
- *action. form task of proposal verification result considering*

C. Means of proposals specification for editing of knowledge base

Consider the number of relations that are used for specification of *actions of developers of sc-models of knowledge bases and structures* that describe the proposal for editing the knowledge base and researching in ***Subject domain of activities aimed at the development and evolution of the knowledge base***.

proposal* - a *binary relation* that connects the sign of *action. consider knowledge base editing proposal* and the sign of the *structure*, which describes the proposal of editing, for example, contains a fragment for inclusion in the current state of knowledge base.

approved* - a *binary relation* that connects the sign of action for consideration of any proposal for editing knowledge base and sign of user of *ostis-system*, which approved (endorsed) this action. Typically, this *administrator** or *expert** of corresponding project.

rejected* - a *binary relation* that connects the sign of action for consideration of any proposal for editing the knowledge base and sign of user of *ostis-system*, which dismissed the action. Typically, this *administrator** or *expert** of corresponding project.

new version* - *a binary relation* that connects sign of *structure* that describes a proposal for editing the knowledge base and the sign of *structure* denoting the version of the proposal after its completion by performer. The presence of such a connection simplifies and speed up the re-testing of proposals for editing the knowledge base.

D. Tools of the specifications of transients in the knowledge base

During the process of its evolution, the knowledge base is undergoing significant changes. There are the most problematic following changes among these types of are:

1) The knowledge base is required to override already entered and used the concept.
   Consider the situation in the following example. There is concept *square* in geometry knowledge base in the *Subject domain of quadrilaterals*. This concept has been defined through the concept of *rectangle*.
   After some time, the domain expert considered that the concept of the *square* must be defined through the concept of *a rhombus*. The problem is that other fragments of knowledge base and concepts related to the concept of the *square*, should be brought into line with the new concept defined by other concepts.
   In this situation it is necessary to fix the status of changing concept during the transition time of knowledge base - the time when the full knowledge base will be made all the necessary changes related to the overridden concept.
2) There is an alternative concept in knowledge base, which eliminates using of another associated with it. Example of this is the following.
   Two sections of geometry knowledge base. *Section. Triangles* and *Section. Quadrilaterals* developed by different developers.
   Concept *side of triangle** was introduced in the *Subject domain of triangles*, connecting a triangle with segment, which is its side.
   In *Subject domain of quadrilaterals*, in its turn, the concept of *side of quadrilateral** introduced connecting rectangle with its side.
   Subsequently, administrator of the section, describing *the polygons* based on the principle of minimizing of the key nodes of knowledge base has decided to introduce a generalized notion of *side of the polygon**. e.g. the developers figure out the conclusion that two previously introduced concepts are redundant, and carry methodological character to define the concepts described.

Following concepts are introduced to solve problems in the situations described above:

concept
<= partitioning:*
{
• *basic concept*
• *non-basic concept*
• *concept, turning from basic to non-basic*
• *concept, turning from non-basic to basic*
}

Basic concepts are concepts which are widely used in the system and can be key elements *of sc-agents*. The ***basic concepts*** are also all undefined concepts.

Each ***non-basic concept*** must be strictly defined by the basic concepts. Such ***non-basic concepts*** are used only for the understanding and appreciation of input information, including, for aligning ontologies. A key element of the sc-agents may not be ***non-basic concepts***.

In the case where a concept completely turned from *the basic concepts* to *non-basic*, that is, become non-basic concept, and the corresponding *basic concept* (through which it is defined) within ab external language there is the same basic identifier with it, then it is added # sign in the front of non-basic concept identifier. If these basic concepts have different identifiers in this external language, no additional means of identification is used.

In the case where the current *basic concept* and the corresponding concept, turning from non-basic to basic the same basic identifier in external language with non-basic concept, then $ sign is added the to the basic. If these basic concepts have different identifiers in this external language, no additional means of identification is used.

V. The ontological model of subsystem of support of team knowledge bases design

OSTIS technology embodied in the form of Intelligent ***Metasystem IMS*** (Intelligent MetaSystem) [34], which is also built on OSTIS Technologies. At each time point metasystem includes accrued and formalized models by this moment, tools and techniques for design of intelligent systems using *OSTIS Technologies*.

In general, the *IMS* system as the parent system interacts with all its *subsidiaries sc-systems* (with systems built using *OSTIS Technology*), ensuring the system will automatically update subsidiaries versions of reusable components of OSTIS [27]. Any subsidiary system based *on OSTIS Technology* acts as an intermediary between the developer of the system and *IMS* system. The developer can choose component based on interest or set of components in one of the libraries and include them in the developed subsidiary system.

Each ***reusable component of sc-model of knowledge bases*** is a *structure* or explicitly represented in the current state of *sc-memory*, or not fully formed *structure*, which if necessary can be completely formed by combining its parts, indicated by *decomposition relations*, such as a *partitioning** or *inclusion** relations.

Integration of ***reusable component of sc-model of knowledge bases*** into the subsidiary system is reduced to gluing key nodes by identifiers and elimination of possible duplications and contradictions that could arise if the developer of subsidiary system manually made any changes in its knowledge base.

The main types of reusable components of knowledge bases stored in the library components of knowledge bases, include:

- ontologies of various subject domains that can be different in content, but must be semantically compatible;
- basic fragments of theories, corresponding to different levels of user's knowledge: from basic school level to the professional;
- semantic neighborhood of different entities;
- specifications of formal languages descripting various subject domains.

To ensure semantic compatibility of knowledge bases components, which are unified semantic models, it's required:

- to approve semantics of all used key nodes;
- to approve basic identifiers of the key nodes used in different components. After that, the integration of all the components that are part of the library, and in any combination is carried out automatically, without the intervention of the developer.

Another aspect of support of knowledge base design is support of activities of developers of knowledge bases already in the process of developing the knowledge base of *subsidiary ostis-system*. For this purpose the ***support subsystem of knowledge bases design team*** is used, tasked with information and technical support of activities of the team of knowledge base developers, including - ensuring the correct and effective implementation of all stages of the envisaged method of designing knowledge bases.

Ontological model of support subsystem of knowledge bases design team includes:

- ***ontological model of knowledge base of support subsystem of knowledge bases design team***;
- ***ontological model of the machine processing of knowledge of support subsystem of knowledge bases design team***;
- ***ontological model of the user interface of support subsystem of knowledge bases design team***.

Ontological model of knowledge base of support subsystem of knowledge bases design team includes sections covering:

- set of top-level ontologies needed for the operation of the subsystem itself and are the basis for the construction of sc-model knowledge bases of *subsidiaries ostis-systems* [27];
- typology of system developers, typology of actions of developers, as well as the formal tools of specification of proposals for knowledge base editing.

Ontological model of knowledge processing machine support subsystem of team knowledge bases design includes a *sc-agents* of the following types:

Knowledge processing machine of support subsystem of team knowledge bases design
∈ non-atomic abstract sc-agent
<= abstract sc-agent decomposition:*
{
- *Abstract sc-agent of knowledge bases verification*
- *Abstract sc-agent of knowledge bases editing*
- *Abstract sc-agent of automation of activity of sc-model of knowledge bases developer*
- *Abstract sc-agent of automation of activity of knowledge base administrator*
- *Abstract sc-agent of automation of activity of knowledge base manager*
- *Abstract sc-agent of automation of activity of knowledge base expert*
- *Abstract sc-agent of calculations of knowledge base characteristics*

}

Abstract sc-agent of knowledge bases verification - the group of agents responsible for verifying the correctness and completeness of the knowledge base.

Abstract sc-agent of knowledge bases editing - a group of agents that provide automation knowledge base editing.

Abstract sc-agent of automation of activity of sc-model of knowledge bases developer - the agents that implement the mechanisms of interaction between the developer knowledge base and design support subsystem.

Abstract sc-agent of automation of activity of knowledge base administrator - agents that implement the mechanisms of interaction between administrator of knowledge base and design support subsystem.

Abstract sc-agent of automation of activity of knowledge base manager - agents that implement the mechanisms of interaction between manager of knowledge and design subsystem design support.

Abstract sc-agent of automation of activity of knowledge base expert - agents that implement the mechanisms of interaction between an expert of knowledge base and design support subsystem.

Abstract sc-agent of calculations of knowledge base characteristics - group of agents that implement the calculation of quantitative and qualitative characteristics of knowledge bases.

User interface of system of support of knowledge base design represented by a set of interface commands that allow developers to initiate activities of required agent, which is a part of this system. [17] This set of fully corresponds to set of agents of knowledge processing machine considered above.

VI. Conclusion

In this paper we consider the ontological approach to the design of knowledge bases based on knowledge representation as a hierarchical structure of interconnected domains and ontologies. Using this approach allows to:

- provide an opportunity for representation of all kinds of knowledge within a unified platform-independent knowledge base;
- reduce the complexity and development time of knowledge base design by:
  - enable possibility of team development of knowledge bases;
  - minimize the number of agreements during the process of team development;
  - using of reusable components of knowledge bases;
  - using of unificated methods of design of knowledge bases and their components;
- increase the clarity and learning level due to their structuring.

The developed support system of knowledge bases design team allows to automate the design, verification and optimization of the knowledge base design process, reduce the number of errors that occur and their elimination time.

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ОНТОЛОГИЧЕСКОЕ ПРОЕКТИРОВАНИЕ БАЗ ЗНАНИЙ

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В настоящее время актуальной является задача эффективного информационного обеспечения различных отраслей человеческой деятельности. Увеличение объемов информации привело к необходимости создания хранилищ знаний, обеспечивающих структуризацию и систематизацию хранимых знаний, а также их эффективную обработку.

Одним из наиболее перспективных направлений в данной области является разработка систем, основанных на знаниях [46]. Ключевым компонентом таких систем является база знаний. Качество разрабатываемой системы такого класса определяется, в том числе, качеством базы знаний и разнообразием видов знаний, хранимых в ней.

Разработка базы знаний является трудоемким и продолжительным процессом. Соответственно, актуальной является задача сокращения сроков разработки и обеспечения эффективности поддержки жизненного цикла баз знаний.

Можно выделить следующие пути сокращения сроков и снижения трудоемкости разработки баз знаний:

- обеспечение совместной разработки баз знаний распределенным коллективом разработчиков [12];
- автоматизация деятельности разработчиков баз знаний;
- повторное использование уже разработанных фрагментов баз знаний [30], [36], [1], [47], [33], [7].

Однако, полностью автоматизировать процесс разработки базы знаний невозможно, поскольку некоторые этапы, такие, например, как формирование системы понятий, требуют согласованных усилий некоторого числа разработчиков и экспертов и носят субъективный характер.

Важным этапом разработки базы знаний является ее структуризация. Структуризация базы знаний, т.е. выделение в ней различных связанных между собой подструктур необходимы по целому ряду причин [3]. В частности, это необходимо для дидактических целей (человеку, усваивающему некоторые знания, желательно иметь, своего рода оглавление этих знаний, что позволяет планировать их усвоение и рассматривать их с различной степенью детализации), а также для организации распределения работ по проектированию баз знаний (когда разным исполнителям поручается разработка разных фрагментов базы знаний, имеющих достаточно четкие границы).

Целью данной работы является разработка унифицированных семантических моделей баз знаний и средств их коллективной разработки, основанных на онтологической структуризации баз знаний, что позволяет снизить трудоемкость и сроки их разработки и модернизации.

Среди проблем в области разработки баз знаний выделяются следующие:

- Отсутствие средств унификации любых видов знаний и моделей представления знаний в рамках одной базы знаний
- Отсутствие формальных средств структуризации, позволяющих представить базу знаний на различных уровнях детализации
- Отсутствие единого подхода к выделению повторно используемых компонентов баз знаний и формированию библиотек таких компонентов, что приводит к наличию большого числа несовместимых уже разработанных компонентов баз знаний; [33]
- Высока трудоемкость модернизации баз знаний и их сопровождения (некоторые изменения, вносимые в базу знаний, могут повлечь необходимость внесения существенных изменений в саму структуру базы знаний)
- Несмотря на наличие достаточно развитых средств проектирования баз знаний, все еще отсутствуют средства, обеспечивающие комплексную поддержку коллектива разработчиков на всех стадиях проектирования базы знаний, обладающие, в свою очередь, достаточной гибкостью и расширяемостью. Кроме того, все существующие средства ориентированы, как правило, на какой-либо конкретный формат хранения знаний, что затрудняет перенос уже разработанной базы знаний на другую платформу интерпретации.

На сегодняшний день существуют десятки моделей представления знаний, однако большинство из них можно свести к основным четырем: семантические сети, фреймы, продукционные и логические модели [2]. Однако, каждая из указанных моделей представления знаний адаптирована для представления знаний определенного вида, в то время как при создании интеллектуальных систем часто возникает необходимость представить различные виды знаний в рамках одной базы, чего не может обеспечить ни одна из вышеперечисленных моделей, взятых в отдельности. [15] [13] В связи с этим возникает необходимость в создании универсальной модели представления знаний, которая позволила бы представлять любые виды знаний в унифицированном виде.

Ключевым моментом в процессе структуризации знаний является формирование системы основных понятий предметной области [3]. В настоящее время при разработке систем, основанных на знаниях, широко распространено использование стандартов консорциума W3C [43]. Его задачей является разработка стандартов в области Semantic Web [43], [25]. В частности, данным консорциумом был разработан язык описания онтологий OWL [39] и язык представления знаний в виде семантических сетей RDF [40]. Также разработаны эффективные хранилища баз знаний на основе RDF, обеспечивающих хранение и доступ к данным средствами языка запросов SPARQL [42]. Для редактирования онтологий создано большое число редакторов, обладающих довольно широким функционалом. [38]

Однако, несмотря на развитие проекта Semantic Web и связанных с ним средств, значительная часть ресурсов Web все еще не содержит семантической разметки и метаданных. Исключением являются семантические ресурсы, которые разрабатываются на основе Wiki-Технологии [44] и становятся все более популярными.

Wiki-Технология позволяет накапливать знания, которые представляются в интероперабельной форме, обеспечивая навигацию по знаниям. Использовать Wiki-Технологию возможно для проектов любого масштаба и тематической направленности (от открытых электронных энциклопедий, до справочных систем различных предприятий и учебных заведений). [21]

Wiki-Технология предоставляет своим пользователям средства хранения, структуризации текста, гипертекста, файлов и мультимедиа. Wiki-технология использует в качестве инструмента платформу MediaWiki [37], которая позволяет осуществлять информационное взаимодействие, обеспечивать доступ к информационным ресурсам всем участникам процесса разработки системы, организовывать управление и наблюдение за разработкой. [6] Среди достоинств данной технологии можно выделить простоту wiki-разметки, коммуникативные возможности, которые реализуются через совместное редактирование страниц, а также посредством электронных обсуждений в wiki или дополнительных средах, таких как чат или форум, проектный характер работы, сотрудничество, формирование единого продукта совместной деятельности обеспечивают содержательное взаимодействие, обмен знаниями, оценку и постоянное совершенствование работ. [21]

Влияние Semantic Web на подобные проекты постоянно возрастает, вследствие чего были созданы движки Wiki-сайтов, которые поддерживают онтологическое представление знаний и семантическую разметку ресурсов при помощи средств Semantic MediaWiki [41]. Данные средства позволяют включать семантические аннотации в Wiki-разметку в виде OWL и RDF и явно разделять структурированную и неструктурированную информацию. [21]

Кроме указанных достоинств, Wiki как технология имеет ряд недостатков: дублирование информации на различных страницах, невозможность структурирования знаний ввиду отсутствия иерархии гиперссылок и отсутствия унификации представления информации, отсутствие возможности автоматической верификации.

В данной работе идеи Технологии Wiki получили свое развитие, однако предпринята попытка устранить указанные проблемы. Вопросам разработки и структуризации баз знаний также посвящены следующие исследования:

- Базы знаний и управление знаниями [2], [3]
- Фрактальная модель структурирования знаний, основанная на представлении разных форм (видов) знаний как объектов расслоенного (стратифицированного) пространства [19]
- Технология разработки порталов инженерных знаний, обеспечивающих выполнение сложных инженерных расчетов [8]
- АТ-Технология [23]
- Технология разработки облачных интеллектуальных сервисов на базе платформы IACPaaS – Intelligent Application, Control and Platform as a Service [9]
- Технология разработки порталов научных знаний [13], [14]

На сегодняшний день разработано большое число баз знаний по самым различным предметным областям [29]. Однако большинство из них не являются хорошо структурированными, согласованными и совместимыми между собой.

В основе предлагаемых моделей лежат следующие основные принципы открытой семантической технологии проектирования интеллектуальных систем OSTIS (Open Semantic Technology for Intelligent Systems) [34]:

- использование онтологического подхода к проектированию баз знаний, что предполагает структуризацию базы знаний на основе онтологий;
- поэтапное эволюционное проектирование баз знаний;
- ориентация на коллективное проектирование баз знаний в рамках проекта;
- ориентация на семантическое представление знаний;
- унификация моделей баз знаний интеллектуальных систем;
- модульное проектирование на основе библиотек типовых многократно используемых компонентов.

Технология OSTIS ориентирована на разработку компьютерных систем, управляемых знаниями – систем, в основе каждой из которых лежит представленная унифицированным образом база знаний, содержащая в систематизированном виде всю информацию, используемую этой системой [4]. В рамках данной работы системы, управляемые знаниями, построенные по Технологии OSTIS, будем называть ostis-системами.

Для решения указанных выше проблем необходимо решить следующие задачи:

- разработать унифицированные семантические модели представления различных видов знаний, основанные на онтологиях
- разработать онтологические модели структуризации баз знаний
- разработать онтологические модели коллективного проектирования баз знаний,
- разработать подсистему поддержки коллективного проектирования баз знаний, включающую средства автоматизации деятельности разработчиков, средства редактирования баз знаний, средства автоматизации верификации баз знаний.

В данной работе предлагается использовать в качестве формальной основы для представления знаний способ представления знаний в виде семантических сетей с базовой теоретико-множественной интерпретацией, позволяющих описывать как знания, относящиеся к предметной области (включая и метазнания, и простой переход от знаний к метазнаниям), так и процедуры их переработки. Указанный способ является базовым в рамках Открытой семантической технологии проектирования интеллектуальных систем (OSTIS). Соответственно был разработан способ кодирования таких семантических сетей – SC-код (Semantic Code). Использование данного подхода к представлению знаний обусловлено его универсальностью, а также возможностью неограниченного перехода от знаний к метазнаниям и рядом других достоинств [4], [5].

Онтологический подход к проектированию баз знаний подразумевает разработку:

- онтологической модели разрабатываемого артефакта, т.е. онтологической модели базы знаний
- онтологии проектной деятельности, направленной на разработку баз знаний, т.е. формального описание методики проектирования баз знаний
- онтологическую модель инструментальных средств поддержки проектирования баз знаний, т.е. формальное описание модели подсистемы поддержки проектирования баз знаний.

Под базой знаний ostis-системы будем понимать конечную информационную конструкцию, являющуюся формальным представлением всех знаний, достаточных для функционирования некоторой компьютерной системы и хранимых в памяти этой системы [4].

В основе разработки баз знаний с помощью технологии OSTIS лежит четкое разделение процесса проектирования формального описания семантической модели, разрабатываемой базы знаний от процесса реализации (интерпретации) этой модели на той или иной платформе [4]. Достоинством такого подхода к проектированию баз знаний является независимость такой реализации от платформы, т.е., разработав только лишь семантическую модель базы знаний, появляется возможность реализовывать эту модель на различных платформах, не изменяя при этом саму модель. Формальные модели баз знаний, представленные в SC-коде будем называть sc-моделями баз знаний.

Суть онтологического подхода при проектировании базы знаний заключается в рассмотрении структуры базы знаний как иерархической системы выделенных предметных областей и соответствующих им онтологий, в частности, онтологий классов решаемых задач, что позволяет сузить область поиска путей решения конкретной задачи, ограничивая ее рамками конкретной предметной области. Это справедливо как в случае автоматического решения задач системой, так и в случае выполнения разработчиками проектных задач. Во втором случае такой подход позволяет минимизировать зависимость процесса разработки одних компонентов базы знаний от других. В тех случаях, когда в процессе решения некоторой задачи задействованы понятия из разных предметных областей, требуется согласование указанных понятий. Одной из задач при формировании структуры конкретной базы знаний и набора предметных областей является минимизация ситуаций такого рода. Кроме того, существенным достоинством использования онтологий при разработке баз знаний является возможность повторного использования уже разработанных компонентов баз знаний, что также сокращает время разработки баз знаний.

Рассмотренный в работе онтологический подход к проектированию баз знаний, базирующийся на представлении базы знаний как иерархической структуры взаимосвязанных между собой предметных областей и их онтологий, позволяет:

- обеспечить возможность представления любых видов знаний в рамках одной базы знаний унифицированным не зависящим от платформы образом;
- снизить трудоемкость и сократить сроки разработки баз знаний за счет:
  - обеспечения возможности согласованной коллективной разработки баз знаний;
  - минимизации числа согласований в процессе такой коллективной разработки;
  - использования многократно используемых компонентов баз знаний;
  - использования унифицированной методики проектирования баз знаний и их компонентов
- повысить уровень понятности и усвоения знаний за счет их структуризации.

Разработанная система поддержки разработчиков баз знаний позволит автоматизировать процесс разработки, верификации и оптимизации базы знаний, уменьшить количество возникающих ошибок и времени на их устранение.

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Ontology-based Design of Knowledge Processing Machines

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Abstract—**The work is devoted to the development of intelligent systems knowledge processing machines design technology, which is based on an ontological model of the machine itself and the ontological model of the design process. A model of system of knowledge processing machines design support also considered.**

Keywords*—*knowledge processing machine, ontology, subject domain, ontology-based design, intelligent system, multi-agent systems, parallel systems, information search, logical inference.

I. INTRODUCTION

A. Objective and Relevance of the Work

The objective of this paper is the creation of technology of design of efficient and flexible knowledge processing machines of different knowledge-based systems and reducing of time and overheads of such machines development.

Nowadays the application of intelligent systems becomes more and more urgent in different spheres of human activity, especially in those of them, where human being can be dangerous or can invoke errors, caused by so-called human factor. One of the most perspective branches in this area is the development of knowledge-based systems [19]. Ontologies are widely used as the formal basis of knowledge representation is such kind of systems [5].

One of the most important components of such a system is ***knowledge processing machine***, which provides an opportunity to solve different problems, related as with basic functionality of system (machine of information search and intelligent problem solver), so as with providing of correctness of system workability itself (information garbage collection, knowledge base quality enhancement etc.) and with providing of system evolution automation. It should be noted, that tasks, solved by any of knowledge processing machine components may not be explicitly formulated. Examples of such kind of tasks are information garbage detection and deleting, knowledge base optimization and so on.

Approaches to problem solvers development can be divided into two main classes:

- **problem solution using stored programs**. This case supposes that system already contains a program of given problem class solution, so solution reduces to search of that program and its interpreting with given input data. This class includes also systems, which use genetic algorithms [26], [37] and knowledge processing models, based on neural networks [22], [30].
- **problem solution in conditions, when solution program is unknown.**This case supposes that there may not be a program of given problem class solution, so it is necessary to apply additional methods of problem solution search, which are not oriented on the narrow class of tasks (for example, halving method, depth-first and breadth-first solution search method, method of random solution search, trial-and-error method, method of dividing tasks into subtasks, so on), as well as different models of logical inference (classic deductive [25], inductive [42], [43], abductive [25]; models, based on fuzzy logic [44], [21], [35], temporal logic [38], so on).

So, there are a lot of approaches to development of difference knowledge processing machines for different computer systems, including intelligent problems solvers, many of which are successfully implemented and being actively used.

Let's consider two main historically formed approaches to knowledge processing machines development.

First approach supposes that system contains fixed knowledge processing machine (for example, logical inference machine), and afterward there can be added a knowledge base, content of which is defined by subject domain, with which system will work. Such systems were named "empty" expert systems [46] or expert system shells [8]. This approach was generally used for development of relatively simple systems and in present time has no wide application.

Second approach, popular in present time, supposes using of software tools for access to information, stored in some knowledge base, which are compatible with different popular programming languages. This approach is widely used, for example, in systems, based on the W3C standards [18]. Structure of knowledge processing machine, based on that approach if defined by the developer in every case and is not regulated by any standards. Such an approach is more flexible, but lack of unification in knowledge processing machine structure and development process leads to inconsistence of machine components if they are designed by different developers. The result is a duplication of the similar solutions and rising of overheads during the development and support process.

It is evident that every intelligent system needs its own unique knowledge processing machine, which considers that system features and supposes an opportunity of its fast adjustment in case of necessary. But most of modern systems has fixed knowledge processing machine, which is able to solve problems from small limited class (for example, execute deductive logical inference, based on the simple if-then rules).

In the same time, the actual question is how to use different problem solution methods in one system in one time. The actuality is caused by high demand of systems, which can work autonomously in unpredictable conditions (for example, in open space or other places, which are unsuitable for humans). Systems, which use fixed set of algorithms cannot satisfy that requirement, so the next actual question is how to provide an opportunity of fast just-in-time enhancement of system abilities.

For example, it is evident, that for even simple autonomous system functioning there must be abilities of decision-making in conditions of uncertainty (for example, logical inference, as reliable, so as fuzzy and probabilistic); of analyzing of signals, received from different sensors, including tools for image processing; of analysis of the consequences of its own activity with the possibility of automatic adjustment of next acts of this activity; of predicting of the future environment states on the basis of the collected data, so on.

It is important, that we are not talking about the creation of a single universal knowledge processing machine, implementing all possible models and solve all possible problems. We are talking about the development of models and means that would support the creation of flexible and efficient knowledge processing machine of different systems within an acceptable timeframe.

B. Problems, Need to be Solved

In spite of the fact that there are a lot of models, methods and means of the knowledge processing, many of which have been successfully implemented in various systems, there still are:

- lack of common universal principles, underlying the implementation of various knowledge processing models leads to a lot of duplications of similar solutions in different systems and the inability to use the solutions, implemented in one system, in other systems. As a consequence, the development of each such machine has very high labor content, periods of their development are too large, it is not possible to use a variety of problem-solving models within one system;
- developed knowledge processing machines are not flexible, i.e. it is very difficult or even not possible to supplement developed machine with new components or make changes in already existing components. As the result, the support of such machines is very labour-intensive, what leads to their rapid obsolescence;
- the level of professional requirements for knowledge processing machines developers is very high;
- attempts to unite a large number of developers in the groups are not efficient enough due to the lack of hierarchy in the developed machines and, as a result, in groups of developers. Difficulties in the coordination of actions lead to additional overheads.

The consequence of these problems is the relatively high labor intensity of the knowledge-based systems development and maintenance, and as a result - their high cost.

In order to speak about the relevance of these problems, it is necessary to specify the criteria for analysis and comparison of knowledge processing machines, as well as to analyze the existing approaches to the development of such machines.

C. Analysis of Existing Approaches to Specified Problems Solution

We have specified the following basic criteria for analysis and comparison of knowledge processing machines:

- **flexibility and expandability**. This criterion shows how difficult it is and whether it is possible to make additions or changes in the already developed machine;
- **portability and platform independence**, i.e. the evaluation of the complexity of the developed knowledge processing machine model transfer to another platform of such models interpretation, for example, change the knowledge storage to another, etc.
- **performance**, that is the actual speed of operation of such machines and necessary resources, such as memory amount. Performance of knowledge processing machines can be enhanced through the use of models and methods of distributed and parallel knowledge processing;
- **class of problems, which the machine is able to solve**. It is clear that the comparison of knowledge processing machines, classes of solved problems for which differ significantly, by other specified criteria has no sense.

Further, because this paper is not devoted to the design of a single knowledge processing machine, and about the models and means, providing the development of such machines, it is necessary to specify the requirements for such kind of models and means:

- the ability to consider each designed model on different levels of the hierarchy;
- existence of the libraries of compatible components of knowledge processing machines of various levels;
- support of the activity coordination of developers' of different professionalism and responsibility levels (due to the hierarchy too);
- availability of automation of changes in already developed machines, existence of verification tools and their components, as well as means of automatic correction of identified deficiencies;
- providing of developed machines platform independence, which significantly increases the duration of their life cycle. This assumes not only already became traditional platform independence of programs, but also platform independence of components of whole knowledge processing machines, their specifications, etc.
- flexibility of the proposed models and means, which implies the ability to make changes in the already developed components and machines, and simplifies staff turnover due to the high level of automation of documentation means and high requirements level for the documentation of each component, as well as the availability of means of developers' information support and/or training;
- availability within the technology of means, fixing the current state of development object, as well as its development plans and the changes history;

Thus, for the development of universal models and means of knowledge processing machines development, which satisfy the above requirements, it is necessary to provide:

- the ability of integrating and coordinated functioning of all components of the knowledge processing machine within the same system;
- the ability to integrate different approaches within each of the components, for example, different approaches to problems solution. In this case, the class of problems, solved by the system, can be significantly expanded, for example, through the use of reliable and probabilistic inference, depending on the given task.
- the ability of knowledge processing machine supplementing with new components without significant overheads;
- the ability of parallel asynchronous solution of various problems within a single knowledge processing machine. Concrete model of parallelism used in the solution of a problem is largely determined by the problem itself. Thus, the technology must provide the ability to implement any parallelism model;

Currently in the development of knowledge-based systems the W3C standards are widely used. In particular, the OWL 2 [14] standard is used for semantic knowledge representation and RDF [15] standard is used for representing knowledge in form of semantic networks.

To access the data, presented in RDF models the SPARQL protocol and the same name language are used [17]. As the next step in relation to the SPARQL language the declarative query language Cypher can be regarded, which was designed by the creators of Neo4j storage [2].

Considered SPARQL and Cypher languages provide only access to stored knowledge, knowledge processing itself is carried out at the level of application, which is working with a repository of knowledge.

There are a lot of implementations of the so-called semantic reasoners, performing logical inference on the base of ontology represented in OWL format, as well as tools for creating and editing of ontologies. A full list of such tools, recognized by the W3C consortium, can be found at [13]. As seen from the table on it, the most of represented tools are capable to perform only the direct inference on the basis of the relations, described in the ontology.

Thus, it can be concluded that currently within the consortium were developed efficient means of knowledge representation, knowledge access and logical inference mechanisms, based on the ontologies, represented in this form. However, there is no common methodology and technology of knowledge processing machine design that causes a large amount of duplication and significantly increases the complexity of application development based on this representation. Reusing of solutions applicable to one system is not possible in most cases for the same reason.

Among integrated approaches to knowledge processing machines development the IACPaaS project can be considered [32], which is actively developed in present time. The aim of this project is to develop cloud platform to build on its base intelligent services for various purposes.

Integrated approaches to the knowledge processing machines design for intelligent systems of different classes, are actively developed in Novosibirsk city [39].

Problems of integration of different solutions, including related to the knowledge processing are also considered in [48].

Component design of knowledge-based intelligent systems is the subject of [23] article, in which the necessity of accumulation and reuse of the various components of intelligent systems is justified.

Analysis of the described approaches shows that the problems formulated in this paper are not solved completely in any of these approaches. This is largely due to the lack of a unified basis for the formal representation of all kinds of knowledge, including various types of programs, the lack of strict principles of the knowledge processing machine design and means for support of the developers of these machines and their components.

D. The Proposed Approach

Within this article we propose to use an ontological approach to solve given problems, in this case - the ontological approach to the design of knowledge processing machines. In general, the ontological approach involves the development of (1) the ontological model of the class of designed artifacts, (2) the ontology of design, describing the activities aimed at the artifacts development and methodology of development and (3) the ontological model of means to support the development of artifacts of given class throughout all stages of the artifact lifecycle.

Thus, to solve the problems in sphere of the knowledge processing machines development described above we need to develop:

- unified ontological model of the knowledge processing machine, having the properties of flexibility, modularity, platform independence, and allows to implement on the its basis any of existing models and methods of knowledge processing, including parallel and asynchronous;
- ontology of knowledge processing machines design, that is based on the specified model and includes a description of the methodology of design and formal typology of such machines' developers' actions;
- ontological model of the system of knowledge processing machines design support, built on the basis of specified model, and designed by the described methodology.

E. Tasks to be Resolved for Proposed Approach Implementation

There several tasks to be resolved for proposed approach implementation:

- to develop a model of the knowledge processing machine based on the system of ontologies which, firstly, will provide the flexibility of these machines, and secondly, would make the complex knowledge processing machines more productive due to parallel execution of certain processes, thirdly, will provide platform independence of developed machines;
- to develop an ontology, describing the activities of various subjects in the computer system memory, including the description of actions and tasks;

- to develop on the basis of this ontology means to coordinate the activity of the various components of knowledge processing machines;
- to develop a universal basic programming language, which does not depend on the interpretation platform and allows it to build on the its basis higher-level languages and their interpreters. To do this, the specified language must be built on the basis of the above-mentioned ontology that describes the activities of the different subjects. This will provide the independence of programs building principles from the programming language level, which is determined primarily by the operators' typology;
- to develop and implement an ontological model of this programming language interpreter;
- to develop an ontology of knowledge processing machines design, including the formal description of such machines developers' activities;
- to develop ontological model of the means of knowledge processing machines design support, built on the basis of specified model, and designed by the described methodology.

As a formal basis for the development of all specified models we will use ***SC-code*** - a format of unified knowledge representation in the form of homogeneous semantic networks with set-theoretic interpretation, used in ***OSTIS Technology*** [29]. Nodes of such a semantic network were named ***sc-nodes***, connections - ***sc-connectors*** (***sc-arcs***, ***sc-edges***). Within this technology is defined the concept of an ***ontology*** as ***subject domain*** specification [34], their typology is released. In this regard, further we will not talk about the formation of ontologies that describe a set of concepts, we will talk about the formation of the subject domains and its specifications, implying that this process includes the formation of all the necessary ontologies.

Computer systems, based on OSTIS Technology were named ***ostis-systems***, due to that we will talk about the ***knowledge processing machines of ostis-systems***.

As a basic programming language the ***SCP Language***, described in the same paper, will be used. Programs of that language are also stored in the form of SC-code constructions. Thus, the task of the basic programming language development is reduced to clarification of the SCP Language evolving it to meet additional requirements discussed above. The use of this language will provide platform independence for developed knowledge processing programs. In addition, the SCP Language also has a number of advantages, which will be discussed in details below.

Model of knowledge processing machine will be build on the basis of multi-agent approach [47], [31], also it is assumed that the interaction of the agents will be performed exclusively by means of semantic memory, which stores the SC-code constructions (***sc-memory***). Such an approach would provide the flexibility and modularity of developed machines, as well as provide the ability of parallel execution of different knowledge processing processes. In addition, in the case of implementation of agent programs on platform-dependent level (not in the SCP Language), such an approach would eliminate the need of the implementation of direct agent communication mechanisms, which have to be implemented using various programming languages.

The effectiveness of multi-agent systems is justified by the use of such systems in various fields [10]. Currently, there are a lot of agent-based modeling environments. A detailed review of these environments is given in the works [12], [11].

In order to build a strict ontological model of multi-agent system, which can be used as a basis for knowledge processing machines design, it is necessary to specify a model of each component included in its composition, namely:

- **model of agent itself**, which is a member of the multi-agent system;
- **model of the environment** in which agents are, at the events in which they react, and with which they can act [20].;
- **model of the agents' communication**, and in particular, the model of agents' activity coordination and resolve conflicts;

A formal model of agents' communication was proposed in [45], but for the application of this model within the proposed approach it is necessary to specify each of its components:

- **principles of the messages exchange between agents**, i.e. the way in which these messages are sent from agent to agent. The proposed approach to messaging uses sc-memory for messaging. This approach can be considered as a development of the idea of «blackboard», proposed in [9].;
- **typology, semantics and pragmatics of such messages**, i.e. the sense of the transferred information and the purpose of such an interaction. Attempts to clarify the mentioned concepts carried out in the ACL and KQML standards [1], [4].;
- **principles of agents' activity coordination**. Several approaches to coordination were considered in [6], [16], [3].

In addition, this work uses several ideas related to improving of the data and knowledge processing efficiency, considered in the works [24], [41].

Let's enumerate those subject domains, development of which is necessary to resolve tasks given above:

- ***Subject domain of actions and tasks***
- ***Subject domain of actions executed in semantic memory of ostis-system (actions in sc-memory)***
- ***Subject domain of agents, which work in semantic memory of ostis-system (sc-agents)***
- ***Subject domain of actions and actions specifications of basic knowledge processing machine (Abstract scp-machine)***
- ***Subject domain of abstract scp-machine agents and corresponding microprograms***
- ***Subject domain of knowledge processing machines developers' actions***
- ***Subject domain of incorrectness in scp-programs***

Each of the described subject domains will be considered in details below. In addition, all subject domains and corresponding ontologies, presented in this paper, were described with SC-code and included in the relevant sections of the IMS Metasystem knowledge base [7].

II. Unified Ontology-based Models of Knowledge Processing

A. Unification of Formal Means of Description of the Various Subjects' Activity in Semantic Memory

In order to be able to formally describe the transformations, performed by knowledge processing machine, we have designed ***Subject domain of actions and tasks***, and the corresponding integrated ***Ontology of actions and tasks***, as well as all ontologies of particular type. Within that subject domain such general concepts are researched as an action, a subject, an object of action, a task and its solution, etc. Further these concepts are used to develop a formal means of agents' coordination in the shared memory, as well as the programming language, oriented on the semantic networks processing and underlying the proposed approach.

Given subject domain and its relation to other works on similar topics were presented in [50], so we will take a closer look only on a few basic concepts which are studied in that subject domain and provide the basis for some of the solutions presented below.

We consider the *class of actions* concept and particular types of that concept:

class of actions
= *set of actions, similar in one way or another*
<= *family of subsets*:*
    action
<= *partitioning*:*
    {
    • *class of autonomous actions*
    • *class of non-autonomous actions*
    }

The autonomy of an action is determined regardless of exactly how the execution of concrete actions that belong to this class is performed.

Every action, which is member of the ***class of autonomous action*** is executed regardless of whether the specified action is a part of the decomposition of a more general action. When such an action is executed the fact that this action precedes any other actions or follow them (that is specified by the relation *actions sequence**) must not be taken into account.

If any of these conditions is not succeeded, the autonomy of the action is broken too.

Thus, autonomous action is semantically consistent act of transformation, executed by some subject, including, for example, in semantic memory.

To each action can be assigned some ***subject*** that executes the action. In relation to ostis-system we can consider concepts of the internal and external subject, and the system itself is considered as a subject of some activity too.

For the detailing of some action execution process we have introduced such relations as *action decomposition**, *sub-action**, *action sequence** and others.

It is important to note that the use of the proposed formal means of the different subjects' activity description at different levels will not only provide the universality and the "clarity" of this description due to the use of the most general concepts, but also the provide possibility of implementing any parallelism model at any level, from parallel execution of operators within the same program, up to agents' communication entire groups in shared semantic memory. The possibility of implementation of a particular model of parallelism in this case is determined only by the characteristics of the problem being solved.

Along with the classes of actions themselves within the given subject domain are also studied various classes of action specifications (*semantic neighborhoods* [34]), such as a *task*, *question*, *plan*, *program* and *solution* (*protocol*).

A ***task*** is considered as formal description of the conditions of a task or problem, that is, in fact, a formal specification of an action, aimed at the solution of this task or problem, which is sufficient to execute this action by any subject. Depending on the specific class of tasks, the internal state of the intelligent system or the required state of the environment can be described.

Each ***plan*** is a *semantic neighborhood*, *key sc-element'* of which is an action for which supposed details of its executing process are described. In the description of the ***plan*** a procedural and declarative approach can be used. In the case of a procedural approach appropriate action is specified by its decomposition into more specific sub-actions and the necessary specification of the sub-actions is given. In the case of the declarative approach plan specifies a set of sub-goals (e.g. using logical statements), the achievement of which is necessary to execute the appropriate action. In practice, both considered approach can be combined.

Each ***program*** is a generalized *plan* of the execution of actions that are members of appropriate class, that is, the *semantic neighborhood*, which *key sc-element'* is a *class of actions*, for elements of which details of their execution process are given.

B. Typology of Actions in Semantic Memory

Special attention should be paid to actions, executed in the semantic memory of a computer system (***sc-memory***). Actions of this class are studied within the ***Subject domain of actions executed in the abstract unified semantic memory*** and the corresponding ontology.

Every ***action in sc-memory*** is a sign of a transformation, performed by some subject (or subjects collective), and aimed on the sc-memory transformation. Specification of action after its execution may be included in the protocol of some task solution.

Transformation of the knowledge base state includes information search, involving (1) the localization of the response to the request in the knowledge base, an allocation of the response structure and (2) translation of the response into some external language.

Set of ***actions in sc-memory*** consists of signs of the actions of various kinds, the semantics of each of which depends on the specific context, i.e., orientation of the action on some specific objects and action membership to some particular class of actions.

It should be clearly separated:

- Each concrete ***action in sc-memory***, which is a sign of process that transforms sc-memory from one state to another;
- Each type of ***action in sc-memory***, which is a class of the same type (in some sense or another) of actions;
- sc-node, denoting a specific ***action in sc-memory***;
- sc-node, denoting a *structure* that is the description, specification or setting of the appropriate action;

Fragment of *set-theoretical ontology*, which specifies the concept of ***action in sc-memory*** using the SCn language [7]:

action in sc-memory
<= *inclusion*:*
    process in sc-memory
=> *inclusion*:*
    - *action in sc-memory, initiated by question*
    - *action of ostis-system knowledge base editing*
    - *action of ostis-system mode setting*
    - *action of editing of the file stored in sc-memory*
    - *action of interpretation of the program stored in sc-memory*

C. Unification of Model of Subject, Performing Transformations Within Shared Semantic Memory

The only kind of *subjects* that perform transformations in the *sc-memory*, we assume ***sc-agents***. For a formal definition of *sc-agent* concept we use the previously introduced concept of a *class of autonomous action*. So, an ***sc-agent*** is some entity that can perform *actions in the sc-memory*, which are members of some *particular class of autonomous action*. Within OSTIS Technology there was developed ***Subject domain of abstract sc-agents*** and the corresponding set of ontologies, specifying the notion of ***sc-agent*** and related concepts, including formal means of providing synchronization of actions executed by sc-agents in sc-memory.

Autonomy of actions, executed by each sc-agent presupposes that each sc-agent reacts on the corresponding class of situations and/or events in the sc-memory, and performs a certain transformation of *sc-text* (SC-code text) in the semantic neighborhood of the processed situation and/or event. Thus each sc-agent usually has no information about what other sc-agents are currently presented in the system and interacts with other sc-agents only by forming messages in shared sc-memory. That message can be, for example, a question, addressed to other sc-agents in the system (not known exactly to which of them), or an answer to the other sc-agents question (again, not known of which agents exactly).

It is important to note that the end user of the ostis-system in terms of knowledge processing is also considered as the sc-agent, forming messages in sc-memory by executing elementary actions, provided by user interface. In the same manner ostis-system interaction with other systems and the environment in general is performed. All information incomes the ostis-system and outcomes the ostis-system exclusively through the relevant interface sc-agents. In the proposed approach, direct access to the sc-memory of the end user or other external actors is not allowed.

Here are some advantages of the proposed approach to the organization of knowledge processing in sc-memory:

- because of the processing is performed by the agents that can exchange messages only through shared memory, adding a new agent or removing (deactivation) of one or more existing agents usually does not lead to changes in other agents because the agents does not exchange messages directly;
- agents often work in parallel and independently from each other, executing different actions in sc-memory; thus even a significant increase of the agents number in one system does not lead to reduction of its performance;
- agents specifications and, as will be shown below, their programs can be written in the same language with processed knowledge; this fact significantly reduces the list of special means, intended for the design of such agents and their collectives, and simplifies the whole system design process due to use of more versatile components.

Since it is supposed, that copies of the same *sc-agent* or functionally equivalent *sc-agents* may work in different ostis-system, being physically different sc-agents, it is rational to consider properties and typology of not sc-agents but the classes of functionally equivalent sc-agents, which we call ***abstract sc-agents***. Concepts of *sc-agent* and *abstract sc-agent* are the *maximal classes of studying objects* within the subject domain considered in this section.

Thus, the ***abstract sc-agent*** is a certain class of functionally equivalent *sc-agents*, various items of which can be implemented in different ways. Each ***abstract sc-agent*** has corresponding specification.

Typology of abstract sc-agents and means of their specification are considered in details in the work [49].

Let's consider the general typology of *abstract sc-agents*, which is a fragment of the set-theoretic ontology of the ***Subject domain of abstract sc-agents,*** presented in the SCn-code:

abstract sc-agent
<= *partitioning*:*
    {
    - *non-atomic abstract sc-agent*
    - *atomic abstract sc-agent*
    }
<= *partitioning*:*
    {
    - *internal abstract sc-agent*
    - *effectoral abstract sc-agent*
    - *receptoral abstract sc-agent*
    }
<= *partitioning*:*
    {
    - *non scp-implementable abstract sc-agent*
        <= *partitioning**
            {
            - *effectoral abstract sc-agent*
            - *receptoral abstract sc-agent*
            - *abstract sc-agent of scp-program interpreting*
            }

• *scp-implementable abstract sc-agent*
}
<= *partitioning*:*
{
• *abstract sc-agent of scp-program interpreting*
• *program abstract sc-agent*
<= *partitioning*:*
{
• *effectoral abstract sc-agent*
• *receptoral abstract sc-agent*
• *scp-implementable program abstract sc-agent*
}
• *abstract sc-metaagent*
}
<= *partitioning*:*
{
• *platform-dependent abstract sc-agent*
=> *inclusion*:*
non scp-implementable abstract sc-agent
• *platform-independent abstract sc-agent*
<= *partitioning*:*
{
• *abstract sc-metaagent*
• *scp-implementable program abstract sc-agent*
}
}

D. The Formal Means of Describing the Actions and Action Specifications of Basic Machine of Unified Semantic Networks Processing

SCP Language is offered as the base language to write programs, which describe *sc-agent* activity within the *sc-memory*.

SCP Language is the graph procedural programming language, developed for efficient processing of homogeneous semantic networks with set-theoretic interpretation, coded using *SC-code*. *SCP Language* is the language of the parallel asynchronous programming.

The language of the submission of data for SCP Written (scp-programs) is the SC-Code. This fact allows us to ensure the independence of the programs implemented in the language of SCP on their interpretation of the platform, in connection with which the majority of the program sc-agents to be realized exactly in the specified language. However, it is obvious that in such a case, the system should also be implemented in a platform-dependent sc-level agents, carrying the interpretation SCP language programs. This restriction is taken into account in the typology of abstract sc-agents provided above.

The language of the representation of *SCP Language* programs (***scp-programs***) is the *SC-code*. This fact allows to ensure the independence of the programs implemented in the *SCP Language* from their interpretation platform, so that variant of the sc-agents program implementation is to be major within proposed approach. However, in that case, there should also be implemented platform-dependent sc-agents, carrying out the interpretation of SCP Language programs. This fact was taken into account in the typology of *abstract sc-agents* provided above.

SCP Language itself is based on the *SC-code*, so the scp-program may also be the processing object for other scp-programs, including first-mentioned program itself. Thus, SCP Language provides the possibility of reconfigurable software creating. However, to enable the reconfiguration of the program directly in the interpretation process it is necessary to ensure on the SCP Language interpreter level (*Abstract scp-machine*) the uniqueness of each executable copy of the original program. This executable copy, generated on the base of *scp-program,* was named ***scp-process***. Adding sign of some *action in sc-memory* in the *scp-process* set guarantees that in the decomposition of that action there will be only signs of elementary actions (***scp-operators***), that can be interpreted by the implementation of *Abstract scp-machine*.

SCP Language is considered as an assembler for graphodynamic computer, which is oriented on the semantic networks processing and storing.

Actually development of SCP Language was not the objective of this work, because this language was already developed and described in details, for example, in [27].

Within this work we discuss the problem of the *SCP Language* adaptation to modern level of knowledge processing machines models and design tools and development of the ***Subject domain of actions and the action specifications of abstract scp-machine***, in which we study all the concepts related to the given language. The mentioned subject area is particular to the *Subject area of actions in sc-memory*, because each *scp-operator* is a sign of elementary action in *sc-memory*.

Within the considered subject domain are allocated additional classes of *structures* (sc-constructions) [34] to work with which some scp-operators are oriented. These classes are *single element sc-construction, three element sc-construction, five element sc-construction, and sc-construction of non-standart type.*

The maximal class of the researched objects within specified subject domain is an ***scp-program***. Each ***scp-program*** is a *generalized structure*, describing one of the possible decomposition variants of the given class of *action in sc-memory*. In fact, each ***scp-program*** is a description of the sequence of elementary operations to be executed in the semantic memory, to execute a more complex action of a given class.

A particular case of *scp-program* is an ***agent scp-program***. *scp-programs* of this class are the programs of knowledge processing agents, and has fixed set of arguments.

An ***scp-process*** is an action *in sc-memory* that uniquely describes a particular act of scp- program execution with the given input values. If the scp-program describes an algorithm for a problem solving in a general way, the ***scp-process*** is a sign of a specific action that implements the algorithm for the specified input parameters.

In fact, ***scp-process*** is a unique copy, created on the base of the *scp-program* in which each generated *sc-constant* corresponds to the *sc-variable* in that *scp-program* [28].

Membership of some action in the *scp-process* set guarantees that in the decomposition of the action only elementary actions signs (*scp-operators*) will be attended, so that action can be interpreted by the implementation of *Abstract scp-machine*.

Each ***scp-operator*** (***scp-process*** operator) is a sign of an elementary *action sc-memory*. Arguments of scp-operator will be called operands. The order of operands is indicated by the relevant role relations (*1'*, *2'*, *3'*, and so on). The type and the meaning of each operand is specified by various subclasses of the *scp-operand'* role relation. In general, the operand of the scp-operator could be any sc-element, including a sign of scp-program, including the program containing that operator itself.

Each ***scp-operator*** must have one or more operands, and there must be specified ***scp-operator*** (or more) to be executed next. The exception to this rule is an *scp-operator of the program execution termination*, which does not contain any operands and after which no scp-operators can be executed within this program.

Let's consider the of fragment set-theoretical ontology that describes the general typology of the scp-operators presented in the SCn-code:

scp-operator
<= *inclusion*:*
    action on sc-memory
=> *family of subsets*:*
    scp-operator atomic type
<= *partitioning*:*
    {
    • *scp-operator of generation*
    • *scp-operator of associative search*
    • *scp-operator of erasing*
    • *scp-operator of condition check*
    • *scp-operator of operand values operating*
    • *scp-operator of scp-processes management*
    • *scp-operator of sc-memory events management*
    • *scp-operator of files content processing*
    • *scp-operator of locks management*
    }

Membership of arguments to the scp-operator is specified using subclasses of role relation ***scp-operand'***. Fragment of set-theoretical ontology that describes the typology of the scp-operands roles presented in SCn-code:

scp-operand'
<= *inclusion*:*
    action argument'
∈ *non-basic concept*
∈ *role relation*
<= *partitioning*:*
    {
    • *scp-constant'*
    • *scp-variable'*
    }
<= *partitioning*:*
    {
    • *scp-operand with fixed value'*
    • *scp-operand with unassigned value'*
    }
<= *partitioning*:*
    {
    • *constant sc-element'*
    • *variable sc-element'*
    }
=> *inclusion*:*
    • *forming set'*
    • *erasing sc-element'*
    • *sc-element type' /* further is partitioned by the sc-elements typology*/*

Most of the advantages of the basic model of *SC-code* texts processing occur due to its following main features:

- texts of SCP Language programs are written using the same unified semantic networks as processed information;
- approach to the description and interpretation of the *scp-programs* is based on common principles of the various subjects' activities description, in particular, it is supposed to create a unique *scp-process* at each *scp-program* execution.

These advantages are:

- in one time in the shared memory can be executed several independent processes, wherein the processes corresponding to the same *scp-program* can be executed even on different servers in case of distributed realization of sc-model interpreter (*interpretation platform of computer system sc-models*).
- *SCP Language* allows to perform concurrent asynchronous calls of subroutines (create subprocesses within *scp-processes*), as well as to perform parallel scp-operator execution within one *scp-process*;
- As *scp-programs* are written using *SC-code*, transfer of *sc-agent,* implemented on the base of *SCP Language*, from one system to another reduces to simple transfer of the knowledge base fragment, without any additional operations that depend on the interpretation platform;
- the fact that the *sc-agents'* specifications and their programs can be written in the same language as the processed knowledge, significantly reduces the list of special funds intended for the knowledge processing machines design, and simplifies their development through the use of universal components;
- the fact that for the interpretation of scp-program the corresponding unique scp-process is created, allows to optimize the execution plan as much as possible (1) before its implementation and (2) even directly during the execution without the potential danger to break the general-purpose algorithm of the entire program. Moreover, such an approach to the programs design and interpretation allows to speak about the possibility of *self-reconfigurable programs* creating;

We cannot say that the idea of creating of a unique process, based on a program, for each act of its execution is a fundamentally new and is only implemented in the *SCP Language*. A similar approach is used in most modern systems, based on the von Neumann architecture and oriented on the work with traditional linear memory. In the discussed in this paper models and traditional systems both, this approach allows to speak about the possibility of the process reconfiguration during its execution, and, in the limit, about self-reconfigurable processes.

However, such an approach used in to semantic memory has a significant advantage, which consists in the such memory *associativity*. Indeed, in traditional memory access to the data is carried out exclusively by the address. In the case of reconfigurable software development address of each fragment in the neighborhood of which the change is performed, or at least the structure of the reconfigured process must be known to the process, which performs such a reconfiguration. This means, that a sense of a single piece of information in the traditional memory almost never can be resolved correctly without pre-known context. This fact leads to a great complexity of reconfigurable programs development, reducing of number of their application fields, and the high level of dependence of reconfiguration performing programs on the changes made by developers of software, in which this reconfiguration is performed. Using of the associative memory and the unified formal semantic basis for the description of any kind programs allows to eliminate these restrictions. Access to the elements within the associative memory is performed not on the basis of addresses, but by the connections between elements, and the number of key nodes, to which the binding is carried, is relatively small. Specification of each element within such memory is constructed by forming appropriate links, which can then be analyzed within the third-party process, i.e., the semantic of each element can be resolved by any process by analyzing the relations of considered elements with others. The number of such connections is not logically limited, so each element can be specified with the required level of detailing. In addition, the construction of *SCP Language* programs and higher-level languages programs bases on common formal means of description of the activity of all kinds of subjects, due to that the reconfiguration algorithms become more versatile because general structure of the program and semantics of transitions it in this case remains the same regardless of the language level.

E. Unification of Formal Means of Synchronization of Parallel Processes Execution in the Shared Memory

Because the only type of entities that perform the transformations in sc-memory are sc-agents, the general principles of the synchronization of their activity are also considered within the *Subject domain of abstract sc-agents*.

One of the concepts, researched in this subject domain is the concept of ***process in sc-memory***, which generalizes the concept of *action in sc-memory*. Concept of process in sc-memory memory is used to describe the principles of the synchronization using terminology in accordance with the literature on the subject, in which it is typically told about the *processes* in the memory of the computer system.

Before talking about the general principles of the various subjects' activity synchronization in the sc-memory, it is necessary to consider the typology of the processes in the sc-memory, which is a fragment of corresponding set-theoretical ontology. In that case we consider not a typology, based on the semantics of the performing transformations (such typology presented above for the class of *action in sc-memory*), but the typology associated with distinguished classes of processes, which use the same synchronization mechanisms.

Typology of *processes in sc-memory* presented in SCn-code:

process in sc-memory
<= partitioning:*
{
- *process in sc-memory, corresponding to platform-dependent sc-agent*
  <= partitioning:*
  {
  - *process in sc-memory, which corresponds to platform-dependent sc-agent and is not action of abstract scp-machine*
  - *action of abstract scp-machine*
    => inclusion:*
    action of scp-program interpretation

  }
- *scp-process*
  <= partitioning:*
  {
  - *scp-process, which is not scp-metaprocess*
  - *scp-metaprocess*

  }

}

In that work ***scp-metaprocess*** is the *process in sc-memory* that describes the activity of *sc-metaagent*, which is implemented with *SCP Language*.

To synchronize the execution of *processes in sc-memory*, the proposed approach uses a ***lock*** mechanism. The ***lock**** relation links the sign of *action in sc-memory* with signs of situational *structures* that contain sc-elements, locked for the duration of that action or any part of this period. Each such structure is a member of some *lock type*.

Three classes of *sc-agents* can be considered from the synchronization mechanisms point of view:

- *sc-agent of scp-program interpreting*
- *program sc-agent*
- *sc-metaagent*

Mechanism of locks, described in this section is used to synchronize the activity of the *program sc-agents*. This class includes all the agents, responsible for the tasks, assigned to a specific *ostis-system*, i.e. actually *sc-agents* of this class provide ostis-system functionality.

The task of *sc-agents of scp-program interpreting* is the maintenance of all described coordination rules (at the level of *SCP Language* programs interpretation platform). Principles of synchronization of agents of this class are more trivial than in the case of *program sc-agents*.

The task of *sc-metaagents* is conflict resolution and optimization of *program sc-agents* activity. Agents of this class operate on a higher level, and to synchronize their activities there are several special mechanisms, that will be discussed below.

To use the terminology, which is common in the literature, we will say that the process performs a transformation within sc-memory (e.g. deleting or generation of sc-element, setting or removing *lock*), meaning that the corresponding transformation is performed by some sc-agent and is a part of *action in sc-memory* (i.e. *process in sc-memory* that describes the transformations, performed in the sc-memory by the active subject) to which mentioned sc-agent is linked by the *executor** relation.

In the current version to synchronize the execution of *processes in sc-memory* there are three *lock types*:

- *full lock*
- *change lock*
- *deleting lock*

Each *structure,* which is ***full lock,*** contains sc-elements, viewing and editing (deleting or adding of incident sc-connectors, deleting sc-elements themselves, content change in the case of file) of which is prohibited for all *sc-agents*, except sc-agent, performing appropriate *action in sc-memory*, which is linked with the structure with *lock** relation. In fact, *sc-elements* falling within the ***full lock***, corresponding to a certain *process in sc-memory*, are temporarily absent for other processes in the current state of memory.

In order to exclude the possibility of implementing of *sc-agents*, which can make changes in the structure, describing the locks of other *sc-agents*, all of the elements of these structures, including structure sign itself (belonging to a set of *full lock*, and any other *lock type*) and links of *lock** relation linking structure and the correspond *action in sc-memory*, are added into the *full lock*, corresponding to this *action in sc-memory*. Thus, each *full lock* has corresponded membership loop, connecting it with the its sign itself.

Each structure which is member of ***change lock*** contains sc-elements, change (deleting or adding of incident sc-connectors, deleting of sc-elements themselves, content change in the case of file) of which is prohibited for all *sc-agents*, except *sc-agent*, executing the appropriate *action in sc-memory*. However, viewing (reading) of these elements is not prohibited for any *sc-agent*.

Basic principles of working with locks that do not depend on the *lock type*:

- at one time one process in sc-memory may correspond to only one lock of each type;
- at one time one process in sc-memory may correspond to only one lock installed on some concrete sc-element. Thus, the locked structures, corresponding to the same *process in sc-memory* do not intersect;
- at the end of the execution of any process in sc-memory all locks, set by it, are automatically removed;
- to improve the efficiency of the whole system, each process at any moment shall lock the minimal required set of sc-elements, removing the lock from each sc-element as it becomes possible (safe);

Each type of lock corresponds to a number of features and algorithms that cannot be discussed in details in article format and presented within the IMS Metasystem knowledge base [7].

If any process tries to set a lock of any type on any sc-element, already locked by another process, on the one hand, the lock cannot be set until another process releases the mentioned sc-element; on the other hand, in order to allow deadlock finding and resolving it is necessary to indicate the fact that a process wants to get access to the sc-element, blocked by any other process. A similar situation and the approach to its solution for the processes in the traditional memory described in [36].

Under the proposed approach, in order to be able to specify which processes are trying to lock an already locked sc-element, it is proposed, along with the *lock** relation use the *planned lock** relation, fully analogous to the *lock** relation. The process, which corresponds the *planned lock**, suspends execution until the already set lock will not be removed, after that the *planned lock** becomes a real lock, and the process continues execution in accordance with the general rules. In the case when several processes plan to install the lock on the same sc-element, also used the *lock priority** relation, linking the pairs of the *planned lock** relation.

In the case of deleting attempt of some sc-element, process can continue execution only when on that sc-element is not set (or planned) any lock by some other process.

To implement this possibility every process can be corresponded by set of *deleting sc-elements**. Sc-elements, appeared in that set, are available to processes, which have already set (or plan to set) the lock on these sc-elements previously (before attempting to delete them), and for all other processes these sc-elements are considered to be deleted already.

In some cases, in order to ensure synchronization, it is necessary to unite several elementary operations in sc-memory into a single atomic action (*transaction*) for which it is guaranteed that no third-party process will be able to read or modify the sc-elements involved in this action, until the action is complete.

In the proposed approach, *seven* transactions are considered. The implementation of them at the level of sc-models interpretation platform is necessary to ensure compliance with all the principles of working with the locks. A list of these transactions and their specifications can be found in IMS knowledge base [7].

Sometimes there can occur conflicts of two *processes in sc-memory*. This is possible, for example, when each of these processes is expected while the second process will unset lock form the desired sc-element, without unsetting the lock set by them on the same sc-element, access to which is required by the second process. Eliminating such a deadlock is impossible without the intervention of specialized sc-metaagent, which has the right to ignore the locks, set by other processes.

In general, the problem of specific deadlock can be resolved by performing the following steps by specialized sc-metaagent:

- rollback of several transactions performed by one of the processes involved in the deadlock to provide the second process access to the necessary sc-elements and possibility to continue execution;
- waiting for the second process until the terminating or until it unset all locks from sc-elements, access to which is necessary for the first process;
- re-execution within the first process of all cancelled operations and the continuation of its execution, but

with the changes in memory, made by the second process.

As mentioned above, the described synchronization rules are valid for the *software sc-agents*. For *sc-metaagents* all sc-elements, including those which describe locks, planned locks, etc., are fully equivalent to each other from the access point of view, i.e., any sc-metaagent has access to any sc-elements, even put into the *full lock* of some other process. This is necessary in order to sc-metaagents be able to identify and eliminate various problems such as the above-described problem of deadlock.

Thus, the problem of synchronization of sc-metaagents activity requires the introduction of additional rules.

Said problem is divided into two more particular:

- ensuring the synchronization of activity among the *sc-metaagents* themselves;
- ensuring the synchronization of activity among *sc-metaagents* and *program sc-agents*;

The first problem is solved by prohibiting parallel execution of *sc-metaagents*. Thus, at any given time within one *ostis-system* can exist only one process, corresponding to *sc-metaagent* and being *present entity* (executing at present moment).

The second problem is proposed to solve by introducing additional privileges for the *sc-metaagents* during the access to any sc-element.

The described mechanism of locks is applicable also in the case where some transformation in sc-memory is performed by the *ostis-system* user with means of the user interface *sc-agents*. In terms of knowledge processing, user is also considered as sc-agent, and therefore has the ability to lock the sc-elements with locks of different type.

In conclusion, it should also be noted that there may be a situation in which the execution of a process in the sc-memory is interrupted due to occurrence of any error. In this case, there is a possibility that the lock, set by that process will not be unset as long as it will be made by the sc-metaagent, which has discovered such a situation. However, at the level of sc-model this problem can be solved only partially, in cases where an error occured during the interpretation of scp-program, it shall be reported to sc-metaagent by the scp-interpreter (corresponding construction shall be formed in sc-memory). Cases where there is an error at the level of the scp-interpreter or sc-storage should be considered at the level of the *sc-models interpretation platform*.

For sc-agents, which programs are implemented using *SCP Language*, all the general principles of the organization of sc-agents and users interaction in shared memory of ostis-systems are applicable, but in that case there is a number of additional refinements, described in details in the IMS Metasystem knowledge base [7].

F. Unification of Ontological Ostis-systems Knowledge Processing Models

1) Ontological Model of Knowledge Processing Machine: ontological knowledge processing machine model, proposed in this paper, is built on the basis of the all principles described above.

Ontological knowledge processing machine model built by SC-code means (*sc-model of knowledge processing machine*), is considered as an ontological model of multi-agent system over shared memory. That memory acts as a communication environment for the agents. Agents included in such a multi-agent system, were named an *sc-agents*.

Using the earlier introduced terminology, we assume that the *sc-model of knowledge processing machine* is a *non-atomic abstract sc-agent*, which is the result of union of all the *abstract sc-agents,* that are part of a particular ostis-systems, into one. In other words, the *sc-model of knowledge processing machine* is a collective of sc-agents, consisted in a given ostis-system and perceived as a whole. For this reason, there is currently no need to introduce the *Subject domain of sc-models of knowledge processing machines*, as all such models are researched within the *Subject domain of abstract sc-agents*.

Thus, there are several basic levels of detailing of any knowledge processing machine:

- the level of knowledge processing machine itself;
- the level of non-atomic sc-agents that are part of the machine, including particular knowledge processing machines;
- the level of atomic sc-agents;
- the level of scp-programs, or programs implemented on the platform level;

Such a hierarchy of levels allows to provide, firstly, the possibility of component stage-by-stage design of the knowledge processing machine, and secondly - the possibility of designing, debugging and verification of machine components at different levels, regardless of other levels, which greatly simplifies the task of development of a knowledge processing machine, reducing overheads.

In addition, on each level there is a probability that some or all of the necessary components have already been implemented by anyone previously and can be reused in the developed machine. In details the methodology of machines component design will be discussed below.

2) The semantic typology of computer systems knowledge processing machines: classification of computer systems knowledge processing machines can be performed according to several criteria. Let's consider a several variants of such a classification, presented in SCn-code, and are part of the set-theoretic ontology of subject domain, presented earlier.

According to the type of the computer system:

Typology of *processes in sc-memory* presented in SCn-code:

knowledge processing machine
=> inclusion:*
- ...
  ∋ Knowledge processing machine of IMS
- *knowledge processing machine of auxiliary computer system*
  => inclusion:*

- *knowledge processing machine of computer system interface*
  => inclusion:*
    - *knowledge processing machine of computer system user interface*
    - *knowledge processing machine of interface between computer system and other computer systems*
    - *knowledge processing machine of interface between computer system and the environment*
- *knowledge processing machine of subsystem of some kind of components development support*
  => inclusion:*
    - *knowledge processing machine of subsystem of knowledge bases development support*
      => inclusion:*
      machine of knowledge base quality improvement
      => inclusion:*
        - *machine of knowledge base verification*
          => inclusion:*
            - *machine of search and elimination of incorrectness*
            - *machine of search and elimination of incompleteness*
        - *machine of knowledge base optimization*
        - *machine of information garbage detection and elimination*
    - *knowledge processing machine of subsystem of knowledge processing machines development support*
      => inclusion:*
        - *knowledge processing machine of subsystem of knowledge processing programs development support*
        - *knowledge processing machine of subsystem of knowledge processing agents development support*
- *knowledge processing machine of subsystem of computer systems and their components development control*
- *knowledge processing machine of separated ostis-system*

According to the type of interpreted knowledge processing models:

knowledge processing machine
=> inclusion:*
- *machine of information search*
  => inclusion:*
    - *machine of search of information, which satisfies given specification*
    - *machine of search of information, which doesn't satisfy given specification*
    - *machine of detection that information, which satisfies given specification, is absent*
- *machine of problem solution using stored programs*
  => inclusion:*
    - *machine, providing neural models interpreting*
    - *machine, providing genetic algorithms interpreting*
    - *machine, providing imperative programs interpreting*
      => inclusion:*
        - *machine, providing procedural programs interpreting*
        - *machine, providing object-oriented programs interpreting*
    - *machine, providing declarative programs interpreting*
      => inclusion:*
        - *machine, providing logical programs interpreting*
        - *machine, providing functional programs interpreting*
- *machine of problem solution in conditions, when there isn't solution program*
  => inclusion:*
    - *machine of depth-first solution search method*
    - *machine of breadth-first solution search method*
    - *machine, implementing trial-and-error method*
    - *machine, implementing problem halving method*
    - *machine of problem solution using analogy*
    - *machine of reduction of problem condition to first-order predicate logic*
    - *machine of logical inference*
      => inclusion:*
        - *machine of deductive inference*
          => inclusion:*
            - *machine of direct deductive inference*
            - *machine of inverse deductive inference*
        - *machine of inductive inference*
        - *machine of abductive inference*
        - *machine of fuzzy inference*
        - *machine of temporal logical inference*

According to the processing object, the goal of the problem solution:

knowledge processing machine
=> inclusion:*
- *machine of actually formulated problems solution*
  => inclusion:*
    - *machine of given quantities values retrieval*
    - *machine of given logical sentence validating within given formal theory*
    - *machine of given problem solution method forming*
      => inclusion:*
        - *machine of given sentence proof forming within given formal theory*

• *machine of given task answer verification*
• *machine of given task solution method verification*
=> *inclusion**:*
machine of verification of given sentence validity within given formal theory

• *machine, providing decision-making support*
=> *inclusion**:*
machine, providing selection from given set of alternatives
• *machine of classification*
=> *inclusion**:*
• *machine of classification of given entity within the given set of classes*
• *machine of classification of given entities using given set of attributes*
• *machine of natural language texts synthesis*
• *machine of natural language texts analysis*
=> *inclusion**:*
• *machine of natural language texts recognition*
• *machine of natural language texts verification*
• *machine of signal synthesis*
=> *inclusion**:*
machine of speech synthesis
• *machine of signal analysis*
=> *inclusion**:*
machine of speech analysis
=> *inclusion**:*
machine of speech recognition
• *machine of multimedia data processing*
=> *inclusion**:*
machine of image analysis
=> *inclusion**:*
machine of images recognition

G. Ontological Model of Interpretation Machine of Knowledge Processing Programs

On the basis of the considered ontological model of knowledge processing machine models of knowledge processing machines of a particular kind are built. One of the most important among them is the ontological model of the interpretation machine of the basic programming language for sc-text processing (i.e. *SCP Language*).

This model is considered as a set of sc-agents on which *Abstract scp-machine* is decomposed, i.e., *atomic sc-agents,* implemented on the platform-dependent level. All these agents are specified within the ***Subject domain of abstract scp-machine agents and corresponding microprograms***.

Decomposition of ***Abstract scp-machine***, presented in the SCn-code:

Abstract scp-machine
<= *abstract sc-agent decomposition**:*
{
• *Abstract sc-agent of scp-programs embedding in sc-memory*
<= *abstract sc-agent decomposition**:*
{
• *Abstract sc-agent of scp-programs actual embedding in sc-memory*
• *Abstract sc-agent of scp-programs preprocessing*
}
• *Abstract sc-agent of scp-processes creation*
• *Abstract sc-agent of scp-operators interpretation*
• *Abstract sc-agent of scp-programs interpretation syncronization*
• *Abstract sc-agent of scp-processes destruction*
• *Abstract sc-agent of syncronization of events in sc-memory and sc-memory realization*
<= *abstract sc-agent decomposition**:*
{
• *Abstract sc-agent of translation of sc-event formed specification into internal representation*
• *Abstract sc-agent of processing of event, which initiates agent scp-program*
}
}

To implement the proposed model of *Abstract scp-machine* web-oriented realization of sc-models interpretation platform was used, described in [40]. Detailed specification of the listed agents is presented in the IMS Metasystem.

III. The Ontological Model of Activity, Aimed at Knowledge Processing Machines Design

As mentioned above, all of the platform-independent components ostis-systems knowledge processing machines may be represented using the SC-code. In this case we are talking about an sc-agent specification, and the full texts of scp-programs, describing the algorithms of these agents.

Thus, the design of ostis-system knowledge processing machine is reduced to the design of such a system knowledge base fragment of special kind. In this regard, for the design of knowledge processing machines can be used all the existing means of knowledge bases development automation of the OSTIS Technology, considered, in particular, in [33], as well as the whole ontology of knowledge bases design.

Next, in is necessary to consider some aspects of the development, specific to the knowledge processing machines. These aspects include methodology of such machines design, discussed in detail in [51], suggesting the six main stages of the machine development, from the formation of the requirements, to debugging and implementation of designed components, as well as ***Subject domain of knowledge processing machines developers' actions*** and corresponding ***Ontology of knowledge processing machines design*** (or rather, their sc-models).

In this paper we consider the typology of classes of actions, aimed at the design and implementation of the ostis-system knowledge processing machine in according to mentioned methodology and are part of the ontology ***Ontology of knowledge processing machines design***.

It is important to note that according to the previously presented knowledge processing machine model of any ostis-system is an *abstract sc-agent*, and therefore the development of the machine is reduced to the development of such an agent.

action. develop ostis-system knowledge processing machine
= action. develop abstract sc-agent
<= partitioning:*
{
• *action. develop atomic abstract sc-agent*
=> *inclusion*:*
action. develop platform-independent atomic abstract sc-agent
=> *inclusion*:*
• *action. decompose platform-independent atomic abstract sc-agent into scp-programs*
• *action. develop scp-program*
=> *abstract sub-action*:*
• *action. specify scp-program*
• *action. find in library an scp-program, which satisfies given specification*
• *action. implement specified scp-program*
• *action. verify scp-program*
• *action. debug scp-program*
• *action. develop non-atomic abstract sc-agent*
=> *inclusion*:*
• *agent. decompose non-atomic abstract sc-agent into particular sc-agents*
• *action. develop abstract sc-agent*
}
=> *abstract sub-action*:*
• *action. specify abstract sc-agent*
• *action. find in library an sc-agent, which satisfies given specification*
• *action. verify sc-agent*
<= *partitioning*:*
{
• *action. verify atomic sc-agent*
• *action. verify non-atomic sc-agent*
}
• *action. debug sc-agent*
<= *partitioning*:*
{
• *action. debug atomic sc-agent*
• *action. debug non-atomic sc-agent*
}

IV. The Ontological Model of System of Knowledge Processing Machines Design Support

Among the tasks of system of knowledge processing machines design support are information and technical support of such machines development, including ensuring the correct and effective implementation of all stages provided by correspondent methodology.

In the design of all components of ostis-systems similar principles are used, some of them are shown in details in [52]. One of the basic principles is the principle of use of already implemented components of various kinds, already available in the Library of OSTIS components, part of the IMS Metasystem. All systems, built on the OSTIS Technology, except of the Metasystem, we will be called *child ostis-systems*.

Thus, each child ostis-system and each system, supporting the design of some components class are closely linked with the *IMS Metasystem*, in particular, with the *Library of OSTIS components*, which is the part of the metasystem knowledge base. It is supposed, that the library is not physically transferred into the child ostis-system, but the signs of required libraries, and specification of these structures are part of the knowledge base of the design support system for given component class, as will be shown below.

The considered system of knowledge processing machines design support itself is ostis-system too, and has the appropriate structure. Thus, this system model includes an *sc-model of the knowledge base*, the *sc-model of knowledge processing machine* and *sc-model of user interface*. Due to this approach, in this system can be used, if necessary, all the agents, used in other systems, such as information search agents.

The considered system can actually be used in three ways:

- as a subsystem within the metasystem of support of intelligent systems design (IMS). This case supposes the debugging of required components within the metasystem and then transferring them to the child system;
- as an independent ostis-system, designed exclusively for the development and debugging of knowledge processing machines components. In this case, the designed components are debugged within that system, and then have to be transferred to the child ostis-system;
- as a subsystem within the child ostis-system. In this case, components debugging is carried out directly in the same system, in which they are supposed to use and an additional transfer is not required.

Regardless of the selected case of system using, developed components can be included in the Library of OSTIS components.

An important stage in the life cycle of any software system is its debugging. There are two fundamentally different level of knowledge processing machine debugging:

- debugging on the sc-agents level;
- debugging on the scp-programs level;

In the case of debugging at sc-agents level, act of each agent execution is considered as indivisible and cannot be interrupted. In this way debugging may be performed for atomic and non-atomic sc-agents both. Initiation of a particular sc-agent, including a member of the non-atomic, is performed by creating appropriate construction in sc-memory, thereby debugging can be carried out at different levels of agents detailing, up to atomic.

Debugging on the sc-agents level supposes the possibility of force setting unsetting of lock, enabling or disabling of any agents, etc., so agents of such debugging support system must be sc-metaagents. Due to the fact that the proposed in this paper model of interaction between agents uses the universal approach of agent interaction through shared memory, the considered system of agents' design support can be used as a basis for building of agents modeling systems with other principles of communication, for example, the direct message exchange between agents.

Debugging at the scp-program level is similar to the existing modern approaches to procedural programs debugging and suggests the possibility of breakpoints setting, single-step program execution, etc.

Let's consider the formal model of system of knowledge processing machines design support. In the following part of this chapter, speaking about this subsystem or any of its components, we mean that we are talking about the sc-model of described entity, that is, about its ontological model, built with the SC-code means.

Subsystem of OSTIS knowledge processing machines development support, and accordingly, its sc-model is decomposed into two particular:

Subsystem of OSTIS knowledge processing machines development support
<= basic decomposition:*
{
- *Subsystem of knowledge processing agents development support*
- *Subsystem of OSTIS basic programming language programs development support*

}

These subsystems are decomposed in accordance with the general principles of ostis-systems architecture. Next, we will consider the main components of these subsystems.

Knowledge base of ***subsystem of knowledge processing machines development support*** includes in addition to *Kernel and kernel extensions of knowledge bases sc-models*, provided on the OSTIS Technology level, and description of the basic unified text processing model (*Abstract scp-machine*) a description of the key concepts, related to the scp-programs verification and debug. Thus, the subsystem includes all the necessary documentation for the developer of the various components of knowledge processing machines.

Now let's consider the basic concepts that are specific to the knowledge base of subsystem of *SCP Language* program design support.

In order to ensure the ability to debug scp-programs, within the ***Subject domain of actions and actions specifications of basic knowledge processing machine (Abstract scp-machine)*** there is a number of additional concepts. In particular, to enable the use of breakpoints within scp-programs appropriate relative and absolute concept are introduced.

Links of *quasybinary relation breakpoints** connect scp-program with a set of *sc-variables*, corresponding to scp-operators within this program. With each generating of scp-process, corresponding to this scp-program, all the *scp-operators*, corresponding to such variables will be added in a set of *breakpoint*, i.e., the execution of the scp-process will be interrupted when the each of these scp-operators will be achieved.

Using of this relation defines the breakpoints for all scp-processes generated on the base of a given scp-program. To specify a breakpoint within the single scp-process, the ***breakpoint*** set shall be used.

To enable scp-programs verification, ***Subject domain of incorrectness in scp-programs*** and the corresponding ontologies were developed.

A typology of such incorrectnesses:

incorrectness in scp-program
<= inclusion:*
incorrect structure
=> inclusion:*
error in scp-program
=> inclusion:*
- *unachievable scp-operator*
- *potentially infinite loop*

error in scp-program
<= partitioning:*
{
- *syntax error in scp-program*
- *semantic error in scp-program*

}
<= partitioning:*
{
- *error in scp-program on the program level*
- *error in scp-program on the parameters set level*
- *error in scp-program on the operators set level*
- *error in scp-program on the operator level*
- *error in scp-program on the operand level*

}

All of shown subject domains and their ontologies are part of the knowledge base of the system of knowledge processing machines design support. In addition, one of the most important part of the knowledge base of the system of knowledge processing machines design support is a library of reusable components of such machines.

Reusable component of OSTIS is some ostis-system component that can be used within other ostis-systems [52]. In this work the general typology of these components (the library structure) and the main principles to work with them are considered.

If ***reusable component of abstract knowledge processing sc-machines*** is *platform-dependent reusable component of OSTIS*, its integration is made in accordance with the instructions, provided by the developer and depending on the platform, as well as in case of any component of this kind. Otherwise, the integration process can be concretized depending on the subclass of components of given type.

Let's consider the structure of the ***Library of reusable components of abstract sc-machines***:

Library of reusable components of abstract sc-machines
= reusable component of abstract knowledge processing sc-machines
<= partitioning:*
{
- *Library of reusable abstract sc-machines*
- *Library of reusable atomic abstract sc-agents*

• *Library of reusable sc-text processing programs*
}

The ***reusable abstract sc-agent*** (both atomic and non-atomic, i.e. whole sc-machine) is the component, corresponding to some *abstract sc-agent* that may be used in other systems, possibly as a part of more complex *abstract non-atomic sc-agents*. Each ***reusable abstract sc-agent*** should contain all the information, necessary for the operation of the corresponding sc-agent in the child system.

After the ***reusable atomic abstract sc-agent*** has been copied to the child system, it is necessary to generate an *sc-node*, indicating a particular *sc-agent,* working in that system and which is member of the selected implementation of *abstract sc-agent*, and add it in a set of *active sc-agents* if necessary.

The structure of the ***Library of reusable atomic abstract sc-agents***:

Library of reusable atomic abstract sc-agents
= reusable atomic abstract sc-agent
<= partitioning:*
{
• *Library of information search sc-agents*
• *Library of sc-agents of knowledge integration into knowledge base*
• *Library of sc-agents of ontologies alignment*
• *Library of sc-agents of actually formulated tasks solution planning*
• *Library of logical inference sc-agents*
• *Library of sc-agents of information garbage collection*
• *Library of coordinate sc-agents*
• *Library of sc-agents of high level programming languages and correspondent interpreters*
• *Library of knowledge base verification sc-agents*
• *Library of knowledge base editing sc-agents*
• *Library of sc-agents of knowledge base developers activity automation*
}

The ***reusable sc-texts processing program*** is a component corresponding to a program, written on an arbitrary programming language, which is focused on the processing of structures that are stored in the memory of *ostis-system*. The priority in this case is the use of *scp-programs* because of their platform independence, except the development of some components of the interface when the full platform independence is not possible (for example, in the case of *effector sc-agents* and *receptor sc-agents*).

In turn, a ***reusable scp-program*** is a component, corresponding to some enough universal *scp-program*, which can be used as part of several *sc-agents*.

After the ***reusable scp-program*** was copied to the child system, it is necessary to add it in a set of *correct scp-programs* (correctness is verified if it enters the library of components within the *IMS*).

A. The Ontological Model of Tools of Knowledge Processing Machines Design Support

Let's consider the structure of the relevant subsystems' knowledge processing machines.

The structure of the knowledge processing machine of *Subsystem of knowledge processing agents development support*:

Knowledge processing machine of subsystem of knowledge processing agents development support
<= abstract sc-agent decomposition:*
{
• *Abstract sc-agent of sc-agents verification*
• *Abstract sc-metaagent of sc-agent collectives debugging*
}

Abstract sc-agent of sc-agents verification
<= abstract sc-agent decomposition:*
{
• *Abstract sc-agent of sc-agent specification verification*
• *Abstract sc-agent of verification of non-atomic sc-agent specification consistency to specifications of particular sc-agents in its composition*
}

Abstract sc-metaagent of sc-agent collectives debugging
<= abstract sc-agent decomposition:*
{
• *Abstract sc-metaagent of search all running processes, which correspond to given sc-agent*
• *Abstract sc-agent of given sc-agent initiating using given arguments*
• *Abstract sc-metaagent of given sc-agent activation*
• *Abstract sc-metaagent of given sc-agent deactivation*
• *Abstract sc-metaagent of setting of given type lock for given process on given sc-element*
• *Abstract sc-metaagent of removing of all given process locks*
• *Abstract sc-metaagent of removing of all locks from given sc-element*
}

Structure of knowledge processing machine of subsystem of OSTIS basic programming language programs development support:

Knowledge processing machine of subsystem of OSTIS basic programming language programs development support
<= abstract sc-agent decomposition:*
{
• *Abstract sc-agent of scp-programs verification*
• *Abstract sc-agent of scp-programs debugging*
}

Abstract sc-agent of scp-programs debugging
<= abstract sc-agent decomposition:*
{
• *Abstract sc-agent of given scp-program starting using given parameters set*

- *Abstract sc-agent of given scp-program starting using given parameters set in single-stepping mode*
- *Abstract sc-agent of search of all breakpoints within scp-program*
- *Abstract sc-agent of search of all breakpoints within scp-process*
- *Abstract sc-agent of adding the breakpoint into scp-program*
- *Abstract sc-agent of breakpoint removing from scp-program*
- *Abstract sc-agent of adding the breakpoint into scp-process*
- *Abstract sc-agent of breakpoint removing from scp-process*
- *Abstract sc-agent of scp-process execution proceeding on one step*
- *Abstract sc-agent of scp-process execution proceeding till the breakpoint or ending*
- *Abstract sc-agent of scp-process information displaying*
- *Abstract sc-agent of scp-operator information displaying*

}

B. The Ontological Model of User Interface of System of Knowledge Processing Machines Design Support

Since the objects of design for the described system are knowledge processing machines models, and particularly, knowledge processing agents and programs represented in *SC-code*, such a system can use the base means of external representation of SC-code texts, for example, SCn or SCg languages [7].

To visually simplify the process of verification and debugging of knowledge processing machine components, an approach is used which supposes, that only the minimum required set of sc-elements is displayed at any given time to the user of the system. For example, when one debug scp-process, it is enough to display only scp-operators and connections between them. If necessary, the user can manually request and view the specification of the necessary scp-operator at the program break moment. This approach underlies the algorithms of all the agents of the described system.

Thus, currently, the user interface of system of knowledge processing machines design support is represented by a set of commands that allow a user to initiate activity of the desired agent, which is part of the system. This set fully corresponds the set of agents discussed above and its detailed consideration in this paper is inappropriate.

V. Approbation of Models and Tools of Knowledge Processing Machines Design

Initial testing of the developed models and tools was carried out on the basis of the IMS Metasystem itself [7] [28]. In the process, the initial filling of the library of reusable sc-agents and knowledge processing programs was carried out.

In addition, the proposed solutions are used in the work of the students of the department of Intelligent Information Technologies of Belarusian State University of Informatics and Radioelectronics to develop knowledge processing machines of intelligent reference systems (IRS) in various subject domains.

Of particular interest are the prototypes of knowledge processing machines of the Euclidean geometry IRS and graph theory IRS. This is due, firstly, regarding the development level and the complexity of these prototypes, and secondly, the fact that these systems use fundamentally different approaches to problems solving.

As part of the Euclidean geometry IRS were implemented depth-first problem solution search strategy and logical inference engine, allowing to solve the problem in a few steps using logical statements (theorems, axioms), stored in the knowledge base.

In turn, within the graph theory ISS was implemented concept of programs package, which is based on a mechanism of reducing the problem to sub-problems, each of which is finally solved by executing a program stored in system memory for some input. This mechanism also allows to solve problems in several steps, i.e. solve such problems, for which there is no ready-made program, with which it would be possible to solve this problem.

In addition, the knowledge processing machine of each of the prototypes under consideration consists a set of search agents, many of which were taken from the *Library of reusable sc-agents*, and some specially implemented for the relevant system, as they are subject-dependent.

A. Knowledge Processing Machine of IMS

Currently, knowledge processing machine of IMS itself, excluding subsystem, includes a set of information search agents, implementing mechanisms of basic navigation within the knowledge base. All these sc-agents included in the correspondent libraries.

The structure of the knowledge processing machine in SCn-code:

Knowledge processing machine of IMS
<= *abstract sc-agent decomposition*:*

{

- *Abstract sc-agent of search of all outgoing constant positive permanent arcs of membership*
- *Abstract sc-agent of search of all outgoing constant positive permanent arcs of membership with role relations*
- *Abstract sc-agent of search of all ingoing constant positive permanent arcs of membership*
- *Abstract sc-agent of search of all ingoing constant positive permanent arcs of membership with role relations*
- *Abstract sc-agent of search of all identifiers of given element*
- *Abstract sc-agent of search of full semantic neighborhood for given object*
- *Abstract sc-agent of search of decomposition links for given sc-element*
- *Abstract sc-agent of search of all entities which are general for given entity*
- *Abstract sc-agent of search of all entities which are particular for given entity*

- *Abstract sc-agent of search of definition or explanation for given object*

}

B. Knowledge Processing Machine of Euclidian Geometry IRS

In addition to the mentioned standard set of basic agents of information search, for Euclidian geometry IRS additional search agents have been implemented and subsequently included in the *Library of information search sc-agents* of IMS, and one of the problem-solving models has been implemented too.

The list of information search agents, implemented within the Euclidean geometry IRS:

- *Abstract sc-agent of search of annotation for given section*
- *Abstract sc-agent of search of axioms for given ontology*
- *Abstract sc-agent of search of theorems for given ontology*
- *Abstract sc-agent of search of direct connections between two objects*
- *Abstract sc-agent of search of concepts, on the base of which given concept is defined*
- *Abstract sc-agent of search of definitional domain for given relation*
- *Abstract sc-agent of search of definition or explanation for given object*
- *Abstract sc-agent of search of examples for given concept*
- *Abstract sc-agent of search of formal notation for given statement sign*
- *Abstract sc-agent of search of illustrations for given object*
- *Abstract sc-agent of search of key sc-elements for given subject domain*
- *Abstract sc-agent of search of concepts, defined on the base of given*
- *Abstract sc-agent of search of construction by given pattern*
- *Abstract sc-agent of search of proof sc-text for given statement*
- *Abstract sc-agent of search of relations, defined on the given object*
- *Abstract sc-agent of search of problem condition and solution sc-text*
- *Abstract sc-agent of search of statements about given object*

As part of Euclidian geometry IRS also implemented a prototype of intelligent problem solver which, as well as some of its components, can be used in other systems. The structure of the solver:

Non-atomic abstract sc-agent of problem solution
<= *abstract sc-agent decomposition*:*

{
- *Abstract sc-agent of search of given quantity value*
- *Abstract sc-agent of statement validity check*
- *Abstract sc-agent of problem solving strategy application*
- *Abstract sc-agent of logical inference*
- *Non-atomic abstract sc-agent of mathematical expressions interpreting*
  <= *abstract sc-agent decomposition*:*

  {
  - *Abstract sc-agent of mathematical expressions calculating coordination*
  - *Abstract sc-agent of exponention, rooting and finding the logarithm*
  - *Abstract sc-agent of numbers and quantitites addition and substitution*
  - *Abstract sc-agent of numbers and quantitites multiplication and division*
  - *Abstract sc-agent of numbers and quantitites comparison*
  - *Abstract sc-agent of trigonometrical expressions evaluating*

  }

}

C. Knowledge Processing Machine of Graph Theory IRS

At the moment, for the graph theory IRS the following agents have been implemented (excluding agents, taken from the library):

Agents which answer general questions about the graph:

- *Abstract sc-agent of graph specification*
- *Abstract sc-agent of search of the graph characteristics*
- *Abstract sc-agent of search of the graph numeric characteristics*
- *Abstract sc-agent of search of sets, characterizing the graph*

Agents, forming sets characterizing the graph:

- *Abstract sc-agent of search of minimal spanning tree of the graph*
- *Abstract sc-agent of search of articulation points set of the graph*
- *Abstract sc-agent of search of bridges set of the graph*
- *Abstract sc-agent of search of deadends set of the graph*
- *Abstract sc-agent of search of anti-deadends set of the graph*

Agents to identify the type of the graph:

- *Abstract sc-agent of graph directivity check*
- *Abstract sc-agent of graph planarity check*
- *Abstract sc-agent of graph reflexivity check*
- *Abstract sc-agent of graph connectivity check*
- *Abstract sc-agent of graph symmetry check*
- *Abstract sc-agent of graph transitivity check*
- *Abstract sc-agent of graph cyclicity check*

Agents of graph numeric characteristics evaluation:

- *Abstract sc-agent of search of connected components of the graph*

Most of the agents above, corresponds to scp-program, which implements the basic algorithm of the agent, and has a specification that allows to resolve the possibility and feasibility of that program use in the process of solving a problem.

To enable the use of multiple programs or logic statements in the process of solving a problem, within the graph theory IRS, discussed above *Non-atomic abstract sc-agent of problem solving* was included in and modified. After the modifying, the agent became to be able to analyze not only the logical statements but the program specifications too, and, if necessary, initiate the implementation of these programs with the required input data. Unlike the original, the modified agent implements a strategy of problem solution search from the target (inverse inference), and tries to construct a sequence of programs and logical statements, use of which on existing input will lead to the desired result.

Actions, executed by modified agent has two arguments. The first argument is a sign of the *entity*, the characteristic of which it is necessary to find or calculate (for example, the sign of a concrete graph), the second - a sign of the class, corresponding to the characteristic described, and the second argument can be an absolute concept or relative. For example, if it is necessary need to check whether a given graph is acyclic, the second argument is a sign of the concept *acyclic graph*; if it is necessary to determine the diameter of a given graph, then the second argument will be the sign of the *diameter** relation.

VI. Conclusion.

In conclusion, we list the main advantages of the obtained results. The development of a universal model of knowledge processing machine, based on the system of subject domains and ontologies presented above, allows to unify different approaches to the knowledge processing, which in turn makes it possible to:

- on a basis of the proposed model, provide the implementation of any knowledge processing models and problems solution methods, including parallel and asynchronous;
- integrate, if necessary, different approaches to problems solution in a single system, and to ensure their simultaneous execution;
- consider any knowledge processing machine as a hierarchical system, which significantly increases the efficiency of the processes of its design, implementation and debugging;
- ensure platform independence of implemented knowledge processing machines and their components;
- through the use of multi-agent approach and unification of principles of agents distinguishing provide the flexibility of implemented knowledge processing machines;
- due to the universal and unified representation of the processed knowledge generalize existing approaches to solution of certain classes of problems, letting to turn the problems formulating way from procedural into declarative, thus providing greater flexibility of implemented solutions;

Development of standardized methods of knowledge processing machines design as ontology of design can significantly reduce the number of situations in which a similar solution being implemented by different developers are incompatible, which leads to the need for duplication of similar solutions in different systems. Furthermore, this approach makes it possible to use the already implemented components in the design of new machines, thus significantly reducing the overheads of their implementation.

Develop and implemented model of system of knowledge processing machines design support will provide automation of the activity of these machines developers and reduce the overhead of their verification and debugging. Moreover, this model is designed with all of the above mentioned approaches, which allows to provide the flexibility of that system itself.

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ОНТОЛОГИЧЕСКОЕ ПРОЕКТИРОВАНИЕ МАШИН ОБРАБОТКИ ЗНАНИЙ

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Работа посвящена разработке технологии проектирования машин обработки знаний интеллектуальных систем, в основе которой лежат онтологическая модель самой машины и онтологическая модель процесса проектирования.

В настоящее время все более актуальным становится использование интеллектуальных систем в самых различных областях человеческой деятельности, в особенности в тех ситуациях, где нахождение человека может быть опасным или приводить к возникновению ошибок, обусловленных так называемым человеческим фактором. В частности, одним из наиболее перспективных направлений в данной области является разработка систем, основанных на знаниях. В свою очередь в качестве основы для формального представления знаний в такого рода системах широко используются онтологии.

Одним из ключевых компонентов каждой такой системы является машина обработки знаний, обеспечивающая возможность решать различные задачи, связанные как с непосредственно основным функционалом системы (машина информационного поиска и интеллектуальный решатель задач), так и с обеспечением корректности работы самой такой системы (машина сборки информационного мусора, повышения качества базы знаний), а также с обеспечением автоматизации развития самой этой системы. Следует отметить, что задачи, решаемые некоторыми компонентами машины обработки знаний, не всегда явно сформулированы. К таким задачам можно отнести, например, выявление и сборку информационного мусора, оптимизацию базы знаний и т.д.

Важнейшим компонентом машины обработки знаний является интеллектуальный решатель задач.

Можно разделить существующие подходы к построению решателей задач на два класса:

- решение задач с использованием хранимых программ. В данном случае предполагается, что в системе заранее присутствует программа решения задачи заданного класса и решение сводится к поиску такой программы и интерпретации ее на заданных входных данных. К данному классу относятся, в том числе, системы, использующие генетические алгоритмы и нейросетевые модели обработки знаний.
- решение задач в условиях, когда программа решения не известна. В этом случае предполагается, что в системе необязательно присутствует готовая программа решения для класса задач, которому принадлежит некоторая сформулированная задача, подлежащая решению. В связи с этим необходимо применять дополнительные методы поиска путей решения задачи, не рассчитанные на какой-либо узкий класс задач (например, разбиение задачи на подзадачи, методы поиска решений в глубину и ширину, метод случайного поиска решения и метод проб и ошибок, метод деления пополам и др.), а так же различные модели логического вывода (классические дедуктивные, индуктивные, абдуктивные; модели, основанные на нечетких логиках, темпоральной логике и т.д.).

Таким образом, существует большое число подходов к построению различных компонентов машин обработки знаний компьютерных систем, в том числе - интеллектуальных решателей задач, многие из которых успешно реализованы и активно используются.

Рассмотрим два основных исторически сложившихся подхода к построению машин обработки знаний.

Первый подход предполагает наличие в системе фиксированной машины обработки знаний (например, машины логического вывода), к которой впоследствии добавляется база знаний, наполнение которой определяется предметной областью, в которой должна работать система. Такие системы получили название «пустых» экспертных систем или «оболочек» (expert system shells). Данный подход, как правило, использовался для разработки относительно несложных систем и в настоящее время не имеет широкого применения.

Второй подход, широко используемых в настоящее время, предполагает наличие программных средств доступа к информации, хранящейся в некоторой базе, совместимых с различными популярными языками программирования. Данный подход широко используется, например, в системах, построенных на основе стандартов W3C. Структура всей машины обработки, построенной на базе таких средств, определяется разработчиком в каждом конкретном случае и не фиксируется какими-либо стандартами. Такой подход обладает большей гибкостью, но отсутствие унификации в структуре и процессе проектирования машины приводит к отсутствию совместимости компонентов машин, созданных разными разработчиками, большому количеству дублирований одних и тех же решений, повышению накладных расходов в процессе разработки и поддержки машины.

Очевидным становится тот факт, что каждой разрабатываемой системе необходима своя уникальная машина обработки знаний, учитывающая особенности конкретной системы и предполагающая возможность ее быстрой корректировки в случае необходимости, в то время как большинство современных систем имеют фиксированную машину обработки знаний, способную решать задачи из небольшого ограниченного класса (например, осуществлять дедуктивный логический вывод на основе нескольких правил).

В то же время, актуальным становится вопрос о возможности одновременного использования в рамках одной системы нескольких механизмов решения задач, что обусловлено высокой востребованностью систем, способных автономно работать в условиях, имеющих высокий уровень непредсказуемости (например, в космосе или других условиях, не пригодных для работы в них человека). Системы, реализующие жестко фиксированный набор алгоритмов, не могут удовлетворить данному требованию, в связи с чем актуальным становится вопрос о возможности быстрого наращивания функционала системы прямо в процессе ее работы.

Несмотря на то, что в настоящее время существует большое число моделей, методов и средств обработки знаний, многие из которых успешно используются в различных системах, до сих пор остаются актуальными следующие проблемы:

- отсутствие единых универсальных принципов, лежащих в основе реализации различных моделей обработки знаний приводит к большому количеству дублирований аналогичных решений в разных системах и невозможности использовать решения, реализованные в одной системе, в других системах. Как следствие, высока трудоемкость разработки каждой такой машины, велики сроки их разработки, затруднена возможность одновременного использования различных моделей решения задач в рамках одной системы;
- разрабатываемые машины обработки знаний не обладают гибкостью, т.е. отсутствует или сильно затруднена возможность дополнения уже созданной машины новыми компонентами и внесения изменений в уже существующие компоненты. Таким образом, высока трудоемкость поддержки разработанных машин, что приводит к их быстрому моральному старению;
- высок уровень профессиональных требований к разработчикам машин обработки знаний;
- попытки объединения большого числа разработчиков в коллективы недостаточно эффективны по причине отсутствия иерархичности в разрабатываемых машинах и, как следствие, в коллективах разработчиков. Трудности в согласовании действий приводят к дополнительным накладным расходам.

Следствием указанных проблем является сравнительно высокая трудоемкость разработки и сопровождения систем, основанных на знаниях, а как следствие — их высокая стоимость.

В рамках данной работы решение указанных проблем предлагается осуществлять с использованием онтологического подхода, в данном случае – онтологического подхода к проектированию машин обработки знаний.

Таким образом, для решения описанных выше проблем в области построения машин обработки знаний предлагается разработать:

- унифицированную онтологическую модель машины обработки знаний, обладающей свойствами гибкости, модульности, платформенной независимости и позволяющую реализовать на ее основе любые существующие модели и методы обработки знаний, в том числе параллельной и асинхронной;
- онтологию проектирования машин обработки знаний, построенных на основе указанной выше модели, включающую описание методики проектирования и формальную типологию действий разработчика таких машин;
- онтологическую модель системы поддержки проектирования машин обработки знаний, построенных на основе указанной модели и проектируемых по описанной методике.

Первоначальная апробация разработанных моделей и средств осуществлялась на базе самой метасистемы поддержки проектирования интеллектуальных систем IMS. В процессе работы осуществлено первоначальное наполнение библиотеки многократно используемых sc-агентов и программ обработки знаний.

Разработка универсальной модели машины обработки знаний на основе представленной выше системы предметных областей и онтологий позволяет унифицировать различные подходы к обработке знаний, что в свою очередь дает возможность:

- обеспечить на основе предлагаемой модели реализацию любых моделей обработки знаний и решения задач, в том числе параллельных и асинхронных;
- при необходимости интегрировать различные подходы к решению задач в рамках одной системы и обеспечить их одновременную работу;
- рассматривать любую машину обработки знаний как иерархическую систему, что существенно повышает эффективность процессов ее проектирования, реализации и отладки;
- обеспечить платформенную независимость реализованных машин обработки знаний и их компонентов;
- за счет использования многоагентного подхода и унификации принципов выделения агентов обеспечить гибкость реализованных машин обработки знаний;
- за счет универсального и унифицированного представления обрабатываемых знаний обобщать существующие подходы к решению некоторых классов задач, позволяя перейти от процедурной формулировки задач к декларативной, обеспечивая таким образом большую гибкость реализованных решений;

Разработка унифицированной методики проектирования машин обработки знаний в виде онтологии проектирования позволяет существенно снизить количество ситуаций, в которых аналогичные решения при их реализации различными разработчиками оказываются несовместимыми, что влечет за собой необходимость дублирования аналогичных решений в разных системах. Кроме того, такой подход дает возможность широко использовать уже реализованные компоненты при проектировании новых машин, существенно снижая при этом накладные расходы на их реализацию.

Кроме того, разработана модель системы поддержки проектирования машин обработки знаний. Разработанная и реализованная модель системы поддержки проектирования машин обработки знаний позволит автоматизировать деятельность разработчиков таких машин и снизить накладные расходы на их верификацию и отладку. Кроме того, указанная модель разработана с использованием всех перечисленных выше подходов, что позволяет обеспечить гибкость самой такой системы.

Ontology-Based Design of Intelligent Systems User Interface

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***Abstract*—The work is devoted to the development of intelligent systems user interfaces design technology, which is based on an ontological model of the interfaces itself and the ontological model of the design process.**

***Keywords*—user interface, subject domain, ontology, intelligent system, ontology-based design, user, interface action, interface command, message.**

I. Introduction

A. Objective and Relevance of the work

The objective of this paper is the creation of technology of design of multimodal intelligent systems user interface and the creation of visualization tools for intelligent systems in particular. The relevance of the topic chosen due to the need to reduce overhead costs and timing of the development of user interfaces, the inability to adapt to the peculiarities of a particular user. As a user of any system communicating with it through an interface, the problems associated with the interface, often form a negative opinion about the system as a whole and does not allow full use of its functionality. This situation is mostly suitable in case of intelligent systems usage as possibilities of such systems is much wider than possibilities of conventional systems.

It is proposed to use ontology-based approach as a basis for the development of intelligent systems user interfaces design technology. The approach involves the development of intelligent systems user interfaces formal ontology. The creation of such ontology promotes coordination of principles and methods for user interface components design at first, promotes unification of user and intelligent system interface activities secondly, promotes decomposition process of user interfaces design and the possibility of its parallelism in third.

B. Problems, Need to be Solved

- the complexity of various kinds of the intelligent systems interfaces leads to the increased time needed to spent on the interface usage training and to learn additional study materials [5];
- long-term design and support of user interfaces and its high costs, what complicates the improvement process and leads to rapid system obsolescence;
- the absence of user interface development process unification what makes it difficult to develop user interfaces in parallel as well as limits the reuse of already developed components;
- long-term user retraining at the stage of learning new intelligent systems interfaces and at the stage of learning new external languages for knowledge representation as a consequence of the absence of such unification;
- there is no ability to use several external languages for knowledge representation simultaneously: various kinds of knowledge may displayed differently if such a display will be convenient for perception. At the same time it should be clear for the user when to use each external language for knowledge representation. In addition there is no possibility of rapid expansion of set of external languages, if it will be necessary;
- difficulties in transferring of user interfaces from one platform to another;
- absence of a common formal basis for constructing models of interfaces void the user's possibility of asking questions related to the interface usage.

C. Analysis of Existing Approaches of Specified Problems Solution

Nowadays there are several scientific researches which aimed to solve the problems of user interfaces development. The user interface is a component of the intelligent system that is prone to frequent changes due to the presence of a wide range of users with different levels of usage culture and requirements for a software system. Create a user interface that satisfies the requirements of all users possible only through a creation of flexible models of such interface, which could then be interpreted by the interpretation of one of the platforms of such models.

In the **classical approach** [14] to create an interface based on user requirements the layout of the interface is built firstly, then the prototype, then, as a rule, determination of the dialogue structure, and work out a possible scenario for the dialogue development, then there is an interface implementation using a suitable programming environment.

Model is the basic of interface development which contains declarative description of a high level of abstraction and does not contain procedural code in **model-orientied approach** [6]. A set of models is different for each model-oriented tool, for each tool and the level of the model different declarative languages are used, which makes it difficult not only to create an interface in one model-oriented tool, but also its subsequent modification as well as to the strong dependence of the developed model to the tool of its development.

Model-oriented approach based on ontology with specified interface models proposed in [10]. The interface in this approach is focused on the conversion of user-entered information presented in a comprehensible user message, into the values of the application program variables and vice versa. Particular importance is attached to the algorithm of automatic interface model transformation to the code, which is controlled by **user interface ontologies** where the characteristics of a particular model are input to the algorithm. However, this approach does not solve the problem of the user interface complexity and the absence of user possibility to ask questions related to the interface usage.

Another approach is **building an adaptive user interface**. The main focus here is on the user's cognitive characteristics taking into account possibility to create a custom interface that focuses on the modification of the parameters for maximum coordination with a cognitive profile. Adaptation mechanism for the implementation is proposed in [7] to establish a set of software tools including the designer interface, diagnostics subsystem, knowledge base for storing interface settings and individual user information important for building personalized interface.

The next approach for user interfaces design is associated with the **theory of activity** [4]. The user interface is considered as a set of information model of the problem domain, tools and methods of interaction of the user with the information model, and components, ensuring the formation of the information model in the process of a software system in [11]. To reduce a minimum set of user actions usage of **universal command** and intuitive approach to the description of the control elements is proposed in [19]. However, this approach does not consider interfaces extensibility aspect.

By visualizing the knowledge in intelligent systems we mean the mapping knowledge base fragment into the external form. Visualization of knowledge related to the user interface has an important role in knowledge obtaining and transferring. Visual languages complement ontological (or conceptual) modeling technology, making ontology content understandable and intuitive is not only for experts and analysts, but for a beginner [1].

There are several approaches to solving the problem of knowledge visualization. **Visualization of ontologies using cognitive frames** is considered in [16] [17]. The cognitive frame is a visualized fragment of ontology which allows to adequately convey to the person (expert) knowledge related to some target concept. The cognitive frame has two components - the contents of the corresponding ontological context of the target concepts and the visual image, presenting to an expert. The structure of the cognitive frame is based on the use of invariant relationships as well as consideration of concepts at different levels of hierarchy. It allows to form content in the frame that satisfies the requirements of compactness, completeness and familiarity for any ontology concepts.

Various visualization techniques such as hyperbolic trees, conceptual maps, goal-oriented visualisation of relationships between the elements of knowledge are proposed in [8]. Focused on goals integration of contextual visualization of relations between knowledge elements significantly improves the transfer of knowledge from the media (teacher) to recipients (students).

The main disadvantages of existing approaches of visualisation of different types of knowledge are the absence of universal language, which would allow to display any kind of knowledge in th form, though less evident than in the case of a specialized language, but clear to the end user.

As can be noted, the use of the approaches outlined above can solve only some of the identified problems of the user interface design. Several problems such as interface flexibility and effective implementation of new specialized communication languages remain unresolved.

D. The Proposed Approach

Problems of unification of construction of the various components of the computer systems principles are solved within the OSTIS Project [9], aimed at creating an open semantic technology design, managed by knowledge. Systems developed by this technology called **ostis-systems**. In this paper we will talk about ***user interfaces of the ostis-systems***.

As a formal basis for building ostis-system models in this technology is the universal language called ***SC-code***. The texts of the language written in the form of homogeneous semantic networks with set-theoretic interpretation. Elements of such semantic networks called *sc-elements*, such as nodes - *sc-nodes*, connections - *sc-connectors* (*sc-arcs, sc-edges*).

The basis of the ontological user interfaces design are the following principles:

- the user interface is a specialized ostis-system oriented on the interface tasks solution and consisting of the knowledge base and knowledge processing machine for user interface. It allows the user to address the various types of questions to the user interface;
- the ontology-based approach of the user interface design is used. It contributes to defined separation of the activities of various user interface developers as well as the unification of design principles;
- SC-code is used as a formal language of the internal knowledge representation (ontologies, subject domains and others). This ensures ease of interpretation of this knowledge by the system and by the person - the user or developer as well as the perception of the uniqueness of this information perception;
- the syntax and semantics of all kinds of external languages are described using SC-code with the appropriate ontology;
- translation from the internal to the external language and back are organized in such a way that translation mechanisms are not depend on external language. For the implementation of new specialized language in such case specification of the syntax and semantics of the language

is only needed. The universal model of the translation will not be affected by this specification;
- each control element of the user interface is an external display of a sc-element stored into the semantic memory (***sc-memory***). This allows to use them as custom commands arguments and correctly interpret the semantics and pragmatics of the interface objects activity;
- selection of visualisation styles carried out depending on the type of knowledge to display (for example, the use of different visualization elements for certain types of knowledge, and the other - for the other types) is supposed. This allows the user to quickly learn new specialized languages as well as to make a simple and understandable display of knowledge;
- the user interface model built independently of the interpretation of the platform implementation of such a model. It allows an easy transfer of the developed model on different platforms.

The use of the ontology-based approach of user interfaces design involves the construction of (1) the ontological model of the user interface as a specialized ostis-system; (2) ontological model of interfaces design process, those interface developers actions ontology which is based on the proposed model. In this paper the main focus is on the construction of the ontological model of the ostis-system user interface.

Within the described technology knowledge base structure of any ostis-system is described by a hierarchy of *subject domains* and the corresponding *ontologies* [12]. Ontology thus treated as specification of the appropriate domain. So speaking about the development of a certain domain we assume that it is development of an appropriate set of ontologies in the particular.

Ontological model of any entity described by SC-code will call sc-model. Knowledge base model and knowledge processing machine model will be called ***sc-model of knowledge base*** [13] and ***sc-model of knowledge processing machine*** [20] accordingly.

E. Tasks to be Resolved for Proposed Approach Implementation

Clarification of the *intelligent systems user interface ontology-based design* concept proposed in the paper includes solving of the following tasks:

- to develop the *sc-model of the user interface knowledge base* presented by hierarchy of domains and their corresponding ontologies;
- to develop the *sc-model of the user interface knowledge processing machine* presented by family of user interface agents;
- to develop a universal meta-language based on the system of concepts of *Subject domain and ontology of languages and visualization tools* which is the basis for a system of visualization and editing knowledge agents;
- to unify the principles of organisation of user and ostis-system interface activities;
- to unify the intelligent systems user interface commands typology;
- to develop a semantic typology of user interface elements which are the objects of the interface activity;
- to develop a library of reusable components of ostis-systems user interfaces, in which distinguish the *Kernel of the unified models of user interfaces*.

II. User Interface Knowledge Base Structure

As mentioned earlier, the user interface as part of the proposed approach is a specialized ostis-system and therefore knowledge base is its necessary component [12]. The knowledge base of the user interface includes the following parts:

- description of the processes related to the past, present and future of the user interface. Under the previous of the user interface meant the history of its exploitation as well as the evolution of the interface. Under the present - the current state of the user interface. Under the future - user interface development plans. Analysis of described temporal processes allows to evaluate the effectiveness of the interface development and enables versioning of the user interfaces design;
- users models with information about users characteristics, capabilities and preferences, which allows the interface to be flexible and adapt to the user, providing the most efficient interaction;
- typology of user and ostis-systems actions, which allows to describe the principles of interaction of the user interface with users at all levels of the interface interaction;
- typology of the objects of these actions, which allows to produce unification and coordination of user interface components as well as to make their hierarchy;
- formal description of external languages of SC-code structures representation, both universal and specialized.

If we consider the General ontology of user interfaces, it makes sense to speak of a system of four interrelated ontologies:

- ***General ontology of user interfaces***;
- ***General ontology of users and ostis-systems interface actions***;
- ***General ontology of user interfaces developer actions***;
- ***General ontology of users interfaces design tools***.

The first of these describes the common model of ostis-systems user interfaces. The second - a multi-level user interface activities on the one hand and the ostis-system interface activities on the other hand. The third ontology deals with the activities of the developer of ostis-system user interfaces. Finally, the fourth ontology considering various user interfaces design tools, including the various editors, translators and other tools.

This paper will consider the first and second of these ontologies and their corresponding subject domains. The fragments (substructures) of the considered subject domains and ontologies will be further shown in the form of *SC-code text* (***sc-texts***), written in SCn-code [3].

A. Subject domain and ontology of user interfaces

As it was mentioned before, user interface is a specialized ostis-system focused on solving the corresponding class of problems [15]. Further, design of user interface will mean user interface of the ostis-system. Therefore all the principles listed below will characterize exactly this type of interfaces. Thus, *sc-model* of this interface is built according to general principles of *ostis-systems* construction:

user interface
= ostis-system user interface
= sc-model of ostis-system user interface
<= abstract decomposition:*
{
- *sc-model of ostis-system user interface knowledge base*
- *sc-model of ostis-system user interface knowledge processing machine*

}

A concept of the *ostis-system user interface*, different user interface elements like windows, controls, states which describe user interface are investigated in the context of the *Subject domain of user interfaces*.

The key concepts of this domain model are:

- concepts, which denote different *classes of the user interfaces*;
- concepts, which denote different objects on which the user interface activity may be directed;
- relations defined on the set of interface activity objects.

Maximum studied object class of analysed subject domain and ontology is the concept of the *ostis-system user interface*.

The following subclasses of user interfaces are defined based on the type of interaction [18]:

user interface
=> inclusion:*
- *command user interface of IMS*
  = interface where commands are given to a computer system using the command line and then transferred for execution
- *graphical user interface*
  = interface where commands are given to a computer system indirectly through graphic images
- *SILK-interface*
  = interface where commands are given to a computer system through the analysis of human behavior
  => inclusion:*
  - *natural language interface*
    => inclusion:*
    - *speech interface*

Each intelligent system operates with knowledge base using internal language. A dialog is represented as a message exchanging between user and intelligent system. So as such a dialog takes place, a fragment of knowledge base should be mapped into some external form.

The universal external language of message exchanging is a language which allows to describe any kind of knowledge. The SC-code and all its representations are examples of this language:

- **SCg-code** - is one of possible languages to visualize SC-texts. The basic principle of SCg-code is that each sc-element is mapped into scg-element(a graphic representation);
- **SCs-code** – a string (linear) representation of SC-texts. It visualizes sc-text as a sequence of characters;
- **SCn-code** – a string nonlinear representation of SC-texts. SCn-code visualizes sc-text in a formatted with special rules sequence of characters in which also can be used basic tools of hypermedia, images and tools for navigation between parts of scn-texts.

The specialized language of an external messaging is a language which intended to describe particular forms of knowledge applicable in specific areas of science and technology. The most widespread examples of this language are language of drawings and language of description of topographic maps.

Geometric primitives are the main elements for language of drawings. This language is used in the geometry intelligent system which is built with help of ostis-technology.

Terrain elements and their properties are the main elements for language of description of topographic maps. This language can be reused in various ostis-systems.

Message exchange is performed with help of user interface actions in the ostis-system. Also it's possible to interact with some objects on the screen. Controls and windows are examples of such objects.

Each ***control*** represents a class of actions which can be initiated by user. Using such actions user has an influence on visible objects and on state of sc-elements associated with these objects.

SC-elements can be divided into groups and marked during visualization(e.g. with some color). The possible groups of sc-elements are:

- sc-elements which have been just generated on the screen by user;
- sc-elements which have been just generated by user and are available in the knowledge base;
- sc-elements which have been just generated by user and are not available in the knowledge base;
- sc-elements which have been displayed on the screen by ostis-system from the knowledge base.

Localization of interaction between a user and ostis-system can be performed via user interface ***windows***. The types of possible ostis-system windows are shown below:

window
= ostis-system window
= sc-text sign or file sign (which may be empty) stored in sc-memory at the current time and displayed on the screen
=> inclusion:*
- *main window of ostis-system*

<= partitioning:*
{
- *frame window of ostis-system*
- *contour window of ostis-system*

}

contour window of ostis-system
= (scg-contour $\cap$ ostis-system window)

= *scg-contour which is the ostis-system window displayed on the screen and can be manipulated*

frame window of ostis-system
= *(scg-frame ∩ ostis-system window)*
= *scg-frame which is the ostis-system window displayed on the screen and can be manipulated*

The ***main window*** is distinguished among *all windows in the ostis-system* based on the principle of inheritance of windows. This window is not a child of any window displayed on the screen.

It has the following properties:

- Only one instance of main window is available for a user session in the ostis-system;
- Main window belongs to the contoured set of elements;
- It's not possible to remove or hide main window.

Relation 'child window'* is an example of concept which is investigated in scope of *Subject domain of user interfaces*. This relation helps to build hierarchy of *windows in the ostis-system*.

Each tuple of the relation consists of window sc-elements and has the following properties:

- Oi child window must be a part of the (be in) parent window Oj;
- There is no such a window Ok, which is a parent for Oi and Oj windows at the same time.

User interface of ostis-system goes from one state into another, defines set and appearance of objects which are visible on the screen. Variety of these states defines a mode of user interface. It makes user interface flexible and helps to distinguish actions which are available for different categories of users.

mode
= *situational set of states of the user interface, which state is considered during executinon of user action.*
⊂ *situational set*
=> *inclusion*:*
  - *mode of identification language*
  - *mode of language for visualization of external texts*
  - *mode for displaying sequences of messages*

The description of each mode is listed below:

- ***mode of identification language*** - the *mode* which set a specific *language for the identification* of displayed object.
  Russian and English identification languages are supported in current version of technology.
- ***mode of language for visualization of external texts*** - the *mode* which set a specific *external language to display selected texts*.
  SCn-code, SCg-code, language of drawings and language of description of topographic maps are supported in current version of technology.
- ***mode for displaying sequences of messages*** - the *mode* which set a specific *visualization sequences of messages** during user interaction with system.
  Display all messages in single window and display each message in new window are supported modes in current version of technology.

B. Subject domain and ontology of users and ostis-systems interface actions

Subject domain and ontology of users and ostis-systems interface actions
<= *sc-structure decomposition*:*
{
- *Subject domain and ontology of ostis-systems users interface actions*
- *Subject domain and ontology of ostis-systems interface actions*

}

1) Subject domain and ontology of ostis-systems users interface actions: Interface language of ostis-system users, like any other language, has its own syntax and semantics and represents a set of a certain kind of texts. The text of such language is a sequence of interface actions of ostis-system users.

The proposal (the minimum meaningful piece of text) of interface language of ostis-system users is the specification of some initiated ostis-system action or the command formulation addressed to ostis-system. In this case, if an action initiated by user [21] does not require the indication of action objects (arguments), the proposal will consist of one elementary interface action of ostis-system user, which is an indication of the type of initiated action.

Development of ***Subject domain and ontology of ostis-systems users interface actions*** solves the problem of a clear separation of the activities of the user interfaces developers for effective and rapid development and facilitates the unification of user interface design principles.

The objects of research in *Subject domain and ontology of ostis-systems users interface actions* in the context of the general typology of actions are elementary user actions, interface commands and ostis-system users messages.

The key concepts of this domain are:

- concepts, indicating different *classes of elementary user actions*, interface commands and *ostis-system users messages*;
- relationships defined on the set of elementary user actions and interface command, related to the *Subject domain and ontology of actions and tasks*;
- relationships defined on the set of ostis-system users messages, related to the *Subject domain and ontology of temporal entities*;
- relationships defined on the set of ostis-system users messages, which can be defined only in scope of *Subject domain and ontology of ostis-systems users interface actions*.

The maximum class of research objects of considered subject domain and ontology is the concept of *ostis-system user interface action*.

On the basis of atomacity (elementary quality) class of shown actions is divided into the next subclasses:

interface action of an ostis-system user
<= union:*
{
- *elementary interface action of an ostis-system user*
  = interface action of an ostis-system user, for which another ingoing in his composition interface actions of the ostis-system user don't exist
- *interface command of ostis-systerm user forming*
- *message of ostis-systerm user forming*

}

The simpliest interface language fragments of ostis-system users are *elementary interface actions of ostis-system users*, for which another ingoing in his composition interface actions of the ostis-system user don't exist. Notice that the description of each elementary user action is abstract, so independence of the actions from implementation on various devices is provided [2].

Like atomic text fragments of any language, elementary action of ostis-system user is associated with its own alphabet (syntactically recognizable typology) below:

elementary interface action of ostis-system user
= the interface action of ostis-system user, for which another ingoing in his composition interface actions of the ostis-system user don't exist
⊃ specification of the type initiated by ostis-system user
⊃ specification of the argument (object) initiated by ostis-system user
⊃ specification of the entity, for which base decomposition is requested
⊃ specification of the of completion of arguments transfer
⊃ cancel of the last elementary action of ostis-system user
⊃ cancel of all specified (listed) arguments

Among the listed subclasses of elementary actions of an ostis-system user special attention should be paid to the action of *specification for the entity, for which the base decomposition is requested*, because the action is an interface user command at the same time. Because output process of the decomposition (base semantic neighborhood) for some entity is the most frequent user request, the action included to the list of elementary user actions, that makes a task of explicit using of the base decomposition request command with specification for its arguments easier.

At the same time, it is worth remembering that not every elementary user action is an interface command, which will be discussed further.

an interface command of ostis-system user
= specification for ostis-system user action, formed in the language of interface actions of ostis-system users and included type specification for an initiated action and specification for its arguments, i.e. objects, for which the action must be executed

The next kinds of forming of an interface command allowed depending on whether the user addresses to the signs of initiated actions by them or uses resources of external editors, that allows to reproduce specifications of initiated actions:

interface command of ostis-system user
<= partitioning:*
{
- *command, formed on interface actions language*
  = command, commiting the fact, that specification for an executing action generates automatically by applying of elementary user actions to the control elements
- *command, formed on external language*
  = command, commiting the fact, that specification for an executing action generates whether by the user, using resources of special editor, or using instraction on natural language

}

Interface actions of ostis-system users are subclasses of regular actions, therefore according to the ontology approach, in particular, the existing system of ontologis and subject domains are possible crossing of subject domains, the object of study of which are this two mentioned concepts. Examples of the relations from *Subject domain and ontology of actions and tasks* in the considered domain are such relations as ***object****, ***result****, ***context of action****, etc.

The most difficult, in terms of structure, interface actions class of ostis-system users is message forming.

message of ostis-system user
<= partitioning:*
{
- *user message in the external language*
  = message generated in the language of the interface actions (interface commands), which represents a sequence of actions with the indication of the objects on which these actions are defined, and the types of actions
  => inclusion:*
    - *scn-message*
    - *scg-message*
- *user message on the internal language*
  = sc-message
  = sc-text, representing the meaning of information built by one subject and intended for use by some particular subject or a group of subjects

}

Depending on what kind of sense carries the generated message, there are following subclasses of message of ostis-system user:

message of ostis-system user
<= partitioning:*
{
- *narrative message*
  = message provided the recipient some information and does not require any additional user action.*
- *imperative message*
  = message, which suggests some action by the recipient after receiving of the message.*

Some interface commands can simultaneously be imperative messages of the ostis-system users, in this case is said about message, which is decorated in the language of the interface commands. However, the main difference between them is that the message directly affects to the sc-elements, i.e, the formation of ostis-system user message means entering this message in the substantive part of the knowledge base.

Moreover, messages movement from one form to another also depends on the used commands. Commands-requests are initiated at once, in this case the message is converted from one form to another almost immediately, commands of editing form the actions protocol connected with the creation of the message content in one of the foreign languages, then the message is translated to the ostis-system memory that runs the process of initiating sequential actions from a protocol and the subsequent integration of the content of the message with the substantive part of the knowledge base.

Specifications of actions, which are the interface commands, does not always mean the use of sc-elements as arguments. For example, when it comes to the commands of editing file, the use of these commands affects the content of these files, but does not affect the sign of the file. However, if you imagine the content of a file as a linked sc-text, the reference to a certain subset of the sc-text (e.g, the sign of the proposal, the sign of some letter) will already imply the formation of user message.

Relations specified on messages consider the temporary connections between them, for example, *sequence of messages** for a particular user during the session of ostis-system operation. The existence of such relations indicates the intersection of the analysed subject domain and *Subject domain of temporary entities*.

Consider the examples of such relations:

sequence of messages*
=> inclusion:*
- *temporary sequence of messages**
- *logical sequence of messages**
  => inclusion:*
  - *answer**
    = binary oriented relation, the first component of the ligament of which is a sign of formulated in the form of an imperative message sender request, and the second component - a sign of narrative message in response to this request.*
  - *message that specifies statement of the problem**
    = binary oriented relation, the first component of the ligament of which is a sign of formulated in the form of an imperative message sender request, and the second component — a sign of recipient* imperative message if the sc-text of the original message is not completed.*
  - *error message**
    = binary oriented relation, the first component of the ligament of which is a sign of formulated in the form of an imperative message sender request, and the second component - a sign of narrative message, representing a formed incorrect structure by the result of request processing.*

Completing the description of the interface actions of ostis-system users, consider some of the relations specific only for *Subject domain and ontology of ostis-systems users interface actions* that reveal deeper aspects of visualization and interaction with the outside world:

- ***outer form of message**** - *binary oriented relation*, the first component of the ligament of which is the *sign of message*, and the second component - a *sign of the file* generated as a result of *sc-text translation** to the external language;
- ***communication environment**** - *binary oriented relation*, the first component of the ligament of which is the sign of message, and the second component - a sign of a certain *subset* of the surrounding environment, in which the messages exchanged between the *sender** and the *recipient**. As a *communication environment** for *ostis-systems* is *sc-memory*.

2) Subject domain and ontology of ostis-systems interface actions: Frequently, in spite of the same appointment of software and the similarity of tasks solved by them, from the user point of view interfaces of such tools externally looks very different, leading to the need for user to retraining and adapting to the new principles of interaction with the system. The solution of the problem is to explicitly allocate semantic types and classes of actions in a variety of ostis-systems interface actions and reflect by the semantics of the syntactic (visual) separation signs of such actions when they are displayed on the screen.

Development of ***Subject domain and ontology of ostis-systems interface actions*** solves the problem of correct and unambiguous interpretation of semantics and pragmatics of elements displayed on the screen This allows to obtain comprehensive information about the purpose and use of objects of interface activity at lower levels of working with it.

The objects of research in Subject domain and ontology of ostis-systems interface actions in the context of the general typology of actions is ostis-system direct action initiated by users and indirect actions the implementation of which is implicit in the execution of other actions.

The key concepts of this domain are:

- concepts, indicating different *classes and types of ostis-systems interface actions*;
- relationships defined on the set of ostis-system interface actions related to the *Subject domain and the ontology of actions and tasks*.

The maximum class of objects of research of the considered subject domain and ontology is the concept of *ostis-system interface action*.

ostis-system interface action
<= partitioning:*
{
- *atomic ostis-system interface action*
  = ostis-system interface action performed by atomic agent
- *non-atomic ostis-system interface action*

= *ostis-system interface action which is a sequence of atomic ostis-system interface actions and performed by non-atomic agent*
}

At the stage of interaction with the elements on the screen ***non-atomic ostis-system interface action classes*** are allocated, the interpretation of which is to provide a list of ***types of user-initiated actions*** relating to this class. Syntax highlighting for classes and types of action is supposed to intuitively understand the purpose of the user interface control elements implies a signs of sc-elements mentioned above.

Speaking about the classification of ostis-system interface actions in terms of their purpose, in this case it is preferable to use a color selection or the introduction of a specified extension as an option for the external representation (for example, SCg-code), which includes into the alphabet primitives associated with different classes of operations.

class of ostis-system actions, initiated by its users
<= *partitioning*:*
{
- *non-atomic class of ostis-system actions, initiated by its users*
- *type of ostis-system actions, initiated by its users*

}
<= *partitioning*:*
{
- *action of interpreting the program stored into sc-memory*
- *information searching action*
  => *inclusion*:*
  - *information searching action into the whole knowledge base*
  - *information searching action into the specified knowledge base fragment*
- *action of knowledge base editing*
- *action of editing file stored in sc-memory*
- *action of ostis-system building*
- *action of ostis-system operation mode setting*
- *windows manipulation action*
- *ostis-system action in the external environment*
- *action of cancelling the latest initiated ostis-system action*

}

In case when the number of initiated action arguments is important, the introduction of syntax rules here is not even a recommendation, but a necessity as receiving information on the number and type of action arguments can not be obtained without recourse to the appropriate action specification. As in the case with the appointment of interface actions syntax highlighting the best option here is to use some variant of the external representation. A complete classification of the types of actions initiated by ostis-system user will be given further:

type of actions initiated by ostis-system user
= *elementary class of ostis-system actions*
= *class of ostis-system actions an indication of which together with the corresponding action arguments (object on which the action is performed) uniquely defines every ostis-system action*
<= *partitioning*:*
{
- *type of actions initiated by ostis-system user with fixed arguments count*
  <= *partitioning*:*
  {
  - *type of actions initiated by ostis-system user without arguments*
  - *type of actions initiated by ostis-system user with one argument*
  - *type of actions initiated by ostis-system user with two arguments*
  - *type of actions initiated by ostis-system user with three and more arguments*

  }
- *type of actions initiated by ostis-system user with any arguments count*

In addition to ostis-system user messages messages of ostis-system itself are distinguished:

ostis-system message
=> *inclusion*:*
- *ostis-system message as a response on the imperative ostis-system user message*
- *ostis-system message initiated by itself*

Possible ostis-systems reactions to the imperative message are:

- an indication of the fact of the completion of certain task. Is typical for behavioral actions for example;
- receiving a response on the assigned task generated either as a result of the of the user interface knowledge base analysis or as a result of analysis of the subject part of the ostis-system knowledge base itself.

Situations in which ostis-system initiates communication itself can be divided into two groups:

- situations arised in the analysis of user activity.
  Examples: assignment arguments, which are not correspond the type of initiated action; hints appearance during the usage of user interface elements.
- situations arised in the analysis of the syntax of the external language texts.
  Examples:incompleteness of sentences formed on the external language; usage of structures, atypical or incorrectly used in the context separately taken external language.

Based on the description of the main entities that reflect the ostis-system interface activities, will describe the scenario of messaging between the user and ostis-system on the example of the work with file.

- receptor agents which fix the fact of performing elementary user actions on a file and generates a sequence of actions in time;
- effector agent recognizes in the generated sequence interface user commands and defines order of execution of these commands;

- the input of formed user message is happening on the external language;
- effector agent of translation the file to SC-code converts (if possible) the contents of the file as a sequence of sc-elements constituting the fragment of connected sc-text unambiguously interpreted in ostis-system memory;
- The formation of ostis-system response message on the external language is happening which was formed by a user message and taking into account the mode of the user interface which is currently set for the user interface.

The same relationships can be set on the ostis-system user interface actions as in the *Subject domain and ontology of actions and tasks* that have been mentioned above in the *Subject domain of user interface actions*. In addition, such taxonomic relations, showing a more complex organization of ostis-systems interface such as ***sub-action****, ***action decomposition**** and others can be used.

A special case of equivalence relation is also introduced for interface actions:

equivalence of the ostis-system actions, initiated by its users*
$\in$ *equivalence relation*
= *relation between the actions which have different specifications but the same result*

III. Structure of user interface knowledge processing machine

User interface knowledge processing machine consists of some collective of sc-agents [12] that provide user experience with control element of ostis-systems. Consider a model of user interface knowledge processing machine as an aggregate of abstract sc-agents that are meant by some software implementation.

abstract sc-agent of user interface
<= abstract sc-agent decomposition:*
{
- *Abstract sc-agent of external texts editing*
  => inclusion:*
  - *Abstract sc-agent of ostis-system's window manipulating*
    <= abstract sc-agent decomposition:*
    {
    - *Abstract sc-agent of new window creating*
    - *Abstract sc-agent of window closing (minimizing)*
    - *Abstract sc-agent of window removing*
    - *Abstract sc-agent of window moving*
    }
- *Abstract sc-agent of mode setting*
  <= abstract sc-agent decomposition:*
  {
  - *Abstract sc-agent of identification language setting*
  - *Abstract sc-agent of external texts displaying language setting*
  - *Abstract sc-agent of message sequence displaying*
  }
- *Abstract sc-agent of work with commands*
  <= abstract sc-agent decomposition:*
  {
  - *Abstract sc-agent of displaying semantic neighborhood of command*
  - *Abstract sc-agent of search of commands, which are members of one class*
  - *Abstract sc-agent of search of command class that matches specified command*
  - *Abstract sc-agent of search of commands, for which given entity can be an argument*
  - *Abstract sc-agent of command recognition from the set of elementary interface actions*
  - *Abstract sc-agent of last executed user command cancellation*
  }
- *Abstract sc-agent of file translation into external language*
  <= abstract sc-agent decomposition:*
  {
  - *Abstract sc-agent of file translation into SCn-code*
  - *Abstract sc-agent of file translation into SCg-code*
  - *Abstract sc-agent of file translation into specialized language*
  }
- *Abstract sc-agent of fixation of elementary user action execution fact*
- *Abstract sc-agent of sc-message translation into external language*
- *Abstract sc-agent of last executed user command cancellation*

}

If you use agents, It will worth to remember the differences in semantic and pragmatic component of any element of an user interface. Semantic component consists of determining sign of witch entity is the element displayed on the screen. Pragmatic component considers applied aspect (aspect of application) of the element displayed on the screen.

Only semantic component matters on sc-memory level. However this fact does not influence on exploitation process of system by user, because both components reflect different sides of the same sign of some entity. For example, every localized sc-text of some *message* is hidden behind *window of ostis-system*, every button hides behind itself sign of some *actions class* initiated by pressing input device keys.

Initiation event for two groups of abstract sc-agents - *Abstract sc-agents of ostis-system's window manipulating* and *Abstract sc-agents of mode setting* - will occur in three cases:

- in connection with keystroke or after selection of specific item in a drop-down list (in this case input parameters of sc-agent are taken by default);
- in connection with using command with previously specified arguments (in this case user choose specific control element as sc-agent's input parameter);
- in connection with generation of action specification and inclusion of this action into set of initiated actions (in this

case user knows set-theoretic interpretation of abstract sc-agent).

The third group of abstract sc-agents - *Abstract sc-agent of work with commands* - is a particular case of search sc-agents, whose task is to view the full or partial semantic neighborhood of the key element of this neighborhood or to find connections between the key element and other entities in the ostis-system knowledge base. These agents don't imply default arguments. It is the reason why only second and third of outlined above ways of initiating are valid for them.

The fourth group of abstract sc-agents - *Abstract sc-agents of file translation into external language* and connected to them *Abstract sc-agent of sc-message translation into external language* and *Abstract sc-agent of sc-message translation into external language* - is involved in messaging between user and ostis-system. These agents are not added into a list of commands that are available to a user as a menu item or as an user interface element because they are initiated by ostis-system. Therefore outlined above initiating events are not applied to these agents.

Finally *Abstract sc-agent of last executed user command cancellation* allows to correct activity of ostis-system's user by retrieval through protocol of executed action in case of committing unintentional errors by user.

IV. Library of reusable components of user interfaces

User interface component is an important concept of this paper.

user interface component
= *a limited set of user interface elements that is unified and that can be used repeatedly in various intelligent systems*

Each *component of the user interface* conforms to a fragment of the knowledge base based on some set of concepts discussed earlier and a set of *sc-agents*, manipulating this fragment in *sc-memory*. Depending on tools one component was developed with, the following subclasses are marked:

user interface component
<= *partitioning**
{
- *platform-independent user interface component*
  = *user interface component developed and maintained on OSTIS Technology tools.*
- *platform-dependent user interface component*
  = *user interface component developed with using of extraneous tools that are different from OSTIS Technology tools*

}

Platform dependent components of the user interface get through a process of integration to function properly as a part of ostis-system. In the course of this process the debugging of this component and sc-memory interaction is made. In the simplest situation it's provided by building of translators to sc-memory and from it.

One of the interfaces designing complication is a platform orientation of interfaces. To solve this problem, the components that realize ***the user interface kernel of intelligent system*** are included in the library of reusable components of a user interface. It consists of knowledge base model containing some subset of the knowledge base of a user interface and a model of a minimum essential knowledge processing machine.

V. Conclusion

The paper reviews the ontological approach to user interface design which is based on presentation of the user interface as specialized embedded intelligent subsystem that is intended for realization of information exchange between intelligent system and its users.

The use of this approach offers the following advantages:

- flexibility of designed interfaces, its maintenance and enhancement.
- time development lowering due to:
  - possibility of the interface activity separation in the design of user interfaces and minimizing the number of agreements in the process of collective development;
  - accumulation and use of project experience (design solutions) of other developers that is presented in the form of the user interface specified components as part of component libraries;
  - the use of unified approach to design of both the user interface and the interface of the ostis-system, its users and developers activity.
- portability of resultant ontological model of the user interfaces for different platforms
- improvement of information perception, that is displayed on the screen, through the use of general-purpose and specialized languages of external texts representation described by a common formal basis - SC-code.

Intelligence of the user interface is expressed in:

- correctness and efficiency analysis of user actions;
- serving out recommendations to user in case of incorrect and inefficient actions;
- identification of user commands, which can lead to dangerous (irreversible) harmful effects: in this case the request of additional action confirmation is carried out;
- formation of response to any user question that concerns the interface activity organization.

Thanks to presentation of the user interface in the form of ostis-system, it is possible to address different queries to the interface, it means, to use it as an all-round help-system, as well as to use objects (sc-elements), that are displayed on the screen, as arguments to any queries that may be useful, for example, when you configure the user interface for user specific needs.

In this way, the screen of the user interface displays the knowledge base fragment that is stored in the memory of ostis-system, though the user interface control elements are appropriate sc-elemets visualization, which adds the conciseness to the interface.

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ОНТОЛОГИЧЕСКОЕ ПРОЕКТИРОВАНИЕ ПОЛЬЗОВАТЕЛЬСКИХ ИНТЕРФЕЙСОВ ИНТЕЛЛЕКТУАЛЬНЫХ СИСТЕМ

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В работе рассмотрен онтологический подход к проектированию пользовательских интерфейсов, в основе которого лежит представление пользовательского интерфейса в виде специализированной встроенной интеллектуальной подсистемы, предназначенной для реализации обмена информацией между интеллектуальной системой и её пользователями.

Для достижения поставленной цели необходимо решить следующие проблемы:

- сложность интерфейса интеллектуальных систем различного рода приводит к затратам времени на обучение использованию таких интерфейсов и изучение дополнительных материалов;
- велики сроки разработки и затраты на проектирование и поддержку пользовательских интерфейсов, что осложняет процесс их совершенствования и приводит к их быстрому моральному старению;
- отсутствие унификации в принципах построения пользовательских интерфейсов затрудняет возможность распараллеливания процесса проектирования пользовательских интерфейсов, а также ограничивает возможность повторного использования уже разработанных компонентов;
- как следствие отсутствия такой унификации, велики сроки переобучения пользователя на этапе освоения новых интерфейсов интеллектуальных систем и на этапе освоения новых внешних языков представления знаний.
- отсутствует возможность одновременного использования нескольких внешних языков внешнего отображения хранимых в системе знаний: различные виды знаний могут отображаться по-разному, если такое отображение будет более удобным для восприятия. Кроме того отсутствует возможность быстрого расширения набора внешних языков при необходимости;
- затруднена возможность переноса пользовательских интерфейсов с одной платформы реализации

на другую;
- отсутствие общей формальной основы при построении моделей интерфейсов лишает пользователя возможности задания вопросов, касающихся организации самого интерфейса.

Проблемы унификации принципов построения различных компонентов компьютерных систем решаются в рамках Проекта OSTIS, направленного на создание открытой семантической технологии проектирования систем, управляемых знаниями. Системы, разрабатываемые по данной технологии, названы ostis-системами.

В основе онтологического проектирования пользовательских интерфейсов лежат следующие принципы:

- пользовательский интерфейс представляет собой специализированную ostis-систему, ориентированную на решение интерфейсных задач;
- используется онтологический подход к проектированию пользовательского интерфейса, что способствует чёткому разделению деятельности различных разработчиков пользовательских интерфейсов, а также унификации принципов проектирования;
- используется SC-код в качестве формального языка внутреннего представления знаний (онтологий, предметных областей и др.), благодаря чему обеспечивается легкость интерпретации этих знаний и системой, и человеком - пользователем или разработчиком;
- средствами SC-кода с помощью соответствующих онтологий описываются синтаксис и семантика всевозможных используемых внешних языков;
- трансляции с внутреннего языка на внешний и обратно организовываются так, чтобы механизмы трансляции не зависели от внешнего языка;
- каждый элемент управления пользовательского интерфейса является внешним отображением некоторого элемента, хранящегося в семантической памяти;
- предполагается выбор стилей визуализации, осуществляемый в зависимости от вида отображаемых знаний;
- модель пользовательского интерфейса строится независимо от реализации платформы интерпретации такой модели.

Использование онтологического подхода к проектированию пользовательских интерфейсов предполагает построение (1) онтологической модели самого пользовательского интерфейса, как специализированной ostis-системы; (2) онтологической модели процесса проектирования интерфейсов, т.е. онтологии действий разработчиков интерфейсов, построенных на основе предлагаемой модели. В рамках данной работы внимание уделено построению онтологической модели пользовательского интерфейса ostis-системы.

В рамках описываемой технологии структура базы знаний любой ostis-системы описывается иерархией предметных областей и соответствующих им онтологий. Онтология при этом трактуется как того или иного рода спецификация соответствующей предметной области. Таким образом, при разработке некоторой предметной области речь идет, в том числе, о разработке соответствующего набора онтологий.

Использование данного подхода даёт следующие преимущества:

- гибкость проектируемых интерфейсов, простота их поддержки и совершенствования;
- снижение сроков разработки пользовательских интерфейсов за счёт:
  - возможности разделения интерфейсной деятельности при проектировании пользовательских интерфейсов и минимизации числа согласований в процессе коллективной разработки;
  - накопления и использования проектного опыта (проектных решений) других разработчиков, содержащегося в виде специфицированных компонентов пользовательских интерфейсов в составе библиотеки таких компонентов;
  - использования унифицированного подхода к проектированию как самих пользовательских интерфейсов, так и к интерфейсной деятельности ostis-системы, её пользователей и разработчиков.
- переносимость сформированной онтологической модели пользовательских интерфейсов на различные платформы
- улучшения восприятия информации, отображаемой на экране благодаря использованию универсальных и специализированных языков представления внешних текстов, описанных с помощью единой формальной основы - SC-кода.

Интеллектуальность пользовательского интерфейса выражается в следующем:

- анализ корректности и эффективности пользовательских действий;
- выдача пользователю рекомендаций в случае его некорректных и неэффективных действий;
- выявление пользовательских команд, которые могут вызвать опасные (необратимые) или вредные последствия: в этом случае осуществляется запрос дополнительного подтверждения их выполнения;
- формирование ответа на любой вопрос пользователя, касающийся организации интерфейсной деятельности.

Дополнительными преимуществами представления пользовательского интерфейса в виде ostis-системы является возможность адресовать интерфейсу вопросы различного рода, то есть, использовать его как полноценную help-систему, а также использовать объекты отображённые на экране, в качестве аргументов любых запросов, что может быть полезным, например, при настройке пользовательского интерфейса под нужды конкретного пользователя.

Integration of an applied ontology and wiki" resources in the context of the unified knowledge base

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***Abstract*—The article considers the architecture of the multi" agent intelligent subsystem designated for construction of the knowledge base (KB) by integrating with wiki" resources. The KB represents the storage of knowledge and contexts of different problem areas (PAs) in the form of an applied ontology with nodes used for building the structure of wiki" resources.**

***Keywords*—knowledge base, wiki" resources, ontology, context, problem area.**

INTRODUCTION

In the process of any large modern organization activity, it is necessary to make urgent management decisions timely that requires specialists to have deep knowledge of the problem area. Moreover, they should be able to use different decision support systems and tools for work with knowledge.

The desire to automate and speed" up the process of obtaining necessary knowledge about the problem area drives the need in the unified multipurpose toolkit for knowledge management that does not require a user to have some additional skills in the field of knowledge engineering and ontological analysis.

Thus, one can identify a number of scientific problems besetting modern organizations. In order to be solved, such problems require the systematic approach and include the following ones:

- the need of developing the semantic basis for representation of electronic information storage content;
- the lack of integrative conceptual models using different approaches to the storage of knowledge about the PA;
- the need of unifying the automated processing of the stored knowledge;
- the need of simultaneous use of multi" aspect contexts of the PA under consideration;
- the need of solving the problem of tracking the clarity of human reasonings.

Thereby, nowadays, the actual problem is providing specialists of a wide range of organizations with a universal tool allowing to address the knowledge management challenges [1], [10]. Furthermore, the tool should not require some extra training of users.

I. KNOWLEDGE BASE OF THE MODERN ORGANIZATION

At the moment, the ontological approach is most often used for organization of knowledge bases of expert systems. A lot of Russian and foreign researchers such as T.A. Gavrilova [3], V.N. Vagin [2], V.V. Gribova [5], Yu.A. Zagorulko [6], A.S. Kleschev [8], I.P. Norenkov, D.E. Palchunov, S.V. Smirnov [9], D. Bianchini, T.R. Gruber, A. Medche, G. Stumme and others address the problem of integration and search of information in order to provide management decision support on the basis of an ontology.

In a broad sense, ontologies are models representing knowledge within the individual contexts of the PA in the form of semantic information" logical networks of interrelated objects where the PA concepts with properties and relations between objects are the main elements.

Ontologies serve as integrators proving the common semantic basis in the processes of decision" making and data mining, and the unified platform for combination of different information systems [4], [14], [15].

However, aside from the obvious advantages of the ontological approach use, the following disadvantages arise:

- the need to involve an expert of the PA in order to construct the KB; herewith, some degree of judgment is brought into the obtained description (model) of the PA;
- conversion from the external representation of any PA object to its internal description on the knowledge representation language that requires an expert to have some certain skills in the field of knowledge engineering and ontological analysis;

- the need of adaptation of the applied ontology to the PA changing contexts that leads to the necessary use of different methods of the KB automated extension.

A lot of the problems reviewed earlier have been solved in corporate knowledge bases (CKBs) represented in different internal and public wiki" resources [13].

A wiki" resource represents a web" site with structure and content that can be changed independently by users with tools provided within the site functionality with the use of the special markup language.

Thus, corporate wiki" resources allow:

1) To construct the certain CKB fragments not requiring the expert to have some additional skills in the field of ontological analysis, knowledge engineering and using different specialized software.
2) To let a number of experts make edits into generated CKB fragments that gives a partial opportunity to avoid the problem of data subjectivity.
3) To monitor the progress dynamics of the KB content, and if needed, return to one of the previous versions of the CKB content.
4) To use the advanced set of program interfaces (API) and extensions allowing to construct and edit fragments of the KB content in the automatic or computer" aided mode.
5) To construct a framework of the PA KB ontology and update its fragments on the basis of the analysis of the content of different CKBs.

In spite of all the advantages of wiki" resources and their naive" user orientation, this type of CKB has an essential disadvantage. It is a lack of the mechanism for checking logical integrity and semantic coherence of the PA objects included in wiki" resources.

Therefore, there is a need for integration of the PA applied ontology with corporate wiki" resources in the context of the unified knowledge base.

II. Constructing the Knowledge Base of the Organization by Extracting Knowledge from Wiki" Resources

One of the KB main problems is providing the mechanism for adapting the Athene technological platform [11] to the concrete PA with the use of methods of ontological analysis and data engineering.

The KB ability of taking into account the dynamic nature of processes refers to the tools existing in the KB ontology that allow to describe the process giving the permitted set of input ontology objects, constraints imposed on them, new or changed ontology objects obtained as a result of the process implementation.

The PA ontology context is a specific state of the KB content than can be chosen from a set of the ontology states. The state was obtained as a result of either versioning or constructing the KB content from different points of views.

Formally, the ontology can be represented by the following equation:

$$O = \langle T, C^{T_i}, I^{T_i}, P^{T_i}, S^{T_i}, F^{T_i}, R^{T_i} \rangle, i = \overline{1, n},$$

where n is a number of the ontology contexts; $T = \{T_1, T_2 \ldots, T_n$ is a set of ontology contexts; C^{T_i} is a set of ontology classes within the i" th context; I^{T_i} is a set of ontology objects within the i" th context; P^{T_i} is a set of ontology classes properties within the i" th context; S^{T_i} is a set of ontology objects states within the i" th context; F^{T_i} is a set of the PA functions fixed in the ontology within the i" th context; R^{T_i} is a set of ontology relations within the i" th context defined as:

$$R^{T_i} = \{R_C^{T_i}, R_I^{T_i}, R_P^{T_i}, R_S^{T_i}, R_{F_{IN}}^{T_i}, R_{F_{OUT}}^{T_i}\},$$

where $R_C^{T_i}$ is a set of relations defining hierarchy of ontology classes within the i" th context; $R_I^{T_i}$ is a set of relations defining the 'class–object' ontology tie within the i" th context; $R_P^{T_i}$ is a set of relations defining the 'class–class property' ontology tie within the i" th context; $R_S^{T_i}$ is a set of relations defining the 'object–object state' ontology tie within the i" th context; $R_{F_{IN}}^{T_i}$ is a set of relations defining the tie between F_{IN} function entry and other instances of the ontology within the i" th context; $R_{F_{OUT}}^{T_i}$ is a set of relations defining the tie between F_{OUT} function exit and other instances of the ontology within the i" th context.

Figure 1 shows the illustrative example of the knowledge base ontology that includes description of the process of the component manufacturing.

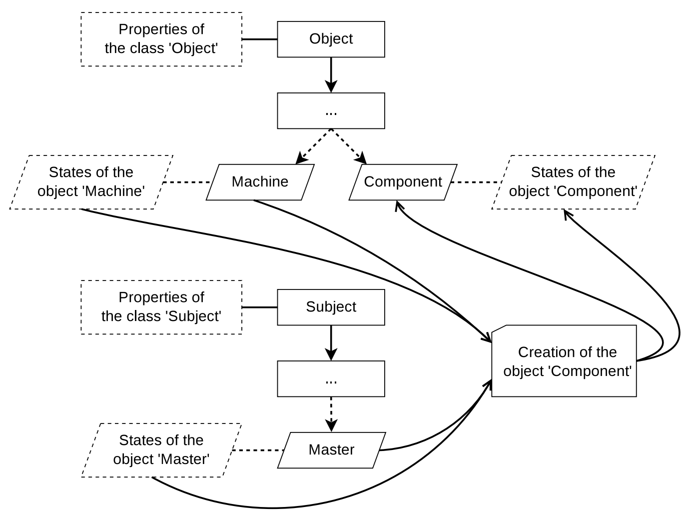

Figure 1. The illustrative example of the knowledge base ontology

The presented ontology includes 'Object' and 'Subject' classes with specific properties. These classes are the parent ones for all other ontology classes, herewith, parent properties are inherited by descendants.

The ontology also includes object 'Machine', 'Component' and 'Master', each of them has its own set of relations. 'Creation of the object 'Component' is a description of the component manufacturing process fixed in the ontology. The process has two inputs: 'Machine' and 'Master', and one output – 'Component'. 'Component' properties directly depend on machine properties and master qualification.

In order to automate the expert work in creating the PA ontology within the context of the KB under review, the method of automated creation of the ontology structure on the basis of external wiki" resources content is used. Herewith, the ontology structure is made in the process of the analysis of the resource categories system and infoboxes (standardized tables containing the key information about the object) described in the article [16], [13].

In order to construct external wiki" resources on the basis of the KB content, the following procedures should be followed:

1) Expert points what ontology classes should be taken into account in the process of creating an external wiki" resource as a category, subcategory, and page.
2) Expert points what ontology relations describe the tie between the object and its description, for example, in the text form.
3) System on the basis of the ontology relations analysis builds the structure of the external wiki" resource.

Also, there is an alternative approach to the constructing wiki" resources (internal wiki" resources) on the basis on the KB content: the user applies the KB mechanisms for obtaining and editing data with the use of dynamically generated screen forms. The approach allows to combine advantages of ontologies and wiki" resources through client" oriented managing tools and mechanisms for checking logical integrity and semantic coherence of the KB content. Figure 2 shows the architecture of the developed knowledge base.

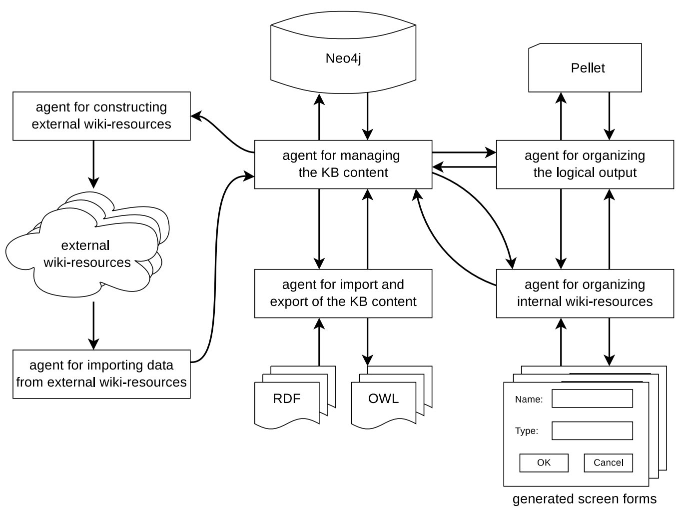

Figure 2. The knowledge base architecture

The KB consists of some agents, which interact closely among themselves:

- agent for managing the KB content;
- agent for import/export of the KB content from/to different formats of the PA ontology description (RDF, OWL, etc.);
- agent for organizing internal (on the Athene platform) wiki" resources on the basis of the KB content;
- agent for constructing external wiki" resources;
- agent for importing data from external wiki" resources to the KB;
- agent for organizing the logical output according to the KB content.

In order to develop agents of the Athene technological platform, Java programming language and Spring framework were used. Such development tools have the following advantages:

1) High development rate.
2) Existence of documentation and active community of developers.
3) Platform independence.
4) Advanced infrastructure.

Neo4j graph database is used as a storage for the managing agent ontology. It has the following advantages:

1) Native format for graph storages.
2) One database instance can serve graphs with billions of nodes and relations.
3) It can process graphs that do not have enough space in RAM.

Agents are performed in the Jetty servlets container with the modular architecture that allows to use only needed functions, thereby, it reduces the performance load on the server. Also Jetty is highly scalable for performing a lot of connections with significant downtime between the queries. It also allows to serve a lot of users.

In order to develop means for interaction with agents, the REST (Representational State Transfer) mechanism was used. It this case, the remote procedure call represents a simple HTTP request (GET, POST, PUT, etc.), and necessary data are transmitted as parameters of the request. The main benefits of REST are the following ones:

- high performance due to the use of cash;
- scalability;
- integration system transparency;
- simplicity of interfaces;
- portability of components;
- modification simplicity.

All the above resources, applications, and technologies are free.

CONCLUSION

Consequently, enhancement of the ontology platform (by the example of the developed Athene one) via using expert knowledge control agents allows to provide specialists of different organizations with the universal toolkit for analysis of the problem area features with the ability of automated fill and extension of the database from public sources; and for problem area visualization in the form of the complexly structured material.

The most important aspect in solving the task of overall information support for specialists is the ability of data representation in the matrix of their contexts including temporary ones and also contexts of different points of view on the PA objects under review.

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ИНТЕГРАЦИЯ ПРИКЛАДНОЙ ОНТОЛОГИИ И WIKI-РЕСУРСОВ В РАМКАХ ЕДИНОЙ БАЗЫ ЗНАНИЙ

В.С.Мошкин, А.А. Филиппов, Н.Г. Ярушкина

В статье представлена модель онтологии нечеткой предметной базы знаний (БЗ), позволяющая описать проблемную область (ПрО) с учетом многообразия ее контекстов. Под контекстом ПрО понимается состояние содержимого БЗ, которое может быть сформировано из множества состояний онтологии, полученного в результате версионирования либо формирования содержимого БЗ с различных точек зрения («point of view»). Также описано применение онтологического подхода для интеграции гетерогенных корпоративных информационных ресурсов. В качестве корпоративных информационных ресурсов рассматриваются крупные корпусы специализированных текстов, непосредственно связанные с ПрО, и различные виды корпоративных БЗ в виде внутренних сайтов и wiki-ресурсов. Также представлена архитектура многоагентной интеллектуальной подсистемы.

Ontological Mapping for Conceptual Models of Software System

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Abstract—**The paper proposes a integration methodology of conceptual models and domain ontology. Also a system based on the use of this technique was considered. The developed system implements the integration of UML-diagrams as conceptual models and ontologies represented on OWL [15]. The results of this system for projects from open source repositories and the ways of further development are presented.**

***Keywords*—ontology, engineering design, conceptual model, UML-diagramm.**

I. Introduction

Description of the application domain [9] in the form of formalized set of documents in OWL format is rare in industrial projects. A formal description of the application domain is time-consuming, both of experts and engineers that have the skills to work with ontologies. Artifacts created during the development of software products are usually described formally. These artifacts include requirements specification, requirements, conceptual models, source code with comments, version control system logs, etc. Transfer the knowledge from these artifacts in an ontology is much easier than from non-formalized texts on relevant topics.[10] [13] This article describes an approach to extracting knowledge from conceptual models and further integration conceptual models with domain ontology.

Generally any manufacture can be automated to some degree. Automation is done using specialized software packages. All stages of working with the products need to design: production, implementation, modernization, marketing, etc. During the creation of software products a qualitative formalization of application domain have a place, because software when is being introduced into production it passes multiple levels of testing. Conceptual models were been chosen as an example of artifacts generated by the development of the software. Conceptual models have a high degree of formalization and semantically close enough to the subject area.

The UML-diagrams are discussed as conceptual models in this article. UML-diagrams are most extended in software development today. By using the UML- daigrams it is possible to describe the system from different view points and all diagrams will be built on the common meta-model.[12]

UML is being developed by a consortium of OMG, while OWL belongs to W3C. Because different consortiums specify UML and OWL technologies it is not surprising that direct way of integrating from the manufacturer does not exist. UML is defined as a comprehensive meta-model in the form of a text description.The users get UML in the form of implementation of the software from one of the vendors, such as Visual Paradigm, StarUML, ArgoUML and others. Each of the vendors interpret UML standard in different ways and stores diagrams in its unique internal format. The way to integrate diagrams from different vendors is XMI format (XML Metadata Exchange). Nevertheless, diagrams from different publishers in the exported XMI format also have unique features.

Designers can use the UML in different ways depending on the purpose of creating diagrams. M. Fowler [8] identifies three different approaches to the use of language: sketches, detailed design and visual programming language.This article presents the results of frequency analysis of UML elements and approaches to using UML.

OWL most relevant language for describing ontologies.To create OWL ontologies software Protégé is used. By using Protégé it is posible to create and edit the ontology and execute queries using different reasoners. Importantly, the Protege allows to export and import OWL ontology in various formats of knowledge representation. Thus OWL format is compatible with most formats of knowledge representation.

The relevance of the integration problems are caused by the accumulation of a large number of artifacts in the projects of large software organizations. It is necessary not only to fix the design decisions in the form of artifacts, but also automate process making changes to the project. Purpose of processing UML-diagrams is to compile a list of conflicts and alternatives. In this area there are several papers devoted similar subject. There are a similar software systems for the transfer of conceptual models to the production knowledge base [1] using its own notation representation of the productive knowledge [2]. Examples of transformation of the same works are presented in [3], [4] [14]. Authors are positioning transformation as a system for the transfer knowledge from the diagrams in the ontology.

The difference of this article from the above is the approach to the problem. Projects in large enterprises have a long history and can be supported and expanded by decades. It is therefore necessary to ensure a permanent connection between conceptual models and the application domain. Such an approach would avoid the most costly mistakes in the development of projects and ensure their semantic coherence. In order to integrate conceptual diagrams and ontology, it is necessary not only automated conversion tool from UML to OWL, but also a system to work with UML an enhanced knowledge by OWL. This research is an attempt to produce integration the domain ontology in the software development process at the level of conceptual models. Thus,the normative documentation [5] [11] and source code should be linked with the ontology.It will allow to automatically detect conflicts and inconsistencies between projects in the same domain ontology.

II. Formulation of the problem

Modern trends in the development are to increase the flexibility and design of information systems, as well as the need to become more flexible.The flexible design suggests frequent modifications version of the conceptual models rather than building them again each time. Designing from the beginning is extremely expensive. Consideration of single system module separately of the remaining components will cause problems. Among the developers it is widely believed that the program can not be described better than the source code, if it is written qualitatively. But this statement is rather the consequence of a lack of understanding and ambiguity the interpretation of conceptual diagrams. Besides the user of conceptual diagrams can be a non-programmer but the domain expert, the customer (or its qualified representative) or manager.

In our opinion, the design should be more standardized and more closely integrated into the development process. We understand integration of design into the process of an information system development not like automatically generate source code, but the exact structure of the program description and the nuances of its interaction. The technology will be accepted by the community when its use reduces the time required to execute a certain work. In order to increase the design flexibility it is necessary automatically perform the consistency check UML diagrams by reasoner working with ontology in which these diagrams are integrated.

For the integration of domain ontology and design diagrams necessary to determine:

1) Format of the conceptual models description;
2) Format of the domain ontology description;
3) Rules for the conversion of conceptual models to the domain ontology;
4) Architecture of software for integration system;
5) The algorithm of integration system;
6) The results of transformation experiments.

III. Format of the conceptual models description

There are several common languages and notations that allow to describe the conceptual models, such as: IDEF0, IDEF1x, IDEF3, DFD, eEPC, UML etc. Some of these notations have not been widely adopted and were considered obsolete, such as IDEF2. Other notations, such idef0 or dfd are successfully applied.Notations and modeling languages are described in the official documentation. Documentation defines the purpose, the basic elements , communication between them and the semantic interpretation of the diagrams. Often diagrams are built without the help of special software, as an image on paper or image file. Diagrams that have been saved as an images can not be updated in case of changes in the system. The value of such diagrams is determined by the date of its creation. These diagrams could be developed to synchronize the view points of developers on the system at the time of creating diagrams. If the diagram is constructed in the form of image, it is impossible to produce on an automated processing. Therefore it is necessary to focus on diagrams constructed with the help of specialized software.

The Unified Modeling Language (UML) was chosen as the format of conceptual models of the for the following reasons:

- availability of detailed and unambiguous documentation;
- implementation a set of diagrams describing all aspects of the system;
- wide popularity among engineers community and IT engineers in particular;
- standardized diagrams export format - XMI .

Different organizations may have their own custom UML design rules somewhat different from the standard or extend it.It is necessary to support not only the most common diagram elements, but also be able to add new items and delete obsolete.

IV. Format of the domain ontology description

As an ontology description format was chosen OWL.OWL has several modifications. Selection of modification defines the semantic power of language by the set of available syntactic rules.For solving the problems of integration are best suitable OWL Full as the most complete implementation of the OWL. OWL Full allows to describe the same concept as a class and as an object in different situations. But using OWL Full has quite impressive drawback, namely the absence of guarantees of solvability query to the ontologies in finite time. Therefore, in the process of implementation of the system we will try to harness the power of OWL full only where it is needed. In other cases, we should use OWL DL.

V. Rules for the conversion of conceptual models to the domain ontology

The elements of conceptual models should be translated into the concepts of the ontology with regard to their semantic interpretation. Semantics of the whole diagram is being formed from the semantics of diagram elements and the semantics of their interaction. Accordingly, it’s important to translate the semantics of the elements of diagrams in view of the global UML meta-model. At an earlier stage of development of the integration system [7], rules for the transfer of some objects the class diagrams have been identified. Consider the rules for conversion of some elements of class diagrams to the concepts of the ontology.

A. Element and Relationship

The Element and Relationship are root concepts and provide the basis for modeling all other concepts in UML. UML-diagram contains Elements. Descendants of Element provide

semantics appropriate to the concept they represent.Each Element can hold other Elements. Elements hierarchy are being represented in the ontology as a hierarchy of classes, in which the certain classes will be presented as nodes of last level.
A Relationship is an Element that specifies some kind of relationship between other Elements. Descendants of Relationship provide semantics appropriate to the concept they represent. By this definition Relationship can be translated to the ontology as a subclass of the class Element. But in terms of the structure of OWL is better to move a hierarchy with root Relationship as ObjectProperty.This problem can be reduced to the problem of dualism of concept and attribute. This problem is enough common, one option of solving is considered in the article [6].

B. Type and DataType

To determine the Elements such as a class with its attributes and operations, it is necessary to correlate the data types of UML and OWL. DataType in UML is a subset of Type. Type is a subclass of Element in turn. A Type specifies a set of allowed values known as the instances of the Type. Basic types of OWL and UML data are taken from XSD that means that the types can be transformed directly without additional logic.The data types in UML and OWL are not completely identical. Unique data types, in turn, are based on the same basic XSD data types, and are specified by the restrictions on the basic data type.

C. Classes

The concept of class exists as in the UML, as well as in OWL.In OWL class is a set of individuals. As a built-in classes are offered the set of all instances of the Thing class and the empty set of instances Nothing class. Custom classes are interconnected by a relationship of ObjectProperty.Custom classes and connected with literal values by using the DataTypeProperty. UML class diagram considers a class as an aggregate internal structure and behavior of objects. Concepts of Class differ semantically, but the translation will be available at the level of the class hierarchy. Internal structure classes from UML-diagrams can be translated in OWL classes using ObjectProperties and DatatypeProperty. Most object-oriented programming languages do not support multiple inheritance because of the ambiguity problems of inheritance of individual members of the class. However, such construction is permissible in the description of domain ontology.

During the the research it was necessary to solve the problem of translating the hierarchy UML class in the hierarchy of OWL classes. Inheritance relationship in UML, and the OWL determined as follows, each instance (an individual) is a subclass of the base class instance.The inheritance relationship in UML, and the OWL defined equally, each instance of a subclass is instance of the base class.

If you need to extract data from a domain uml-diagram to fill the ontology class hierarchy can be translated uml-diagram hierarchy OWL classes without any additional changes. But in the case of integration uml-diagrams with the ontology is necessary to present UML meta model in the form of ontologies, and specify classes as individuals.In this case the generalization from UML-diagram is entered as relation between individuals. Generalization from UML will be translated to OWL as subproperty of Relationship, which in turn is ObjectProperty subproperty.

D. Classes:Attributes

Class attributes can be divided by data types on a attributes of primitive type (xsd schema) and custom attributes. Custom attribute contains a reference to the class object, transfer, etc.The attributes of the primitive data types are translated into the ontology as a DataTypeProperty. Domain of DataTypeProperty equal to the class that owns the attribute and Range equal to the primitive type. Enumeration translated into a user-defined data type DataTypeProperty for which are set predefined values. Class attribute that contains a reference to an object of another class is translated into ObjectProperty. Domain of ObjectProperty equal to the class that owns the attribute and Range equal to the class to which the attribute refers.

E. Links

Relations used in the design of UML class diagrams, usually do not have a direct analog in the ontological representation of the domian. A different approach to the description of the relationship between the elements is explained by the different objectives of creating diagrams and ontologies.

When transferring data from diagrams, it was required to establish a conformity of relationship UML-diagrams and ontologies.Attempts to implement this conformity in previous research were limited use of private cases. Also rarely the result such conversion can be uniquely interpreted in the reverse conversion. In order to implement long-term integration between diagrams and ontology, this approach can not be used.

When using ontology built on the basis of a meta-model of UML relationships all meta-model will be transformed into a hierarchy ObjectProperty. Specific relationships defined on a particular UML-diagram are converted into instance of ObjectProperty for classes translated as individuals.

VI. Architecture of software for integration system

General scheme of the system is shown in Figure 1. The diagram presents the key components of the system, the connection between them, the data format of relations and the role of users are interacting with them. It is assumed that the organization has the following staff: programmer (developer directly), designer (the most experienced programmer) and domain expert. We assume that the domain expert and a specialist in working with ontologies are one and the same person. Although are generally, in practice, it is still two different people. Furthermore, one specialist of ontologies usually aggregates in the ontology knowledge of a large number of domain experts.The same employee may be located in different roles at different times. For example, designer can also be a computer programmer.

The set of UML diagrams usually characterize more than one project. For example : server application, client applications for different platforms, tools, services, etc. can be realized as independent applications, but its UML-daigrams may substantially intersect. Programmers working on different projects,

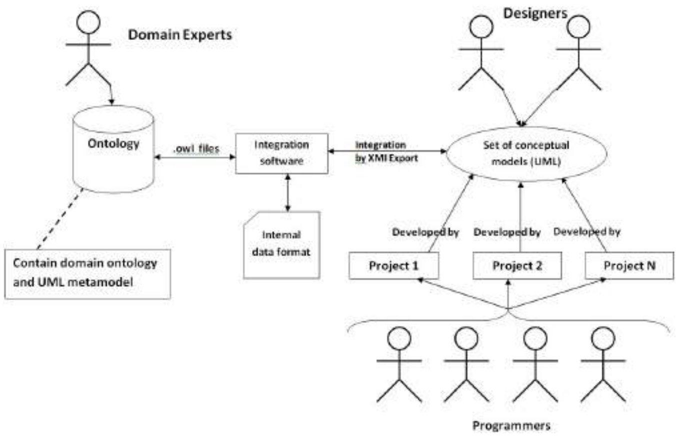

Figure 1. General scheme of the system

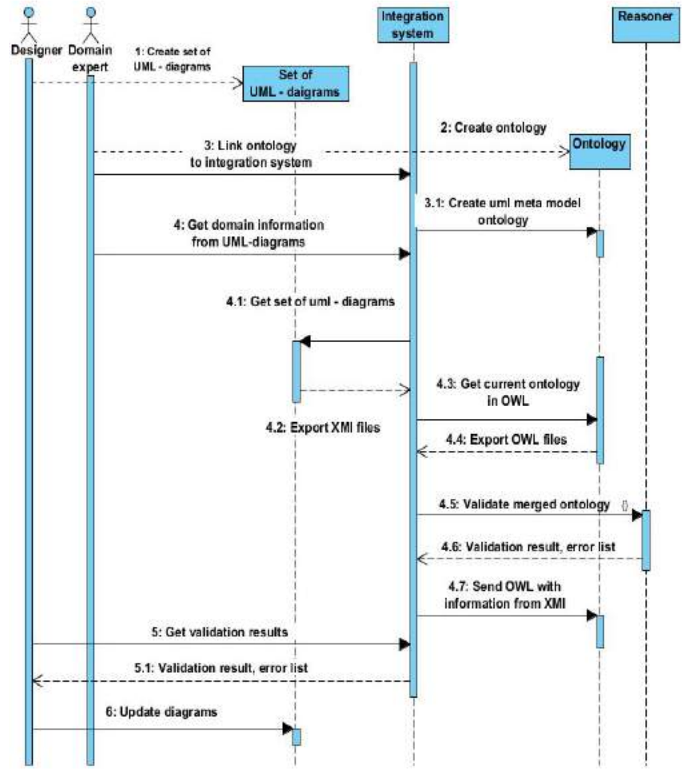

Figure 2. Workflow of Integration system submitted to the sequence diagram

can spend less time on the synchronization of applications through the use of common parts of design.

Integration System creates an internal project that includes the data from the conceptual models and data from the domain ontology. UML- diagrams can be loaded into the project in the XMI format. Ontology in OWL format can also be added to the project.

Domain experts could work with ontology directly through the instrument to which they are accustomed. A feature of the ontology used in the scheme is a part responsible for the representation of meta-model UML diagrams.Not all elements of the UML diagrams can be unambiguously represented on the application domain.In this regard, it is proposed to link the elements of domain ontology with elements of the UML meta-model with the help of a special relationship.

Figure 2 shows a sequence diagram representing the workflow of the system integration during designing:

- 1.The designer creates a set of UML-diagrams;
- 2.Domain expert creates ontology.In this case, it does not matter which action will occur first and which is second. Usually the enterprise already has existing set of UML diagrams, because the creation of a UML diagrams set is shown first;
- 3. Domain expert formulate request to integrate ontology and a set of UML-diagrams.This action is performed by the domain expert, as it becomes relevant only after the creation of ontology;
- 3.1 Integration system creates a UML meta-model part in a given ontology;
- 4, 4.1, 4.2 Integration System takes data from domain ontology in OWL format;
- 4.3, 4.4 Integration System takes data from the UML-diagrams in XMI format;
- The integration system combines the data obtained from the UML-diagrams and ontology using rules of integration between 4.4 and 4.5 messages ;
- 4.5, 4.6 integration system checks the consistency of the ontology and uml diagrams for axioms specific to this application domain;
- 4.7 The integration system updates the ontology by the data derived from UML;
- 5, 5.1 The designer receives a diagram of processing results using reasoner from the system integration;
- 6 Designer updates UML-diagrams.

VII. The Algorithm of Integration System

The algorithm processes the XMI file, which is a specific structure of xml file. This feature allows to build non-trivial queries to the document. Thus, it is possible to not think about the implementation of a query at a low level (indexing, data structures for storage, etc.).

Listing 1. Parsing UML in XMI format

```
begin
    classDiagram = getClassDiagramm(
        XMIroot);
     if (classDiagramm == null) than
         exit;
     UserTypes [] =  getTypes(
         classDiagram);
     Classes [] = getClasses(ClassDiagram
         )
     foreach(class in Classes[])
     begin
         class.Attributes = getAttributes
             (class);
```

```
            class.Operations = getOperations(
                class);
            class.Childs = getChilds(class,
                Classes[]);
            class.Parent = getParent(class,
                Classes[]);
          end
        MatchingDataTypes(Classes [],
            UserTypes[]); // Replacing XMI ID
             on the type of names
        Associations [] = getAssociations(
            root, Classes []);
        Dependencies [] = getDependencies(
            root, Classes []);
        //Generation of OWL
        owl = writeHeader(owl);
            //Generation ontology header
        owl = writeDataTypes(owl, UserTypes);
            //DataTypeProperties
        owl = writeClasses(owl, Classes[]);
            //Classes
        owl = writeLinks(owl, Classes[],
            Associations [],
            Dependencies [])//ObjectProperties
                ;
        ErrorList [] = reasoner.Validate(owl)
            ;
        foreach(error in errorList)
        begin
            print(error);
        end
    end
```

This algorithm was implemented in the Visual Studio development environment, the language C # in the form of a desktop application. The core modules are implemented as linked libraries.

VIII. The results of transformation experiments

The experiments have been some exceptions, but all diagram elements described in the article, have been successfully translated into ontology. It is worth noting that the developers rarely use a wide range of elements. Using UML in such a way leads to creation of sketches intended for understanding difficult situations in project functioning. The histogram in figure 3 represents the frequency distribution of the elements of the class diagram.

For testing implemented systems were selected for the class diagram of various projects of the Open Source GitHub. We were searched diagrams on the basis of the file expansion names. In this regard, we chosen development tools uml-diagrams supporting XMI export.

Table 1 contains a summary of the editors of uml-diagrams. Many editors do not implement export XMI at all, some supports outdated version of the format. Some editors allocates export to XML as a paid functionality. As a result, test a few editors were selected: Visual Paradigm, Enterprise Architech and Altova UModel.

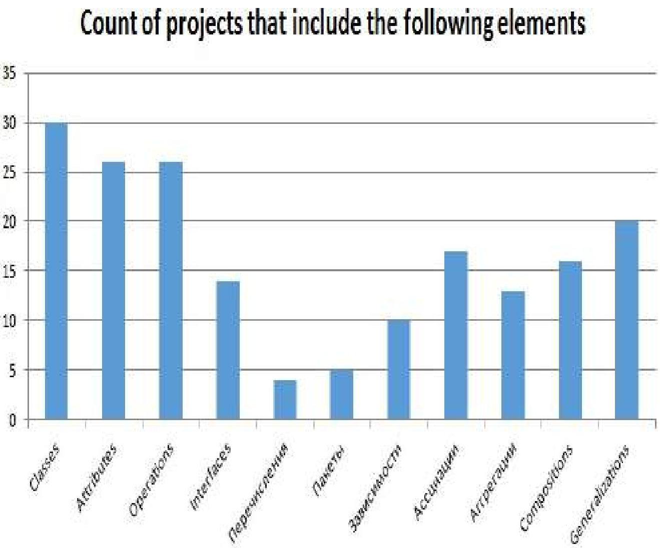

Figure 3. Histogram of the frequency of use of the elements

Table I. Results of testing by export UML diagram to XMI format

Editor	Version XMI	Export	Translation	Comment
ArgoUML	1.2	Success	Impossible	Outdated version XMI
Astah	1.1	Success	Impossible	Outdated version XMI
Altova UModel	2.1, 2.4.1	Success	Success	
Enterprise Architect	1.1, 2.1	Success	Success	
MagicDraw	2.1	Success	Impossible	Only in paid version
Innovator Enterprise	2.1	Success	Impossible	Only in paid version
modelio	1.1	Success	Impossible	
StarUML	1.1	Success	Impossible	
Visual Paradigm	2.1	Success	Success	

Figure 4 shows a histogram of the frequency distribution by use UML in projects. Classification of approaches to the use of UML borrowed from M. Fowler [8]. M.Fowler offers to share the use of UML on the way:

1) Sketches are local description of complex parts of the system. Sketches do not describe the global behavior of the system, the interaction of components at current moment;
2) Detailed description of the project represents the non-trivial part of the project taking into account all aspects, given the interaction of the system modules. Detailed description do not contain obvious part of the project,for example, the properties or fields are needed to implement the encapsulated class capabilities;
3) A visual programming language provides code generation designed by class diagram. Visual programming language suggests mandatory accounting of all aspects of the system, even the most obvious.

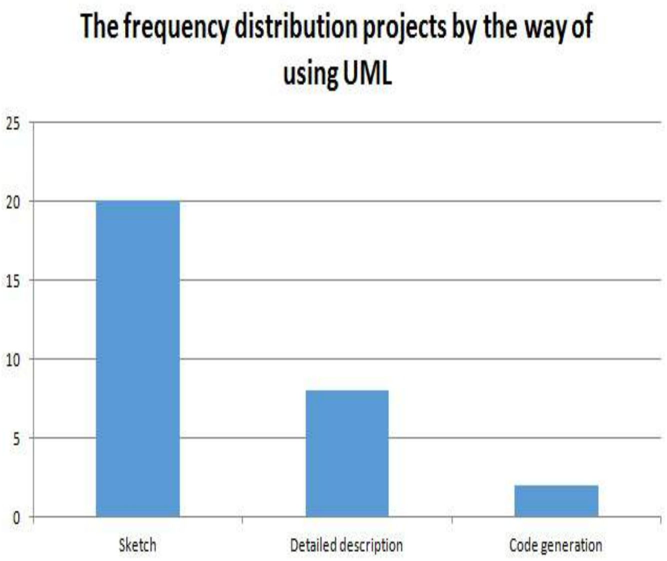

Figure 4. Histogram of the frequency distribution projects by the way of using UML

IX. Conclusion

This research modified and greatly expanded the concept of the system integration of conceptual models and ontologies. A new ontology structure consisting of two parts was developed.These parts are a presentation of a UML meta-model and domain ontology. Result of research reformulated conversion rules of uml class diagram elements and a special case of the conversion elements of the meta-model. We collected data allow to estimate way to use uml-diagrams.

Acknowledgment

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ИНТЕГРАЦИЯ ОНТОЛОГИЙ И КОНЦЕПТУАЛЬНЫХ МОДЕЛЕЙ ИС

Гуськов Г.Ю., Наместников А.М.

В статье предлагается методика интеграции концептуальных моделей и онтологии предметной области. Так же в статье рассмотрена система основанная на данной методике. Кроме того в статье приведены основной алгоритм системы интеграции и её поведение на диаграмме последовательностей. Проведён анализ подходов к использованию языка UML и частотности использования его элементов. Разработанная система позволяет интегрировать концептуальные модели в виде UML-диаграмм с онтологиями в формате OWL[15]. В завершении статьи представлены результаты работы системы над проектами из открытых репозиториев исходного кода и пути будущего развития системы.

The Fuzzy Ontology as a Core of the Knowledge Base for the Technical Electronic Archive

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***Abstract*—The article describes the structure of the ontology presented on the basis of the fuzzy extension of the description logic $\mathcal{SHOIN}(\mathcal{D})$. A set of metalevels of the ontology reflects the specificity of the domain – development of complex automated systems. The results of computational experiments are presented.**

***Keywords*—ontology, electronic archive, description logic, fuzzy sets, knowledge base.**

I. Introduction

Development of intelligent electronic archives of design organizations entails construction of knowledge bases that represent integral parts of any intelligent system. According to the up-to-date point of view on constructing intelligent information systems presented in [1],[2],[3], the ontology can be considered as a tool for expert knowledge representation. Nowadays, a wide range of languages for representing applied ontologies are known. Taking into account the W3C (The World Wide Web Consortium) support of the languages based on the OWL group on the level of standards, $\mathcal{SHOIN}(\mathcal{D})$ formalism will be used as a logic basis of the description language for the ontology of automated system (AS) designing information support [4]. The description logic $\mathcal{SHOIN}(\mathcal{D})$ has a lot of possibilities of representing the domain model. Nevertheless, in order to represent knowledge about semistructured information resources, it is not quite sufficient to use this formalism. The natural language features and incompleteness in description of classes, entities, and relationships between them in project diagrams require to use formalisms that are able to work with fuzzy and incomplete data. One of the extensions of $\mathcal{SHOIN}(\mathcal{D})$ is $fuzzy\mathcal{SHOIN}(\mathcal{D})$ formalism (see [5], [6]), combining linguistic possibilities of the basic description logics and advanced mathematical tools of the fuzzy set theory.

II. The Ontology Structure

The domain of complex ASs designing imposes requirements to the structure of an applied ontology [7] . The specificity of the structure and content of information resources of electronic archives and project activity taken as a whole brings about the necessity of constructing the ontology including the set of metalevels shown in Fig. 1.

Formally, the set of the electronic archive ontology components may be written as the following sequence:

$$O = \langle PL, DL, CL, AL, R, F \rangle,$$

where PL is a metalevel of projects including information about implementing projects i.e. the taxonomy of projects classes and instances including technical documents; DL is a metalevel of documents including the taxonomy of documents classes and instances; CL is a metalevel of concepts based on the taxonomy of concepts related to the domain of the design organization and implementing projects; such relationships as «hasAPart», «associatedWith» an others are additionally used; AL is an atomic metalevel including term atomic level (TAL), class atomic level (CAL), entity atomic level (EAL); R is a set of relationships between concepts and/or instances related to different metalevels of the ontology.

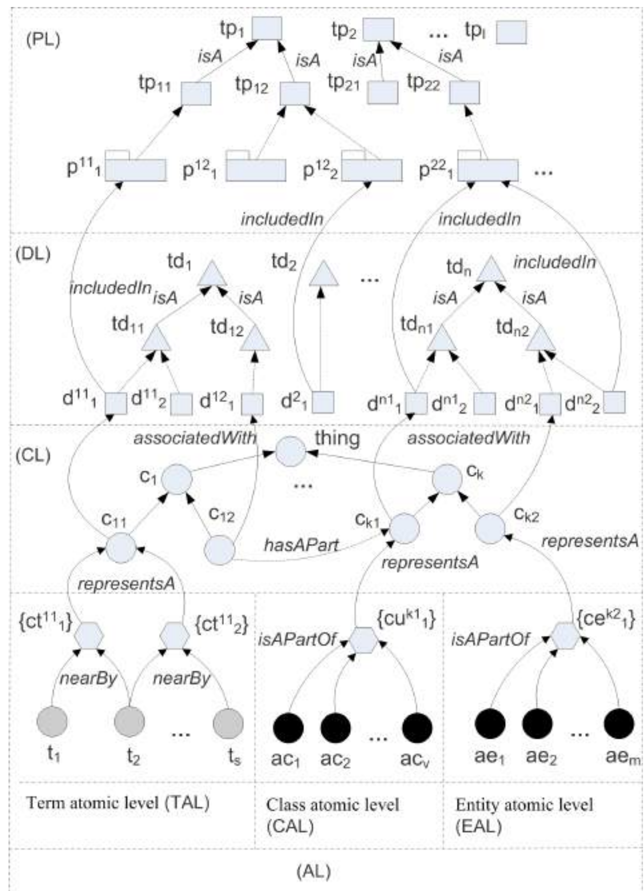

Figure 1. The structure of ontology for the electronic archive

Separation of the atomic metalevel into three ones $\{TAL, CAL, EAL\}$ (Fig. 1) means that in the procedures of conceptual design of AS, the intelligent analysis is carried out for the following electronic archive information resources: textual technical documents, class diagrams, fragments of program subsystems models and data models.

III. The Knowledge Base Description

In the context of the description logic $\mathcal{SHOIN}(\mathcal{D})$, an ontology represents the knowledge base defined by the following equation $\mathcal{KB} = \{TBox, ABox\}$,

where $TBox$ is a set of terminological axioms representing the common knowledge about the concepts of the design organization electronic archive and their relationships; $ABox$ is a set of statements (facts) about the individuals.

Taking into account the ontology structure, let us denote $TBox^{arch}$ as the terminology of the project archive, $TBox^{dom}$ as the terminogy of the design organization domain; $ABox^{arch}$, $ABox^{dom}$ as the corresponding sets of facts: $TBox = TBox^{arch} \cup TBox^{dom}$, $ABox = ABox^{arch} \cup ABox^{dom}$.

$TBox^{arch}$ (accordingly, $ABox^{arch}$) includes terminology (facts) of the metalevels of projects and the ontology documents (Fig. 1). The metalevel of concepts and atomic metalevel defines as $TBox^{dom}$ and $ABox^{dom}$.

Let us write the $TBox^{arch}$ terminology content based on the ontology structure (Fig. 1).

$\mathbf{TBox^{arch}}$ terminology:

$$
\begin{array}{ll}
tp_{11} \sqsubseteq tp_1 & tp_1 \sqsubseteq tp \\
tp_{12} \sqsubseteq tp_1 & tp_2 \sqsubseteq tp \\
tp_{21} \sqsubseteq tp_2 & \vdots \\
tp_{22} \sqsubseteq tp_2 & tp_l \sqsubseteq tp
\end{array}
$$

$$tp \equiv \top \sqcap \leq 1 hasATypePrjName.String,$$

here $hasATypePrjName$ is the name for the functional role «has a name of the project type», $String$ is a concrete domain of the string type.

The concept «Project» can be defined as

$$
\begin{array}{c}
P \equiv \top \sqcap \leq 1 hasAPrjName.String \sqcap \\
\sqcap \leq 1 hasADeveloperName.String \sqcap \\
\sqcap \exists hasAInitialDate.Date \sqcap \exists hasAType.tp,
\end{array}
$$

here $hasAPrjName$, $hasADeveloperName$, $hasAInitialDate$, $hasAType$ are the names for the corresponding roles «has a project name», «has a developer name», «has the initial date of the project», «has a type». $Date$ is the concrete domain of data type.

$$
\begin{array}{ll}
td_{11} \sqsubseteq td_1 & td_1 \sqsubseteq td \\
td_{12} \sqsubseteq td_1 & td_2 \sqsubseteq td \\
\vdots & \vdots \\
tp_{n1} \sqsubseteq td_n & td_n \sqsubseteq td \\
tp_{n2} \sqsubseteq td_n &
\end{array}
$$

$$td \equiv \top \sqcap \leq 1 hasADocTypeName.String,$$

here $hasADocTypeName$ is the name for the functional role «has the name of the document type».

The concept « Document » can be defined as

$$
\begin{array}{c}
D \equiv \top \sqcap \leq 1 hasADocDecimal.String \sqcap \\
\sqcap \exists hasAAuthor.String \sqcap \\
\sqcap \exists hasADate.Date \sqcap \\
\sqcap \exists hasAType.td \sqcap \forall includedIn.P,
\end{array}
$$

here $hasADocDecimal$, $hasAAuthor$, $hasADate$, $hasAType$, $includedIn$ are the names for the corresponding roles «has a decimal number», «has an author», «has a date», «has a type» and «included in».

The set of $\mathbf{ABox^{arch}}$ **facts:**

$$
\begin{array}{ll}
p_1^{11} : P & \langle p_1^{11}, tp_{11} \rangle : hasAType \\
p_1^{12} : P & \langle p_1^{12}, tp_{12} \rangle : hasAType \\
p_2^{12} : P & \langle p_2^{12}, tp_{12} \rangle : hasAType \\
p_1^{22} : P & \langle p_1^{22}, tp_{22} \rangle : hasAType \\
 & \\
d_1^{11} : D & \langle d_1^{11}, td_{11} \rangle : hasAType \\
 & \langle d_1^{11}, p_1^{11} \rangle : includedIn \\
\vdots & \vdots
\end{array}
$$

$\mathbf{TBox^{dom}}$ terminology:

In case of defining $TBox^{dom}$ terminology, the use of the concrete domain is not quite sufficient. The question at issue is defining the degree of expression of the ontology concepts (in the context of the metalevel of terms) in the documents of the design organization electronic archive. Each concept c_i can relate to any document fragment d_j with different membership degrees. For this purpose, fuzzy predicates with predefined membership functions are offered to use.

The trapezoidal and triangular functions, the L-functions and R-functions are not only computationally simple but most frequently used to specify membership functions of fuzzy variables. In this paper, the functions are defined on $[0, 1]$. The trapezoidal function $trz(x; a, b, c, d)$ is defined as follows: suppose $a < b \leq c < d$ d from the set of $[0, 1]$, then:

$$
trz(x; a, b, c, d) = \begin{cases}
0, & \text{if } x \leq a; \\
(x - a)/(b - a), & \text{if } x \in [a, b]; \\
1, & \text{if } x \in [b, c]; \\
(d - x)/(d - c), & \text{if } x \in [c, d]; \\
0, & \text{if } x \geq d.
\end{cases}
$$

The triangular function $tri(x; a, b, c)$ is defined as

$$
tri(x; a, b, c) = \begin{cases}
0, & \text{if } x \leq a; \\
(x - a)/(b - a), & \text{if } x \in [a, b]; \\
(c - x)/(c - b), & \text{if } x \in [b, c]; \\
0, & \text{if } x \geq c.
\end{cases}
$$

The *L-function* $L(x; a, b)$ is defined as

$$
L(x; a, b) = \begin{cases}
1, & \text{if } x \leq a; \\
(b - x)/(b - a), & \text{if } x \in [a, b]; \\
0, & \text{if } x \geq b.
\end{cases}
$$

Finally, the *R-function* $R(x; a, b)$ is defined as

$$
R(x; a, b) = \begin{cases}
0, & \text{if } x \leq a; \\
(x - a)/(b - a), & \text{if } x \in [a, b]; \\
1, & \text{if } x \geq b.
\end{cases}
$$

Let us write the terminology of the concept metalevel (the structure is shown in Fig. 1).

$$\begin{array}{ll} c_{11} \sqsubseteq c_1 & c_1 \sqsubseteq c \\ c_{12} \sqsubseteq c_1 \sqcap \exists hasAPart.c_{k1} & \vdots \\ c_{k1} \sqsubseteq c_k & c_k \sqsubseteq c \\ c_{k2} \sqsubseteq c_k & \end{array}$$

$$c \sqsubseteq \top \sqcap \forall associationWith.D \sqcap$$
$$\sqcap(\exists hasAExpValue.High \sqcup \exists hasAExpValue.Middle \sqcup$$
$$\sqcup \exists hasAExpValue.Low)$$

$$c^{exp} \sqsubseteq c \sqcap \exists hasAExpValue.High,$$

here $hasAPart$ is a name for the role «has a part», $hasAExpValue$ is a name for the role «has a value of a degree of expression». $High$, $Middle$ and Low are the fuzzy concrete predicates defined as

$$High, Middle, Low : [0,1] \to [0,1].$$

The individual concept c^{exp} represents the ontology concept with high degree of expression in any document.

The parametrically fuzzy predicates are defined as follows:

$$\begin{array}{rcl} Low(x) & = & L(x; 0.2, 0.4); \\ Middle(x) & = & trz(x; 0.2, 0.4, 0.6, 0.8); \\ High(x) & = & R(x; 0.6, 0.8). \end{array}$$

Let us define the $TBox^{dom}$ terminology related to the atomic metalevel and associated with the terminology of concept metalevel terminology as follows:

$$\begin{array}{c} \{ct_1^{11}\} \equiv \top \sqcap \leq 1 representsA.c_{11} \\ \{ct_2^{11}\} \equiv \top \sqcap \leq 1 representsA.c_{11} \\ \{cu_1^{k1}\} \equiv \top \sqcap \leq 1 representsA.c_{k1} \\ \{ce_1^{k2}\} \equiv \top \sqcap \leq 1 representsA.c_{k2} \\ T \equiv \top \sqcap (\exists nearBy.\{ct_1^{11}\} \sqcup \exists nearBy.\{ct_2^{11}\}) \\ \{cu_1^{k1}\} \equiv \top \sqcap \leq 1 representsA.c_{k1} \\ AC \equiv \top \sqcap \exists isAPartOf.\{cu_1^{k1}\} \\ \{ce_1^{k2}\} \equiv \top \sqcap \leq 1 representsA.c_{k2} \\ AE \equiv \top \sqcap \exists isAPartOf.\{ce_1^{k2}\} \end{array}$$

The set of $\mathbf{ABox^{dom}}$ **facts:**

$$\begin{array}{ll} ct_1^{11} : \{ct_1^{11}\} & \langle t_1, ct_1^{11} \rangle : nearBy \\ ct_2^{11} : \{ct_2^{11}\} & \langle t_2, ct_1^{11} \rangle : nearBy \\ cu_1^{k1} : \{cu_1^{k1}\} & \langle t_2, ct_2^{11} \rangle : nearBy \\ ce_1^{k2} : \{ce_1^{k2}\} & \langle t_s, ct_2^{11} \rangle : nearBy \\ t_1 : T & \langle ac_1, cu_1^{k1} \rangle : isAPartOf \\ t_2 : T & \vdots \\ \vdots & ct_1^{11} : c^{exp} \geq 0.75 \\ ae_m : AE & ct_2^{11} : c^{exp} \geq 0.6 \\ & cu_1^{k1} : c^{exp} \geq 0.8 \\ & ce_1^{k2} : c^{exp} \geq 0.7 \end{array}$$

The facts as $a : C \geq \eta$ mean that the instance a pertains to the concept C with the membership degree not lower than threshold η.

IV. The Conceptual Index of the Electronic Archive

Suppose $C = \{c_i\}$, $i \in I = \{1, 2, 3, ..., n\}$ is a finite set of the domain concepts fixed in the ontology; $D = \{\tilde{d}_j\}$, $j \in J = \{1, 2, 3, ..., m\}$ is a family of fuzzy subsets in C. The pair $\widetilde{CI} = (C, D)$ is called a fuzzy nonoriented hypergraph if $\tilde{d}_j \neq \emptyset, j \in J$ and $\bigcup_{j \in J} \tilde{d}_j = C$; herewith, $c_1, c_2, ..., c_n \in C$ are the graph vertices and a set D containing $\tilde{d}_1, \tilde{d}_2, ..., \tilde{d}_m$, is a set of fuzzy edges of the hypergraph.

Taking into account that an individual document has its ontological mapping as a result of conceptual indexing, a set $D = \{\tilde{d}_j\}$ can be defined as a set of documents in the conceptual index, $\tilde{d}_j$ is an individual ontological representation of the j-th document. We get that the fuzzy ontology hypergraph

$$\widetilde{CI} = (C, D) \tag{1}$$

formally defines the conceptual index of the document base.

The two concepts c_α and c_β (hypergraph vertices) of the conceptual index are fuzzy adjacent if a document (fuzzy hypergraph edge) exists and the document includes both notions where a degree of adjacency for the c_α and c_β concepts can be defined as follows:

$$\mu(c_\alpha, c_\beta) = \bigvee_{d_i \in D} \mu_j(c_\alpha, c_\beta), \text{ where} \tag{2}$$

$$\mu_j(c_\alpha, c_\beta) = \mu_{d_j}(c_\alpha) \& \mu_{d_j}(c_\beta).$$

The value $1 - \mu(c_\alpha, c_\beta)$ represents the distance between the c_α and c_β concepts on the basis of the document content.

The index can be used for specifying the user's project query to the archive of documents in case when the concept of user's interest exists in the query but the result are leaved to be desired. In order to specify the query, the text input of the concept that has the shortest distance to the initial one is used.

Two documents $\tilde{d}_\gamma$ and $\tilde{d}_\delta$ are fuzzy adjacent if $\tilde{d}_\gamma \cap \tilde{d}_\delta \neq \emptyset$, moreover,

$$\mu(\tilde{d}_\gamma, \tilde{d}_\delta) = \bigvee_{c \in (d_\gamma \cap d_\delta)} \mu_{d_\gamma \cap d_\delta}(c) \tag{3}$$

is a degree of adjacency between $\tilde{d}_\gamma$ and $\tilde{d}_\delta$. The value $1 - \mu(\tilde{d}_\gamma, \tilde{d}_\delta)$ describes the distance between documents in the information base on the basis of documents content and the electronic archive ontology. The value can be used in fuzzy clustering in the information base content, i.e. in tasks where the distance between the cluster centre (a hypothetical document, for example) and analysed documents is of paramount importance for the target function.

V. Computational experiments

In case of analysis of the computational experiments results on the basis of the documentation of FRPC JSC 'RPA 'Mars' electronic archive, the domain-specific ontology was used.

The domain-specific ontology consists of 300 concepts. They include 219 concepts from standards used at the enterprise and 81 concepts and 10078 unique terms from realized projects.

The expert of FRPC JSC 'RPA 'Mars' prepared the selection involving 5017 technical documents. The selection is grouped into three main sections:

- the section based on the documentation class that consists of 34 groups;
- the section based on work sectors that consists of 28 groups (products discussed in documents);
- the section based on the documentation type that consists of 52 groups (GOST 2.601, 2.602, 2.102, 2.701, 3.1201).

In order to perform the experiment of quality evaluation of structuring FRPC JSC 'RPA 'Mars' electronic archive documentation, the index containing both ontological and traditional representations of technical documents (set of «term-frequency» pairs) was used. Further, the indices were structured with the use of different variants and subsequent quality evaluation according to the following list:

- structuring the traditional representations of technical documents with the use of Oracle Text tools;
- structuring the traditional representations of technical documents with the use of the modified FCM-algorithm of clustering;
- structuring the ontological representations of technical documents with the use of the modified FCM-algorithm of clustering;

Figure 2. Quality evaluation of FRPC JSC 'RPA 'Mars' electronic archive documentation structuring

As indicated by Fig. 2, the most appropriate values of the evaluation function for ontological results were obtained in case of structuring the technical documentation selection in work sectors as it performs structuring in individual documents content. In case of structuring according to the document type, Oracle Text outperforms the others. The algorithm works well in case of structuring in accordance with the document type when Oracle Text gives the best results. The modified FCM-algorithm of clustering ontological representations of technical documents provides structuring of highest quality in accordance with work sectors regarding to the content.

VI. Conclusion

The computational experiments show that the results of structuring the ontological representations of technical documents is 40% better than results structuring with the use of Oracle Text. The time spending on indexing and structuring processes of technical documentation ontological representations is, on the average, 7% less than the total time spending on indexing and structuring processes of technical documentation traditional representations. The ontological approach to indexing and structuring technical documentation makes possible structuring the electronic archive for less time.

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НЕЧЕТКАЯ ОНТОЛОГИЯ КАК ЯДРО БАЗЫ ЗНАНИЙ ДЛЯ ТЕХНИЧЕСКОГО ЭЛЕКТРОННОГО АРХИВА

Наместников А.М.

В статье приводится структура онтологии на основе нечеткого расширения дескрипционной логики SHOIN(D). Множество метауровней онтологии отражает специфику предметной области разработки сложных автоматизированных систем. В работе определены основные логические аксиомы, на основе которых выполняется логический вывод.

Development and Study of a Combined Algorithm for Temporal Series Clustering

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Abstract—**This paper offers a combined algorithm for temporal series clustering based on the primary clustering of the points of each temporal series, and then on the secondary clustering of a set of temporal series by a set of parameters that are statistical characteristics of the primary clusters.**

The paper describes the experiments to reveal the minimum set of parameters for the temporal series clustering, and compares the results of the algorithm operation for various methods of clustering.

The proposed algorithm allows the clustering of temporal series with various numbers of points, with various time scales; it unites into one cluster the temporal series with a consistent similarity of parts of the graphs with the accuracy up to their contraction, extension, shift along the OX and OY axes, and symmetries.

Keywords—clustering, temporal series, parametric clustering, centroid method, Ward's method, single linkage method.

I. Introduction

The study of time series, their semantics , extract knowledge is interest because time series have many applications in various fields of science and technic, economy, medicine, etc. Often study of data sets are using as unlabeled time series. A common task is defining groups of homogeneous time series. The results of analysis can be used to monitor multiple processes in different time periods.

The time series clustering increased interest in order to analyze data dynamics. Works about dynamic clustering (clustering of time series) is more less than – static clustering. However, the interest in this topic grows.

Initially, cluster analysis was developed as methods designed to work with static data, for which values remain constant over time or change slightly. The target of cluster analysis is identification of structure in studied data set by organizing homogeneous groups for which intergroup differences and intragroup similarities are minimal. Clustering is useful when data sets is not structured and belong to one of the following types: binary, numeric, interval, ordinal, relational, textual, spatial, temporal, spatio-temporal, image, multimedia or their combination.

Modern software is using for on clustering static data. The software exists in form of application programs or as part of software packages for data processing or data mining.

II. An overview of the approaches clustering time series

The clustering methods are the divisive clustering, agglomerative clustering, density based clustering, mesh methods, and model methods [1]. The paper [2] gives the description of each clustering method category. The following clustering methods are frequently used: single-linkage clustering [3], average linkage clustering [14], complete-linkage clustering [5], Ward's method [6], centroid linkage clustering [7], [8], [9], [10], K-mean clustering [11], [12], and others.

The hierarchical methods of clear clustering have a weak point which is the correction of elements belonging to the clusters after the clusters are formed. The papers by Karypis, Han, Kumar [13] and Guha, Rastogi, Shim [14] show the linkage analysis at each phase of the hierarchical splits. The paper by Zhang, Ramakrishnan, and Livny [15] uses the iteration permutation to specify the results obtained using the hierarchical agglomerative clustering more correctly.

In the clear clustering algorithms, each object belongs to one cluster; in the fuzzy clustering algorithms, each object belongs to several clusters. FCM is the fuzzy clustering method [16] used together with one of the clear clustering algorithms, the choice of which determines the result. In papers [17], [18], the fuzzy C-method is described. This is a heuristic algorithm successfully used for finding spherical clusters on small and medium data arrays.

The data extraction from temporal series using the cluster analysis methods attracts heightened interest. More often, the temporal series clustering also known as dynamic clustering is discussed for the dynamic data analysis. At the temporal series clustering, some measure of similarity, based on the representation of the temporal series in the form of a model or a set of parameters, is required. The existing dynamic series clustering methods can be classified by the manner the input data is treated: directly – with input data, frequency-temporal characteristics, area data, models or functions obtained from the input data.

The dynamic clustering conditionally includes two stages: obtaining the set of parameters by which clustering is to be performed; selection of the static clustering method and its application. Obtaining the set of parameters, and their application are the subject of today's intense study and discussions. At that, the issues of choosing the adequate set of parameters, the choice of the static clustering method responsible for the problem setting, the assessment of the clustering results compliance with the problem setting and the objectives of the study still remain open.

Static clustering methods are used at the temporal series clustering. Special literature concerning this topic shows the interest to the following methods:

- The density based clustering (the paper [19] develops the idea of "a cluster as the density that does not exceed some schedule in a certain area").

- The methods based on the quantum mesh with a finite number of cells on which clustering is performed. The typical example of such method is given in paper [20]. It uses several levels of rectangular cells that correspond to different levels of resolution. Statistical information is calculated. According to the attributes in each cell, the mesh cells parameters are considered starting from the largest allowable scale. For each cell in the current layer, the confidence interval reflecting the correspondence of the cell to the given (current) request is calculated. The cells that do not agree with the request are removed from the consideration. The request process continues on the next level – the lower one – for the selected cells, until the lower level is reached.

- The model based methods that compare a model with each cluster. At that, the set of models is compared with the data array. Both can be primary. At present, static and neural network approaches to the model description are offered. An example of the static data description approach is given in the paper [21], where the Bayesian static analysis for the evaluation of the cluster number. Examples of the neural network approach are given in [22], [23].

III. Problem setting

We have conducted a series of experiments for the study of temporal series clustering where the lists of standard parameters of cluster statistical description obtained by separate clustering of each temporal series were used as the data for clustering.

The task was the obtaining of visually similar temporal series clusters with the accuracy up to the normalization along the OX and OY axes.

The objectives were: the development and testing of the algorithm of combined temporal series clustering; the study of the set of parameters (compliance of the selection to the set task, minimization of their number); the study of the static clustering method applicability in the proposed algorithm.

The outcome of the experiment was the obtaining, basing on the statistics and cluster analysis methods, of a minimum set of parameters that characterizes the temporal series. This set is used for the temporal series reclustering.

Input data description. 72 temporal series are used as the input data. The temporal series belong to different types, i.e. they have different numbers of points, global tendencies, spans of values, etc. For each separate series, the coordinates of the points were normalized.

IV. Description of the proposed algorithm

We are going to cluster a temporal series into N1 clusters; at the clustering, the data is normalized along the reference axis. For each cluster, we get an ordered set of values. The studied parameters were the dispersion, maximum, minimum, span and arithmetic mean value for the X and Y coordinates and the temporal series points. We sort the clusters in the chronological order concerning the clusters center X coordinate. In this order, we write down the parameters that characterize the first cluster, the second one, ... the N1 cluster. For each temporal series, we get a list of parameters of dimensionality which is the product of the number of studied parameters multiplied by the number of N1 clusters. We form the lists of parameters obtained using the above described method for each studied temporal series. These lists are used for the clustering into N2 clusters.

The algorithm uses the clustering procedure twice. First, we perform the points clustering for each temporal series. Second, we perform clustering of the set of temporal sequences by the parameters that are the temporal series. It is appropriate to minimize the set of parameters due to the exclusion of the mutually depending quantities. At that, the results of the second clustering remain almost unchanged. The experiments have shown that the temporal series clustering results utterly do not change if we go from the set of parameters {X dispersion, X maximum, X minimum, X span, X arithmetic mean value, Y dispersion, Y maximum, Y minimum, Y span, Y arithmetic mean value} to the set {X dispersion, X arithmetic mean value, Y dispersion, Y arithmetic mean value} for each cluster after primary clustering.

V. Experimental study of the proposed algorithm

We have conducted a series of experiments for the above described algorithm using the following clustering methods: centroid linkage clustering, Ward's method, single linkage method. 72 temporal series were clustered into N2=10,20,30,40,50 clusters; at that, the clustering into N1=2,3,4,5,6,7,8,9 clusters was applied for obtaining the list of parameters. All in all, we conducted a series of 120 experiments. We wrote a program in the C# programming language for automated experiment conduction.

During the automated experiment, each temporal series was normalized (the normalization was made over the OX and OY axes); the results for each cluster were recorded in a png. file in the normalized form.

By setting N1, we specify the number of clusters into which each temporal series is to be clustered, i.e. what number of multi-dimensional points with the coordinates {X dispersion, X maximum, X minimum, X span, X arithmetic mean value, Y dispersion, Y maximum, Y minimum, Y span, Y arithmetic mean value] to the set {X dispersion, X arithmetic mean value, Y dispersion, Y arithmetic mean value] we were going to use to represent the temporal sequence. We have the possibility to compare the temporal series over these multi-dimensional points. When N1=2, the series were compared over two points. This was a too rough comparison. When N1=9, we obtained an exceedingly sensitive tool of comparison requiring a high degree of conversion for the temporal series; at that, each sequence was found in a separate cluster. We have discovered experimentally that the values close to 6 were the most appropriate ones.

By using in turn N2 = 10,20,. . . ,50, we could follow the clustering progress for all temporal series. The obtained clusters can be conditionally split into 3 groups by the degree of similarity: groups of series similar by behaviour (see Fig. 1) – "strongly similar"; groups of series with relative similarity (see Fig. 2) – "moderately similar"; and the clusters that include one or, less frequently, two temporal series – "solitary" without similar ones (see Fig. 3). Let us mention that the source temporal series had absolutely different areas of determinations and values and sometimes differed by 5-6 orders.

In the case of N2=10, a significant part of the temporal series got into the second group. As N2 was increased from 10 to 50, we observed the growth of the number of clusters belonging to the first group. For all values of N2, about a half of the clusters were referred to the third group.

We discovered that the most successful clustering turned out to be that with N2=20 and 50. At N2=50, we can observe the initial stages of the agglomerative clustering when the "strongly similar" temporal clusters are grouped. At N2=20, for this set of temporal series, we managed to obtain the most informative and expressive clustering results.

We have discovered that the result of the algorithm operation depends on the chosen clustering methods.

The centroid method showed the best results out of the used methods (see Fig. 1). The experimental results provided the separation of the temporal series into three above mentioned groups of clusters, at that the separation turned out to be quite sharp. The presence of one or two multi-component clusters and big amounts of fringe clusters is characteristic for the method. For the centroid method, in the series of conducted experiments the discard of the major part of the temporal series for which no similar series were found, into solitary clusters was characteristic (see Fig. 3).

At the comparison of temporal series, the issue is the identification of the different-length areas where the graphs are similar with the accuracy up to the graph contraction or extension along the OX and OY axes with the accuracy up to the shifts and symmetry. The paper [24] is devoted to this issue. Here the issue of identification of the graph areas similar with the accuracy up to contractions, extensions and shifts is solved automatically, as the secondary parameters at the reclustering are also subject to normalization. For each temporal series, the OX axis is split into various-length sections D1, D2, ..., DN1. For all series the parameters associated with the sections D1, D2, ..., DN1, respectively, are compared. They undergo normalization at the parameters reclustering (i.e. the contraction or extension along the OX and OY axes is performed separately for all series in the D1 sections, then in the D2 sections, etc.). Thus, the proposed algorithm is sensitive to the presence, in all compared series, of sequential sections of graphs similar to the accuracy up to contraction, extension and shifts along the OX and OY axes.

The same effect is observed at the use of the single linkage method (see Fig. 4). The single linkage method has shown itself quite well: quite similar series are separated (see Fig.4

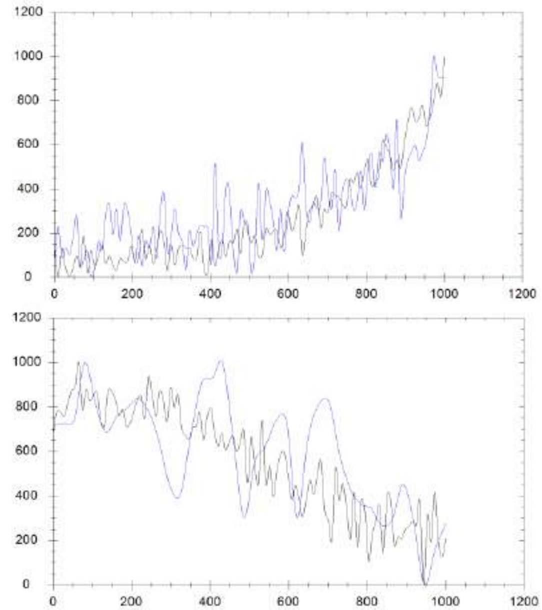

Figure 1. N1=6, N2=20, centroid method, "strongly similar".

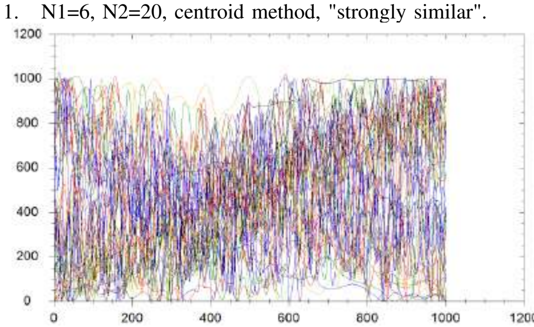

Figure 2. N1=6, N2=20, centroid method, "moderately similar".

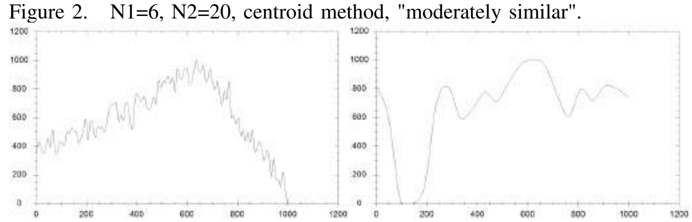

Figure 3. N1=6, N2=20, centroid method, "weakly similar".

). This algorithm is able to group the temporal series similar to the accuracy up to the symmetries of separate sections (see Figs. 5-6).

Ward's method is based on the aggregate dispersion minimization. The results of the algorithm application with the use of the Ward's method are given in Figs. 7-9; no pure visual similarity is observed there. This means that this method meets the set task least of all the used methods.

A particular case of the combined temporal series clustering algorithm is the clustering at N1=1 or one-stage clustering. A set of statistical parameters is imposed to correspond to each temporal series; these sets are used for clustering all temporal series. The series are compared "over one point". The combined temporal series clustering provides better result, since it allows comparison over N1 point. The results at N1=6 and N1=1 are shown in Figs. 1-3 and 10-11, respectively.

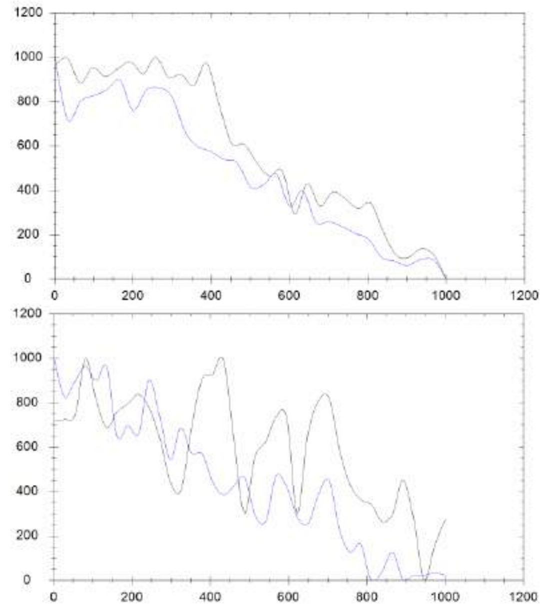

Figure 4. N1=6, N2=20, single linkage method, "strongly similar".

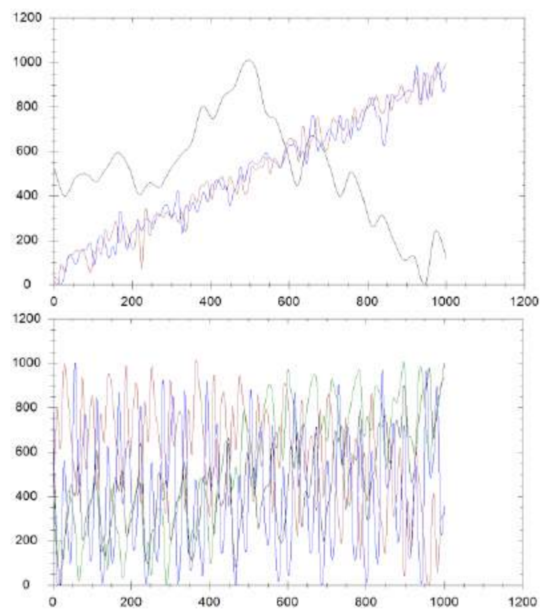

Figure 5. N1=6, N2=20, single linkage method, "moderately similar".

In practice, the clustering with initially set centers, e.g. using the K-mean method, can be helpful. One and the same cluster analysis method shall not be obligatorily used both for obtaining the temporal series parameters and for clustering over these parameters. The clustering methods can be combined.

Fuzzy clustering methods can be used in this algorithm, but with account for their application specifics. Our team develops such algorithm modifications, but they go beyond the scope of this paper.

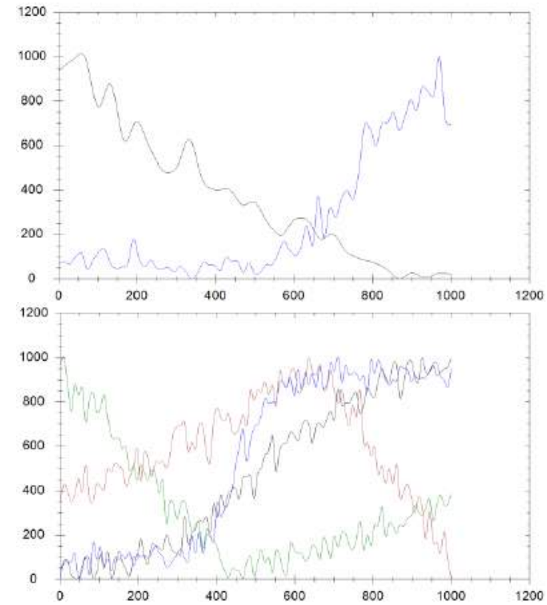

Figure 6. N1=6, N2=20, single linkage method, "weakly similar".

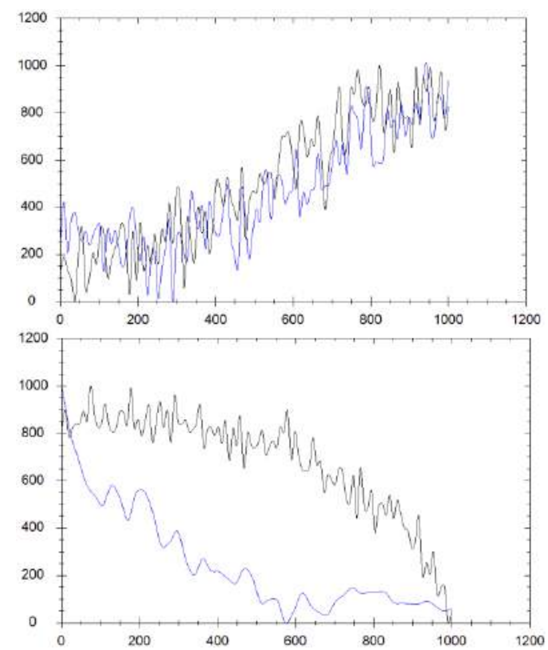

Figure 7. N1=6, N2=20, Ward's method, "strongly similar".

VI. Conclusions

The proposed algorithm can be applied for temporal series clustering for the purposes of identification of series with visually similar behaviours with the normalization accuracy along the OX and OY axes.

The developed temporal series clustering program has shown its performance and allowed us to conduct a series of 120 experiments in an automated manner within rather short time.

The algorithm is applicable for the comparison of various-length temporal series. Other activities, for the purposes of

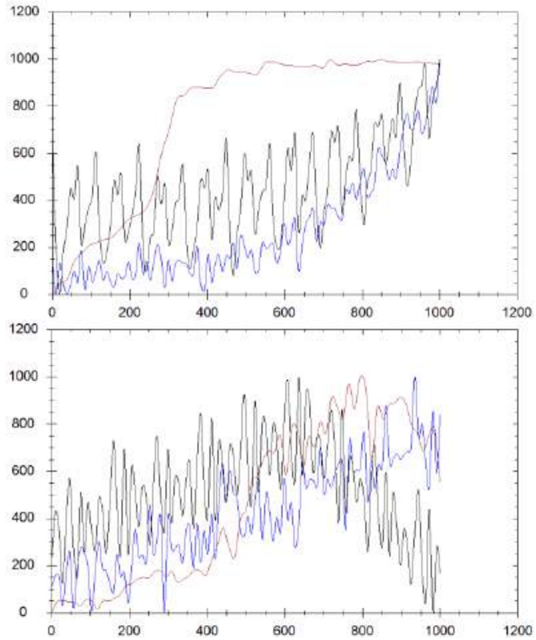

Figure 8. N1=6, N2=20, Ward's method, "moderately similar".

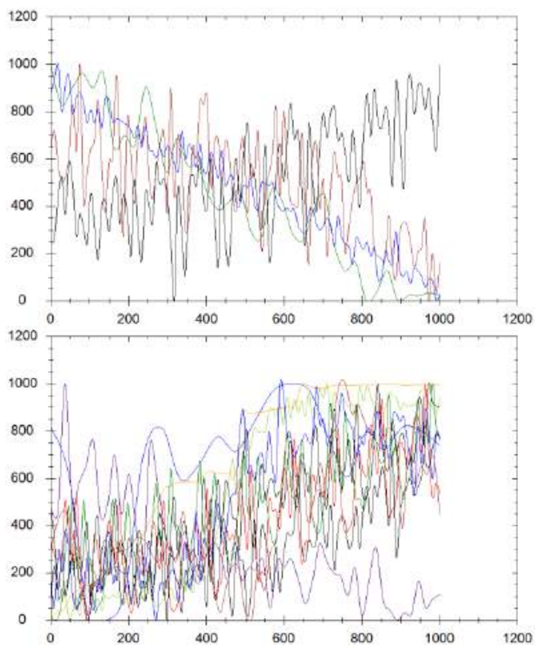

Figure 9. N1=6, N2=20, Ward's method, "weakly similar".

temporal series comparison, use artificial methods (arithmetic, statistical, reduction) for bringing the temporal series to one number of studied points. When our algorithm is used, there is no need to do this.

The algorithm compares the series with different temporal scales.

The proposed algorithm is sensitive to the presence, in all compared series, of sequential sections of graphs similar to the accuracy up to contraction, extension and shifts along the OX and OY axes. The issues of temporal series splitting into various-length homogeneous sections, the issues of contraction

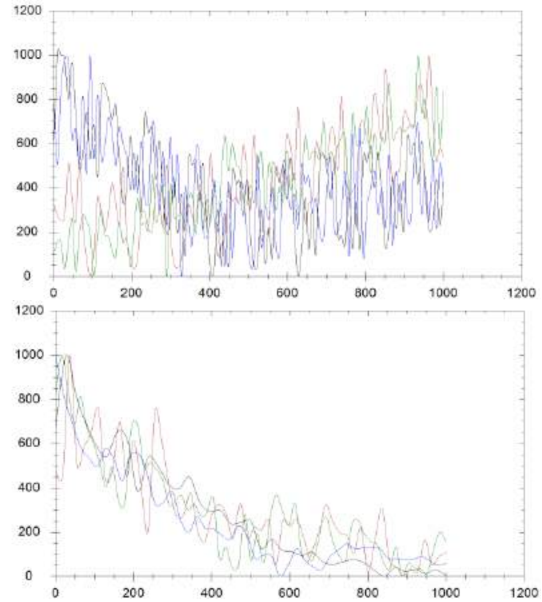

Figure 10. N1=1, N2=20, centroid method, "strongly similar".

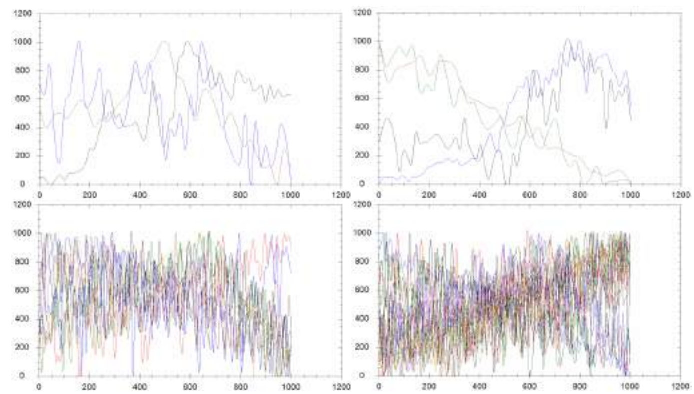

Figure 11. N1=1, N2=20, centroid method, "moderately similar".

and extension of these sections are solved on the level of normalization during cluster analysis in automated manner. The use of single linkage method in the algorithm as the clustering method allows the identification of the series similar to each other with the accuracy up to the symmetry of separate sections of graphs.

In our algorithm, different clustering methods can be used depending on the study objective and traditions of the field. Clustering is used twice (for the points of each temporal series and for the sets of parameters corresponding different temporal series). Different clustering methods can be combined.

At the comparison of experimental results, when different clustering methods were used, the centroid method showed itself quite well. At the reclustering, the single linkage method provides clusters with approximately similar order with quite similar temporal series as the components. The single linkage method identifies the temporal series similar to each other with the accuracy up to the symmetry of separate sections of graphs; with some modification the separation of graphs with symmetrical areas into one cluster can be eliminated. Ward's method in this algorithm showed unsatisfactory results.

Temporal series are clustered by a set of parameters which are the statistical characteristics of the primary clustering clusters for each temporal series. Our experiments have shown that the reduction of the number of parameters down to {X dispersion, X arithmetic mean value, Y dispersion, Y arithmetic mean value} for each primary clustering cluster utterly does not change the clustering results.

We have obtained a temporal series clustering algorithm with a high degree of modularity. By selecting the problem-oriented sets of mutually independent parameters of primary clustering of each temporal series, using classical clustering methods or those specially developed for applied problem we can gain the temporal series clustering for a given problem.

We are working on the fuzzy modification of this algorithm; we study its properties and application to gain knowledge on the sets of temporal series.

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РАЗРАБОТКА И ИССЛЕДОВАНИЕ КОМБИНИРОВАННОГО АЛГОРИТМА КЛАСТЕРИЗАЦИИ ВРЕМЕННЫХ РЯДОВ

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В данной работе предложен комбинированный алгоритм кластеризации временных рядов, основанный на первичной кластеризации точек каждого временного ряда, затем – на вторичной кластеризации множества временных рядов по набору параметров, являющихся статистическими характеристиками первичных кластеров.

Описаны эксперименты по выявлению минимального набора параметров для кластеризации временных рядов, сравниваются результаты работы алгоритма для разных методов кластеризации. Предлагаемый алгоритм позволяет кластеризовать временные ряды с разным количеством точек, разных временных масштабов, объединяет в один кластер временные ряды с последовательным сходством участков графиков с точностью до их сжатия, растяжения, сдвигов вдоль осей OX и OY и симметрий. Написанная нами программа позволила автоматически произвести 120 серий эксперимента в сравнительно короткие сроки. В качестве входных данных используется набор из 72 разнотипных временных рядов.

The Use of Ontological Knowledge for Semantic Search of Complex Information Objects

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***Abstract*—The problems deal with information retrieval by the Web intelligence applications are analyzed. The ontological analysis is used as a basis for knowledge representation in the semantic search. An ontological model of the interaction between the open information environment, intelligent information system and its users is proposed. A method of acquisition of knowledge about the complex information objects which structure is also formalized by ontologies is represented and described on example of competence analysis tasks.**

Keywords—semantic search; ontological model; information object; knowledge

I. Introduction

A large part of modern information systems is more or less intelligent: they focus on the use and processing of knowledge about the subject domain that is interesting for user. Most of these systems are designed to operate in the open information environment; in particular, they use the search of the actual and pertinent information to achieve the goals of the user. The object of such search may be not only data, but also programs, services, knowledge, and other complex structured information entities.

The rapid increase of the amount of the Web information resources (IR) as well as the complication of their structure predetermine the need of the automated and intelligent means of information retrieval. Models and methods of the semantic search allow the use of knowledge about users, information resources and objects that should be obtained from external sources and the experience of performing the search process.

Personification of semantic search which is based on the use of knowledge about particular users and their spheres of interests (subject domains), their current information needs, the ability to perceive information and experience allows to retrieve information more efficiently.

II. Problem Statement

Development of the ontological model that formalizes the information relations between the open information environment, intelligent information system (IIS) and its users, is an actual scientific and applied problem which solution requires the development of knowledge representation of the search domain, its objects and subjects, construction of methods either for obtaining this knowledge from the variety of information sources or for use of this knowledge to improve the efficiency of the IIS work.

This model allows to describe formally the information objects (IOs) which are processed in the IIS, their structure and properties, and to develop the methods and tools for use and obtaining information about these IOs.

III. Features of Semantic Search

In the most general sense an information search is a matching of the user conceptions about relevant knowledge with the content of available IR and constructing of IO (or a set of IO) on the basis of such comparison where the values of IO property are acquired from these IR.

Semantic search uses in this matching various knowledge about it's subjects (users, resources, results of previously performed search procedures), as well as knowledge about the search domain. If ontology is used for formalization of such knowledge then we propose the ontological model of search.

Semantic search is a process of information retrieval which meets the user information needs arising from during the process of solving a particular problem if the knowledge about different subjects and objects of the search procedure is applied (explicitly or implicitly to user) and methods of analysis of this knowledge [1].

This knowledge can deal both to the user and his information needs (the personification of the search), and IRs among which the search procedure is executed (e.g., the Internet of Things or the Web of Things, GRID environment) [2], or IOs which results the search (e.g., search of Web-services or ontology).

Semantic Search System (SSS) is an information system that provides search and recognition of different types of IO and uses knowledge to match the request with the existing IRs on the semantic level. SSS can be considered as an intelligent superstructure over the traditional information retrieval systems [3, 4]. Modern SSS acquired knowledge dynamically from the open environment [5-7].

IV. Personification of the IO Semantic Search

Semantic search, in contrast to the usual one, allows user to specify the desired search object. SSS can find not any particular IR (document or some fragment of document) but an information about IO of the certain class that user can (explicitly or implicitly) specify. It can be quite simple and common class, for example, "human" of "multimedia object", or specific class of some domain such as "scientific publication", "abstract". The user can explicitly specify the desired IO type by use of the relevant standards and taxonomies, for example, for retrieval from the ontology repositories or Web-based services [8], RDF descriptions [9] and XML structures [9].

IO can be considered as an information model of domain object which defines it's structure, attributes, integrity constraints, etc. From the viewpoint of the semantic search IO is the information that the user receives as a result of the search

V. Ontologies and Semantic Search

SSS user can describe IOs by use of appropriate ontology [11, 12]: the ontology class can be used as the basis for presenting the structure of IO, and instances of this class can be formed by information from IRs. Examples of IO are organizations, educational institutions, humans, Web-services etc.

User can choose IO ontology from any open repository or create it himself with the help of some appropriate methodology and software tools [13, 14].

User has to:

- Understand what type of IO (or the set of IO types) is interested for him from the viewpoint of current problem;
- Find an ontology which classes represent the structure of the required IOs;
- Identify the set of IRs that contains information about the values of the IO properties (for example, by the request to the external retrieval system).

SSS provides to user:

- Extraction of knowledge about these properties of the selected IO from the selected IR;
- Acquisition of desired knowledge in a form understandable and convenient for user.

VI. Classification of IOs and Retrieval Situations Associated with them

Solving of the semantic search tasks associated with the recognition of the complex IO set causes a number of problems that need in special term definitions, in particular, to state which information deal with the search result and which one – with it's conditions.

In the simplest version of the information search the search engine receives input as a set of keywords and provides the output as a set of links to the documents.

Search problem becomes much more difficult if it's the input data is a description of a complex problem with the interaction of complex structured IO and output is a reference to the IO instances that satisfy the complex set of conditions.

IO ontology O_{IO} is an ontological structure that contains the IO class $t_{IO} \in T_{IO}$ and its subclasses that describe different subsets of IO, and the classes T_{Prop} that are used for describing of IO properties:

$$O_{IO} = \langle T_{IO} \cup T_{Prop}, R, A \rangle .$$

User can describe the IO of his interests by referring to the class of any formally described ontology. Thus, IO is the class of IO ontology which has a set of characteristics that describe its structure and possible links with other classes and class instances.

IO instance is an instance of IO subclass of corresponding ontology which can be clearly identified and that has a proper name.

Situation is a non-empty set of IO instances of one or different classes, such that every IO of this set has a link with at least one other IO from this set. If situation uses IO described with use of different ontologies then it is necessary (explicitly or by means of the automated comparison of ontologies) to establish links between these ontologies (or at least between those IO and the classes that describe the properties of IO appeared in the situation).

Situation scheme is a situation that is not used IO individuals but only IO classes. We can consider situation schema as a search query and the set of satisfying situations as its result.

Invalid situation scheme is a situation schema which the conditions can not be satisfied by any set of IO individuals.

The scheme is *invalid* if it contains inconsistent conditions: $f_0(a_1,...,a_n), f_1(a_1,...,a_n),...,f_m(a_1,...,a_n), a_i \in t_i \subseteq T_{IO}$

and a logical conclusion of some subset of them $f_1(a_1,...,a_n),...,f_m(a_1,...,a_n), a_i \in t_i \subseteq T_{IO}$ is a $\neg f_0(a_1,...,a_n)$.

Unique situation is a situation which conditions are satisfied only by the single set of the IO individuals. An example of such a situation is a search of book by it's ISBN.

Concretized situation is a situation which description contains at least one IO instance. An example of such situation is a request about organizations where persons living in the same house with a person X with identification number work.

Personal situation is a situation that uses an instance of class "user" of semantic search ontology that characterizes the SSS user, i.e. the person who determines the situation. This variant of the search problem is quite common if the user is trying to find some information deal with himself – for example, links to his own publications, the possibility of his employment in a particular organization, the rating of his specialty etc.

Each personal situation is concretized through the use of specific instance of class "user", but the use of personal situations allows the development of the typical queries where a certain piece of information is not entered manually by the user but is imported from his profile.

For example, instead of the query "all references from the author's A publications to the publications of the author B " user can call much simpler query "all references to my publications from author's A publications" for which the list of "My Content" that can be built automatically and updated by searching of the relevant Web-resources.

The situation *satisfies the scheme* if conditions are satisfied for all IO and IO instances that are included to this scheme.

Search is *impracticable* if it's condition is invalid circuit situation.

Search is *executable* if its conditions can be satisfied (even if combination of the IO, satisfying these conditions is not detected).

Search is *trivial* if it results the unique situation.

Recognizing of situations which use multiple IO of the same or different classes with a complex structure is in general a very difficult task for search engines, even for those that carry out the search based on semantics. But for some special cases quite effective methods and means of the search are already exist. These methods operate on base of the specifics of certain IO types. These tools are designed for the most widely used IO that need in automated association in certain situations as a prerequisite for their effective application.

The best known examples of such IO search is the composition of semantic Web-services (solving of user problems requires a set of services that implement the various sub-task, and the order of their implementation); and the problem of complex search of multimedia data (information that is retrieved from one multimedia IO is used to find another one that satisfies certain conditions – for example, all other films of some actor). Analysis of these examples can be used for generalization of best practices for wider class of IO.

VII. Matching of Competencies

Model of semantic search can be adapted quite easily for a variety of applications including related with the search of complex situations which conditions use IO of different classes. We propose to consider it on example the problem of competence mapping [15] which is an integral part of such widespread practice tasks as finding by employer of suitable employees; ranging of experts in new domains; estimation of the successful implementation of the scientific project; comparison of specialists of different specialties (in particular, by qualification standards of different countries); choice of educational institution with a specific set of disciplines. Performing these tasks requires a knowledge of the respective organizations, persons and activities that should be compared.

Such problems can be considered as special cases of the search situation. For example, to choice by the entrant of the educational organization need to compare instances of "school" with instances of the class "discipline" that is used IOs of two different classes.

Both of these classes contain property of class "competence": for the first class of the property "provides the learning process", the second – the property "includes". Matching is provides by comparison of sets of values of these parameters. Due to the fact that the results of the comparison may not match exactly it is necessary to take into account the weight of the different disciplines for the entrant.

Use of the class "competence" provides the comparison of such IO as «discipline», «learning organization», «employer», «expert», «employee», «speciality» etc not on the level of names but on the level of their semantics.

Now the term "competence" is unclear and depends on the specifics of a particular subject domain. In general, the competence is an ability to operate successfully on the basis of existing knowledge and experience in problem solving. The first study of competencies for predicting the level of efficiency of execution of the work was proposed [16] to search for actors able to perform certain types of work.

The objective assessment of the transfer possibility for students from one educational institution to another is an example of the personal situation: various disciplines of different learning institutions from the list (this list can be proposed by user or forms automatically from those ones that satisfy some specific conditions – for example, those learning institutions that are situated in a selected by user city) are compared.

In this situation IO of classes "discipline", "educational institution", "competence" and "user" are applied. It should be noted that each personalized situation is concretized: it applies a specific instance that is associated with SSS user. In this case the user does not need to enter a list of what he learned – these data can be retrieved from his personal profile. A comparison is also performed using the properties of class "discipline" that contain instances of the class "competence". So it takes into account the semantics of the processed IO.

The solution to all these problems can be based on a common ontological model [17] which sets out the basic concepts related to competencies, their structure and relationships between instances of such basic classes that corresponds to this concept as "competence", "discipline", "person", "educational institution", etc. and their subclasses [18].

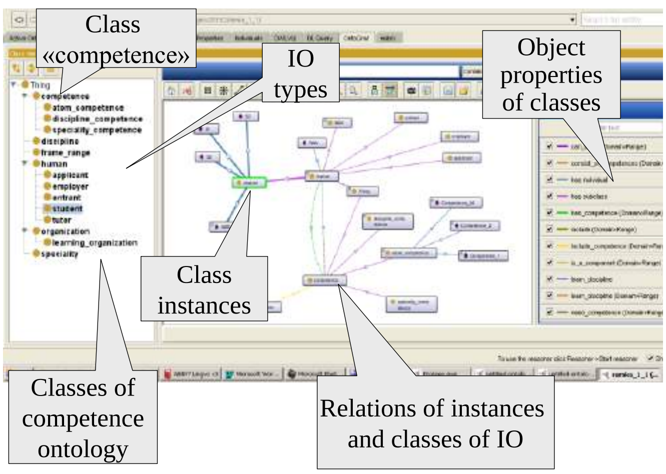

Fig.1 – Ontological model of competence analysis task

Furthermore, this model can contain classes relevant to the search resulted information objects (Figure 1). For example, resulted IO of the employee finding task belongs to the class "person", and resulted IO of the education evaluation task – to the class "organization" but both IOs can be characterized by the same sets of properties of a class "competence". The possibility of formal and unambiguous definition of the type and structure of desired IO improves pertinence of the search results and makes them much more suitable for the user.

This ontological model of semantic search allows to perform complex information requests, to import the personal characteristics of users with complex and stable information needs (specific to research activities and educational services), to take into account education, experience and expertise of users in various fields, and to integrate with other intelligent applications which are also based on ontologies.

The user describes his need for information by indicating the class of the ontology which required IO and conditions that are imposed on properties of IO values. Conditions can be described as a set of instances of the class "atomic competence". Thus, the query is reduced to comparison of these sets – for example, to comparison of the values of property "includes competence" that refers to the class of "atomic competence" with the values of property "speciality" for individual of class "specialist".

This approach clearly indicates the semantics of information needs, so you can search that differentiates various relations between IOs and the required set of competencies.

For example, different subsets of atomic competencies can be associated with the same instance of class "human" by relations "owns", "has the certificate", "can teach," "has an experience in use". This enables more accurate satisfaction of users' information needs by semantic retrieval of pertinent IO.

To perform the comparison of different types of IO – for example, professions, skills and competencies of people and organizations we need to acquire their common parameters, i.e., the properties of instances of these classes that belong to the same class. Analysis of research in this area points to the appropriateness of the use for these purposes the values of "atomic competence" class which is a subclass of "competence". Thus, an individual of any of the above classes is characterized in terms of a given domain by the set of reference atomic competencies [19].

Class "atomic competence" is a subclass of "competence", so that $\forall a \in$"atomic competence" there is at least one element of class "Competence", such that, but for a single element of the class $\forall b \in$"atomic competence", $a \subseteq b$ that there is no other element of this class $c \in$"atomic competence", such that $c \subseteq a, a \not\subset c$. Class "atomic competence" has the property "be part of the" of class "discipline" and the property "included in the" of class "competence".

The most important issues that arise in the process of solving this problem, are associated with the formation of the set of atomic competencies which requires considerable intelligent efforts of experts and can be automated only in part, and with the completion of the knowledge base by information about individuals of IOs that require permanent processing of a large volume data.

An instance is considered to be atomic, if any other instance of this class is not a subset of it, that is instances of the class "atomic competence" are not intersected.

This definition provides a generic mechanism for building of atomic competencies for selected domain on base of the set of competencies that characterize this domain and can be built from the normative documents – the descriptions of specialties, disciplines, etc. For example, if two competencies A and B are intersected than other three potentially atomic competencies A1, B1 and B are constructed: $A \cap B = C$, $A_1 \cup C = A$, $B_1 \cup C = B$.

VIII. Structure of Competence Ontology

Competence ontology defines the of the semantic properties and relations of the main IO which relate to competencies of individuals, groups and organizations that are carriers of these competencies, their customers or means of their acquisition.

We propose to use competence $c \in C$ as a basic element of this ontology. Competencies are subdivided into atomic competencies C_{atomic} and complex competencies $C_{complex}$, $C = C_{atomic} \cup C_{complex}$.

$$c \in C_{complex} \text{ if } \exists c`, c` \neq c, c` \in C, c` \subseteq c.$$

Atomic and complex competencies belong to subclasses ontological class «competence». Other important classes of this ontology – "Discipline"; "Specialty"; "Human"; "Organization".

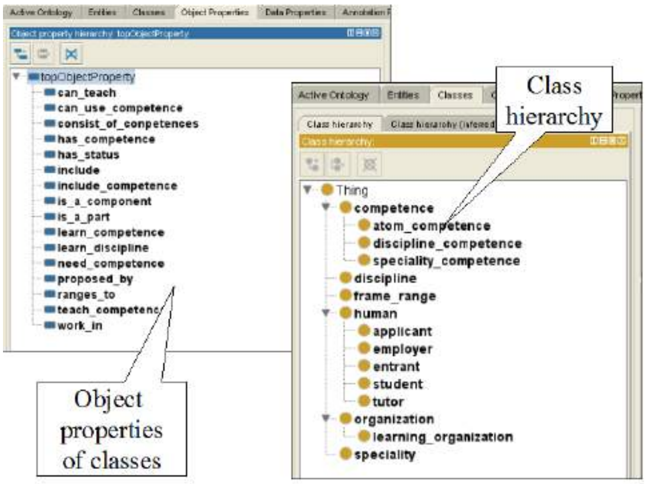

Fig.2 – Classes and object properties of IOs of competence ontology

All subclasses of these base classes have some common characteristics. For example, all subclasses of "person" have the data properties "name", "date of birth", "address", etc. and object properties «has parent» of class «person». These classes become more specific by means of different subclasses with various semantic properties of the object. For example, the class "person" has the subclasses of "student", "employer", "teacher", "researcher", "graduate student" and etc. These subclasses are distinguished by the presence of some additional properties: "student" has the object properties of a "place of learning", «speciality» and data properties "year of learning", "post-graduate" has object property "Supervisor" from class «human» and data property "topic of research" (Figure 2).

An important characteristic of this approach semantics is the fact that all the base classes of this ontology have the object properties with values of the class "competence" that determine their aspects related to competence analysis.

Today we don't have any universal ontology of competencies and qualifications that is harmonized with all national and international approaches. But we can use a set of such ontologies that would be matched one with others.

That's why we propose the following method of competence matching:

- define the documental content that can be used for description of the set of atomic competencies that define some complex information object (for example, requirements of employer or passport of postgraduate speciality)
- transform these documents into the Wiki representation
- build the ontology that defines relations of atomic and complex competencies, disciplines, specialities, professions etc.
- semantically mark up these Wiki resources by the concepts of this ontology that can be used as classes and by object properties of this ontology that can be used as semantic properties at Semantic Media Wiki
- at last, we can built semantic requests to these resources that are oriented on retrieval of individuals (humans, institutions etc.) with appropriate values of defined properties

We understand that there is no way to realize all these activities by any single organization. Some parties of this work can be executed by relevant educational organizations or governmental structures. But we propose the approach to decision of the knowledge-oriented part of this task – the development of structure of competence ontology and methods of matching of various information objects marked up by the elements of this ontology.

An important characteristic of proposed approach is the fact that all main classes have semantic object properties with value from class "competence" that define their semantic aspects deal with competence analysis.

This approach is compatible with different mathematical knowledge-oriented models of qualifications. For example, eight levels of qualification of the European EQF standard can be represented by subclasses of class "qualification" with numerical values of data property "level" from 1 to 8, value of data property "qualification system" equal to "EQF" and with object properties "Knowledge", "Skills" and "Communication" with values from class "Competence".

Every individual of class "Qualification" that has data property "qualification system" equal to "EQF" obligatory has unique value of data property "level" from 1 to 8 and three nonempty sets of object properties "Knowledge", "Skills" and "Communication" with values from class "Competence".

The simplest model of qualifications $q \in Q$ on base of competence ontology can be formally represented by triple, $Q = \langle Iq, Lq, Compet = Kn \cup Sk \cup Com \cup \ldots \cup Compet_p \rangle$, $p = \overline{0,r}$ where

- $iq_j \in Iq, j = \overline{1,n}$ – the identifier of qualification system;
- $Lq = \bigcup_{j=1}^{n} \left\{ lq_{i_1}, \ldots, lq_{i_{s_j}} \right\}$, where $lq_{i_{s_j}}$ is a number of various levels in classification system iq_j;
- Kn is a set of atomic competencies that characterizes the knowledge of appropriate qualification;
- Sk is a set of atomic competencies that characterizes the skills of appropriate qualification;
- Com is a set of atomic competencies that characterizes the communications of appropriate qualification
- $Compet_p$ is a set of atomic competencies that characterizes the p-th set of appropriate qualification (hear we don't concretize the criteria of building of these sets that deal with specifics of different national and international qualification systems).

Various sets $Compet_p$ can be used in different qualification systems, but we state that two qualifications $A \in L$ and $B \in L$ are equal if their sets of competencies are identical: $A \in L \equiv B \in L \Leftrightarrow Compet_A \equiv Compet_B$.

Specialties and disciplines are modeled similarly. The model of specialties $s \in Sp$ on base of competence ontology can be formally represented by triple $Sp = \langle Is, Ls, Compet = Compet_1 \cup \ldots \cup Compet_m \rangle$, where

- $is_j \in Is, j = \overline{1,n}$ – the identifier of classification system of specialties;
- $Ls = \bigcup_{j=1}^{n} \left\{ ls_{i_1}, \ldots, ls_{i_{s_j}} \right\}$, where $ls_{i_{s_j}}$ is a number of various levels in classification system of specialties is_j;
- Compet is a set of atomic competencies that characterizes the appropriate competencies of specialties.

The formal model of disciplines $d \in Disc$ on base of competence ontology can be formally represented by triple

$Disc = \langle Id, Ld, Compet = Compet_1 \cup \ldots \cup Compet_m \rangle$, where

- $id_j \in Id, j = \overline{1,n}$ – the identifier of qualification system;
- $Ld = \bigcup_{j=1}^{n} \left\{ l_{i_1}, \ldots, l_{i_{s_j}} \right\}$, where $l_{i_{s_j}}$ is a number of various levels in classification system of disciplines id_j;
- *Compet* is a set of atomic competencies that characterizes the appropriate competencies of disciplines.

Competence ontology and atomic competencies can be used for semantic markup of various natural language IRs, for example, for semantic Wikis [19] deal with learning, scientific research, qualification estimation, expert retrieval etc. Complex requests can be realized on base of this markup where classes of competence ontology are used as categories of Wiki pages, and competencies (atomic and complex) are used as semantic properties of page content. Such domain ontology can be built automatically by special functions of Semantic Media Wiki or by special algorithms according to personal needs of users.

We can build semantic requests to semantically marked up information objects that are represented by Semantic Media Wiki. For example, we can find all organizations from category "learning organization" where disciplines with proposed set of competencies are learned and show important information about these organizations. This request is based on the function "ask".

{{#ask:
[[Category:learning organization]]
[[Discipline::Programming]]
[[Competence::C++]]
|?City
|?Country
|?Rating
|?Adress
|format=broadtable
}}

Personal domain ontology – for example, generated by pages edited by some user – can be used as a formalized model of user competencies and defines the sphere of expertise of this person. By comparing of such ontologies we can retrieve experts, tutors or other specialists by analysis of their competencies on semantic level

IX. CONCLUSION

Formalized ontological model that represents knowledge about the structure of complex IOs from the subject area user of interests allows IIS to find more efficient results by means of personified semantic search of information from the Web. It takes into account the individual information needs of users and explains him the obtained results.

The use of ontologies for knowledge representation provides access to information from outside sources and repositories and allows to use a variety of tools for analysis and semantic processing of this information. However, we need in further development of the terminology and tools for handling of multifarious sets of information objects hat are oriented on specifics of the different subject areas and types of information objects and their relations.

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ИСПОЛЬЗОВАНИЕ ОНТОЛОГИЧЕСКИХ ЗНАНИЙ В СЕМАНТИЧЕСКОМ ПОИСКЕ СЛОЖНЫХ ИНФОРМАЦИОННЫХ ОБЪЕКТОВ

Рогушина Ю.В.

Рассматриваются проблемы, связанные с поиском информации в Web интеллектуальными приложениями. Онтологический анализ используется как основа для представления знаний в семантическом поиске. Предложена онтологическая модель взаимодействия между открытой информационной средой, интеллектуальной информационной системой и ее пользователями. Такая модель позволяет формально описывать информационные объекты (ИО), которые обрабатываются в ИИС, их структуру и свойства, и разработать методы и средства использования и получение информации относительно этих ИО.

Разработан метод получения знаний о сложных информационных объектах, структура которых тоже формализуется с помощью онтологий, которые проанализированы на примере задачи анализа компетенций.

Ontological Approach to Matching of the Domain Competence of Specialists for Research Projects

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Abstract—objective methods of competence evaluating of research project developers based on the semantic comparison of the project description and documents that characterize the competence of developers in the chosen subject domain are proposed. We propose to acquire ontological knowledge from the Web open environment - Wikis, scientometric databases, personal blogs, official websites of organizations and metadata, domain ontologies etc. Specialized ontology of scientific activities oriented on unified describing of qualification terminology is developed.

Keywords—research project; ontology; competence; scientometric indicators.

I. Introduction

Today it is difficult to imagine practically all spheres of human activities without the use of information technologies and, consequently, without the development of research projects that allows new innovative technologies and applied intelligent information systems (IIS). Preparing of the request for research project is a complex interdisciplinary problem which solution needs in use of the modern technologies of the intelligent information processing. In particular, these technologies allow to evaluate the originality and relevance of the project, to find the most relevant experts and actors, to predict the likelihood of its success.

These technologies are oriented on information processing on the semantic level by use of apply knowledge from subject domain of the project, as well as knowledge on research activities in general. The analysis of international experience shows that the use of ontological models for knowledge formalizing is one of the most promising approaches to such problems.

II. Problem Statement

We analyze a particular case of complex information retrieval task that deals with estimation of matching of researcher qualification with scientific research project. As experience shows, this parameter is crucial for predicting of the project success and therefore it should be taken into account first of all in decision-making on project funding and grants, especially for new and interdisciplinary research fields where traditional formal methods are not efficient.

We propose to use semantic processing of information from open sources (for example, from information resources (IRs) from the Web) to match the scope of researchers competencies to the subject domain of proposed project: specialist can be highly qualified in some domain but be very poorly prepared to participate in project from another domain from the same sphere of knowledge. This matching problem can be divided by the following subtasks:

- Generation of the set of natural language IRs that describe the project;
- Selection of documents that describe qualification and experience of particular researchers (with indicating of the importance level and trust of each source);
- Acquisition of the formalized project model from its description;
- Building of the formalized profile of researcher on base of his documents (directly proposed by applicant or retrieves from the Web and other open sources);
- Matching of researchers profiles with project domain model and a quantitative estimation of their proximity.

The main source of information about the project is its natural-language description (application, request or requirements specification), as well as additional IRs such as external ontologies, Wiki pages proposed by project authors that contain structured and semantically meaningful information regarding the considered domain.

III. Competence and Expertise of Researchers

The most difficult from these subtasks is an analysis of information about the project participants. Some part of this information about them is clearly formalized and can be clearly evaluated without taking into account the semantics of domain and additional knowledge about the project (level of education, experience in the relevant field, the presence of previously developed projects). But often this information is not sufficient to determine competence on the development of a research project in the new and rapidly changing domains.

It is necessary to distinguish concepts "competence" and "expertise". The person knowledge and experience that have to provide successful execution of various tasks in accordance with some rules, laws, etc. characterize competence, and expertise is the relation between the person and the competence which means that certain person has this competence.

In our case, competencies are the characteristics and tasks that are necessary for the development of a research project, and expertises are specialist properties, their characteristics, experience and capabilities. Expertise can be defined based on the analysis of professional activity of specialist, his awareness of the science and technology achievements, his understanding of the investigated problems and ways of their solving. In the field of research projects development there are both formal and informal requirements for specialists that can be considered as competencies.

One of the most objective criteria of evaluation of competence sphere for scientists is an analysis of their publications presented by the Web – various scientific articles, papers, reports and presentations that usually are represented by natural language texts or structured metadata.

Document pertinence to discovered project depends on such parameters as the number of references to the main terms in the document and the number of main project terms used in the document. There is a lot of works regarding the automatic determination of competence on the basis of documents.

However, different information sources of the Web have different assessment of the information quality. it is important to take into account the evaluation of researcher activities by the scientific community – by the presence of references by other authors in their work. In addition, information about researchers can be imported from a knowledge bases of intelligent applications that provide personalized information services. For an objective assessment of competence of developers and experts it is advisable to use external quantitative parameters that reflect the overall efficiency and the intensity of their scientific activities.

Thus, we propose to use as a source of information about the researcher expertise the following IRs [1]:

- official documents acknowledge education and experience (for example, university diploma, academic degree, certificates and awards);
- IR that describe the semantics of these official documents (passports of specialties and disciplines, the requirements for obtaining of scientific titles and degrees, job descriptions, taxonomy of national academic degrees, etc.);
- texts of published articles, abstracts, monographs, textbooks, technical reports, patents and other intelligent property presented in the form of natural language documents and published by the Web that are rate by scientometric databases;
- Wiki pages of persons and organizations that provide structured presentation of information;
- personal blogs and pages from social nets;
- official Web pages of organizations and institutions deal with applicants (for example, membership in the international scientific and technical societies, editorial boards of scientific journals, cooperation with the National Academies of Sciences, educational institutions).

IV. SCIENTOMETRIC CHARACTERISTICS OF RESEARCH ACTIVITIES

The effectiveness of scientific activities of individuals, groups and organizations can be evaluated using both qualitative and quantitative indicators. Qualitative ratings are based on opinions of domain experts. However, the subjectivity of such assessments significantly reduces the reliability of results, and the lack of a quantitative expression complicates their use.

The term "Scientometrics" was introduced in 1969 by V.V.Nalimov [2]. The increased interest in scientometric indices is caused primarily by the ability to automate the evaluation of the results of scientific activity [3].

Scientometric indicators are suitable for estimating the results of fundamental research which demand is assessed by the references of the scientific community. Scientometrics is a science that involves statistical studies of the structure and dynamics of scientific information flows. It studies the evolution of science through a numeric measurement of scientific information, such as the number of scientific articles for a certain period of time, citation, etc.

Now generation of the researcher rankings use various parameters such as number of publications (in total or separately for types – monographs, articles, theses, publications in journals indexed in the Web of Science, Scopus or Google Scholar, etc.) and references to them. Sometimes the volume and impact factor of publications are took into account. Integral criteria based on these ones are formed.

The effectiveness of scientific activity can be evaluated using both qualitative and quantitative indicators. The most effective and the most common characteristics of scientific work productivity, in particular, are the Hirsch index and impact factor [4, 5].

In 2005, Hirsch proposed a new index - *h-index* [6] defined by the maximum integer h which means that the author has published h papers and each of them was referred in other articles at least h times. Hirsch index is popular because of easy calculation and insensitivity to the typical methods of factitious improvement of considered above scientometric indicators.

Hirsch index can be calculated using a free public scientometric database on the Web (for example, Google Scholar, Elibrary.ru, ADS NASA), and the database with a paid subscription (for example, Scopus or ISI Web of Science). However, many paid databases give the h-index of scientists in the public domain. It should be noted that the Hirsch index has different rating meanings of the same researcher in dependence of the indexed IR set.

Hirsch index gives more objective results in the case of withdrawal of the author references to their own articles. For example, in the ranking of scientists of Ukraine according to the Hirsch index calculation is made on the database Scopus with the withdrawal of the authors of references to their own articles.

Impact factor indicates the average number of links on each article that was published in the journal for the next x years after its release [7, 8]. This quantitative measure of the importance of a scientific journal is calculated annually by the Institute for Scientific Information (ISI) and is published in the Journal Citation Report.

Impact factor allows to compare different journals and research groups by formal parameters [9]. Generally, the calculation of the impact factor is based on a three-year period. The impact factor of the journal A for year x is calculated by the formula:

$$\operatorname{Im} p(A, x) = \frac{Cit(A, x-2, x) + Cit(A, x-1, x)}{Pub(A, x-2) + Pub(A, x-1)},$$

where $Cit(A, y, z)$ is the number of references during the year on the z articles published in the magazine A during the year y in magazines publications monitored by Institute for Scientific Information, and $Pub(A, y)$ is the number of publications in the journal A during the year y.

Citation Index is an accepted by the scientific world measure of the significance of scientific work of some scientist or research team which is the total number of links in the indexed articles on reviewed publication. Citation depends not only on the level of scientific results but also on other factors, for example, the publication timeliness.

Scientometrics databases (SMDB) that used to obtain these estimates are bibliographic and abstract databases with tools for citation tracking of articles published in scientific journals.

Scopus of Publishing Corporation Elsevier is one of the most well known SMDB . Scopus do not apply the concept of impact factor but it widely used Hirsch index. This database is available by subscription through the Web-based interface (http://www.scopus.com). Furthermore, authors of articles can not register to view their rating page http://www.scopus.com/search/form/ authorfreelookup.uri.

Web of Science (WoS) of Thomson Reuters is one more very popular SMDB . It contains links to the full text in the original sources and lists of bibliographic references that appear in each publication.

Index Copernicus (Poland) (http: //www.indexcopernicus.com) is an international SMDB which covers indexing, ranking and abstracting of journals and is a platform for scientific collaboration and joint research projects.

Google Scholar (http://scholar.google.com/) indexes the broadest spectrum of research papers represented on the Web. This SMDB processes the full text of scientific publications in all formats and disciplines. The main scientometric indicator that generates by this SMDB is Hirsch index (both general and for the last five years).

Now many national SMDB oriented on indexing and evaluation of publications in the languages other than English are developed. For example, Web-site "Ukrainian Science Citation Index" (http: //uincit.uran.ua) provides to rate the publication activity of individual scientists and scientific institutions of Ukraine by the scientometric indicators.

V. THE ROLE OF ONTOLOGIES FOR COMPETENCE ESTIMATING OF SPESIALISTS

In addition to general professional level, it is necessary to assess the expertise of researchers in domain of particular project. Formal models of such domain can be represented by its ontology.

Ontological analysis is now the most common approach of domain knowledge representation that provides the analyses and comparison of the competencies of experts and developers in new research areas [10]. In addition, the availability of the domain ontology that is known and used by researchers usually indicates their deep knowledge in this domain (especially when it concerns to information technology).

At the same time with domain ontologies it is advisable to use a common ontology of research activities that enables unambiguously establish the terminology associated with the rating publications, scientific degrees and academic titles, types of organizations, etc. [11].

We have developed the following ontology oriented on the determining of the competencies of the research project authors that can be integrated with organizational ontologies of scientific institutions, Academy of Sciences, UDC classifier and other relevant knowledge bases (Figure 1).

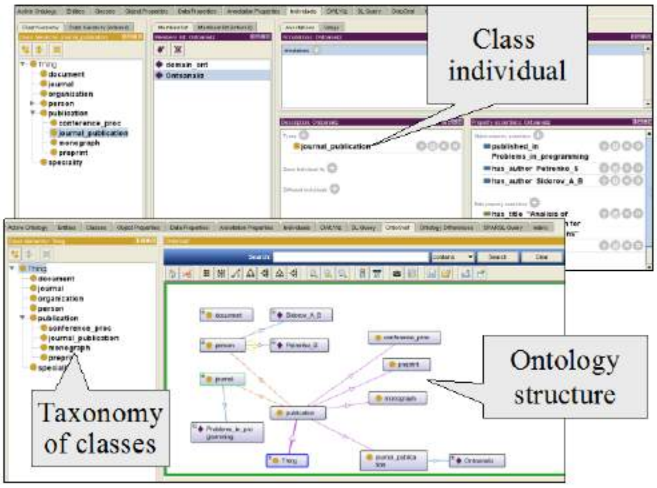

Fig. 1 – Ontology of research activities

This ontology contains such terms specific to research activities as «publication», «monograph», «research project», «diploma», «researcher», «specialty», «academic degree», «education» etc. and expresses such relationships between classes as "to be co-author of", "to work in the organization", "to be the author of the publication," "have a degree in the specialty" and properties such instances of classes like "to be publishing", "to have the Hirsch index ".

Developers of research projects can use this ontology as a model for the description and classification of the submitted documents which have to certify their competence level both in scientific work in general and in some particular research domain of information technology.

VI. DOMAIN THESAURI AND ONTOLOGIES AS THE MEANS OF MATCHING OF NATURAL LANGUAGE DOCUMENTS

We propose to generate the thesaurus of project and thesauri of IR that describes project participants: matching of these thesauri provides the evaluation of proximity of researchers qualification with project domain.

Thesaurus of the natural language IR can be considered as a projection of domain ontology [12]. Thesaurus of the project participants is generated as the join of the IR thesauri with account of weight of the individual IRs which should be considered as the significance of the document to describe the competence and level of trust to this IR. For example, the weight of thesis abstract is more then the weight of diploma, and impact factor of journal can define the weight of publication.

It is assumed that each of project developers generates a set of documents that are most pertinence to proposed research project.

For example, if the author has n scientific publications then he chooses m of them that are relevant with the project. However, the author should seek to ensure that all the concepts of the domain ontology that have linguistic equivalents in the project text of these would be present in his selected works (the weight of each comparison depends on the weight of IR due to the function of the status and rating of the document). Status of document characterizes the level of documentary evidence of this type of IR and rating of document characterizes its estimation in scientometric databases.

Project thesaurus Th_{proj} depends on the project description and of the selected domain ontology. It is a set of pairs (t_i, q_i) where $t_i \in T$, T is a set of terms of domain ontology $O_{domain} = \langle T, R, A \rangle$, and q_i is a number of matches that determines the weight of the term (if some term appears in the description of the project 10 times than it is assumed to be more important than that those one that appears only 2 times).

For each term of the domain ontology text fragments are retrieved.

The overall estimation of the team competence is determined by the array

$\left(t_i, \sum_{j=1}^{m} p_{IR_{j_i}} * v_{IR_j} \right)$, where

- t_i is a number of domain ontology terms from T;
- $p_{IR_{j_i}}$ is a number of matches with this term in the j-th IR;
- v_{IR_j} is a weight of the j-th IR.

It is important that this array does not contain all terms of domain ontology (domain in general can be much broader than it's part relevant to project), but only those ones that have matches with project.

We determine the weight of the j-th IR in such way: default weight of each document is w=1 and then it can grow under these conditions (evaluation can be summed):

- for scientific publications:

- If the article is published by journals with impact factor greater than 0.5 then w=w+5,

- If the article is published in the materials of the conference then w=w+1,

- If the article is published by the foreign edition then w=w+3,

- If the article is indexed in Google Scholar, then w=w+2,

- If the article indexed in Scopus then w=w+10;

- Passport of specialty or diploma w=w+5;
- Description of the organization profile w=w+3;
- Description of the earlier successfully fulfilled research project w=w+5;
- Description of the earlier proposed but nor realized project w=w+1;
- Abstract of a thesis w=w+4.

It is obvious that different articles have different weights for estimation of specialist competencies. Therefore we can take into account impact factor of journal and the year of publications (new publications are more important then the old ones). In this case, an overall estimation of the researcher is as follows:

$$C = \sum_{i=1}^{n} q_i * \left(\sum_{j=1}^{m} p_{IR_{j_i}} * v_{IR_j} * \operatorname{Im} p(IR_{j_i}) \right) \quad (1),$$

where $\operatorname{Im} p(IR_{j_i})$ is an impact factor of journal that publishes this IR.

In the future, it is advisable to enter various other normalized ratios that can reduce the impact of a large volume documents that are poorly saturated with the domain terms.

However, system development of these ratios requires much more detailed study of the hierarchy and content of documents submitted for examination by the authors and in a great measure depends on the project specifics. For example, different conditions are applied for young scientists and monograph reviewers.

Estimation (1) does not use domain semantics and relations among the domain ontology terms. Therefore we proposed to use the following more complex estimation:

$$C = \sum_{i=1}^{n} q_i * \left(\sum_{j=1}^{m} p_{IR_{j_i}} * v_{IR_j} \right) * s_i \quad (2),$$

where parameter s_i determines the value of the i-th term of the ontology by the number of its relations with those terms of ontology that are also included to the project thesaurus and take into account the semantic distance between them.

General qualifications of each of the developers of the research project can be took into account (in addition to the domain specialization) by their rating derived from SMDB. In particular, we propose to use information from Google Scholar and Scopus because this information is accessible for all the Web users.

In addition, it gives an opportunity to differentiate qualified individual researchers and just do not summarize their results. The following estimation of x-th researcher uses knowledge from external SMDBs:

$$C_x = \sum_{i=1}^{n} q_i * \left(\sum_{j=1}^{m} p_{IR-x\,j_i} * v_{IR-x\,j} \right) * s_i * h_x \quad (3),$$

where h_x is a sum of Hirsch index of researcher from Google Scholar and Scopus. If other SMDBs are available then their Hirsch ratings can be sum up too.

The general estimation of the qualifications of the project developers can be measured as the sum of estimation of the participants or their normalized sum. The first approach is advantageous because knowledge and experience of each can be used independently of the number of participants. Therefore, the normalized estimation can be used only as an complementary or for teams with greatly different number of members.

The results of this objective competence estimation of scientists for new research domains characterized by high dynamics of innovation and technology were used in the preparation of a request for funding for a new project on the EU program Horizon 2020. Project Title: «Novel scalable E-call platform based on an intelligent ontological system - NEMO». The main idea of this project consists in creation of intelligent system for emergency medical care and for people with the risk to their lives.

One of the problems that exist in such systems (for example, warning system 112) is break or termination of telephone communication with affected person due to various reasons and the impossibility of obtaining comprehensive data about this person to send him the special care services.

The ontology-based approach that uses intelligent software agents allows to identify the missing information about affected people from the distributed network and helps to redirect this information to relevant support services in the shortest possible time and in appropriated form.

The definition of this project is semantically marked up by means of the Semantic MediaWiki (fig.2).

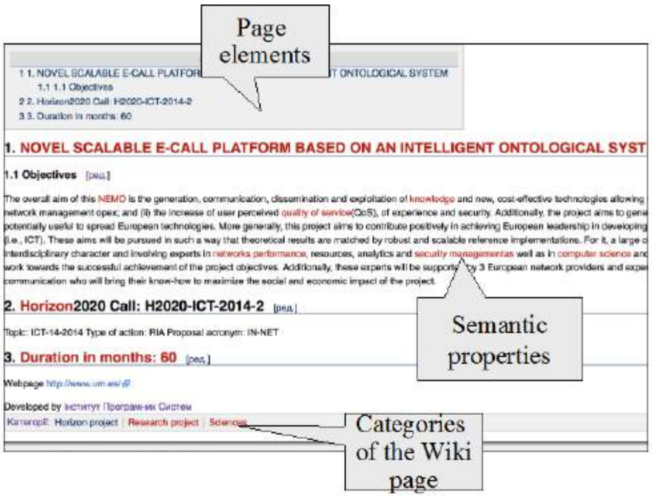

Fig. 2 – Structured description of the project

Project ontology can be built automatically by this structured description by means of the Semantic MediaWiki and be represented by OWL language [13, 14]. This ontology can be processed by Protégé [15] for knowledge visualization, extraction of some data and for integration with other external domain ontologies (fig.3).

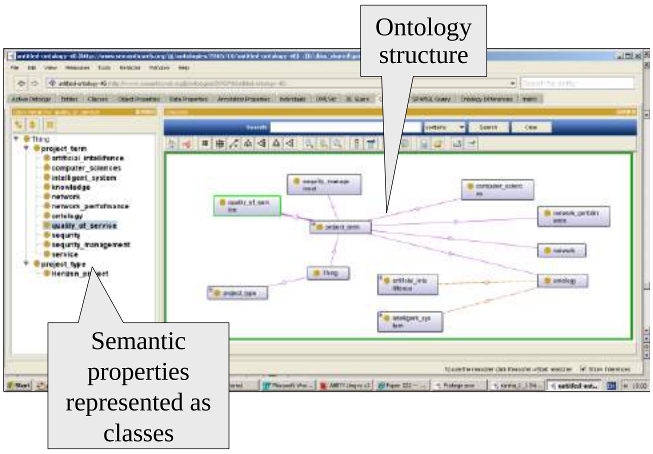

Fig. 3 – Ontology of the project domain

Then the terms of this ontology are used for semantic markup of the documents such as articles, certificates, diplomas that describe the competencies of potential project members. For example, semantic markup of the Semantic MediaWiki uses constructions that provide selection of different types of semantic properties for every Wiki page: [[semantic_property_name::semantic_property_value]], e.g. [[project term ::quality of service]] (fig.4). These elements are added to the document content at the places that are relevant to meanings of these terms.

The markup process can be performed manually or by specialized software instruments that help user in retrieval of relevant text fragments [16]. Unfortunately these tools depend hardly from the natural language of document and have to be developed for every language that is used [17].

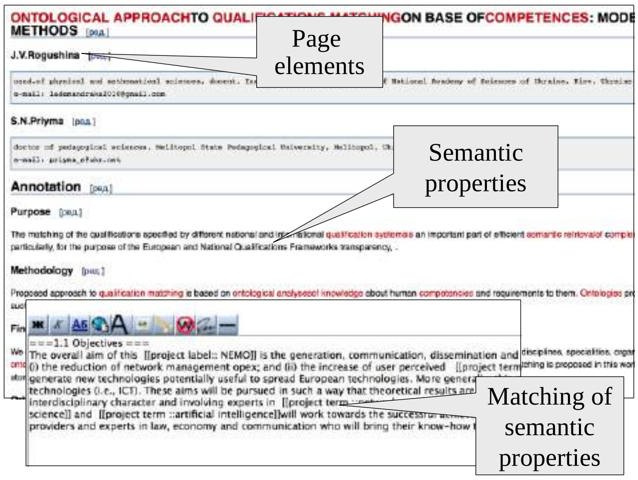

Fig. 4 – Structured description of the project

On the basis of the described above method objective competence assessment of experts and developers from different European countries was performed in order to form a consortium of developers of the different countries and institutions. Project Consortium members: Ukraine (Institute for Software Systems and the International Center of NASU), Germany (Technical University of Darmstadt), Spain (University of Murcia) and France (Paris Polytechnic School). NEMO project ontology was created on the basis of preliminary project description, formalization of requirements and tasks to it (WPs) need to be addressed when creating the system. This ontology has been used for creation of subteam of experts and developers for the project. Currently this joint project aimed at developing a new intelligent service support for people in a situations that threaten their lives is submitted to the EU Commission Horizon 2020 and passed the first restrictive selection committee.

VII. Conclusions and prospects for further research

A new approach to solving the problem of objective competence evaluation in the context of new information and communication technologies has a lot of important specific features. These specifics is caused by which by high dynamics and heterogeneity of the Web information resources that demand semantic processing .

The approach proposed in this article is based on use of ontological knowledge: it provides matching of project thesaurus and thesauri of project participants which are based on the same domain ontology to evaluate the semantic distance between competencies of researchers and competence needs of project. Thesauri are generated by processing of the natural-language project description and information about participants (their publications, diplomas, descriptions of previous research projects, information about their organizations, etc.).

The goal of this research work is a development of the objective methods of qualification evaluation of potential project participants from the viewpoint of project domain competencies. These methods are oriented on taking into account a significant number of knowledge available by the Web. We think that these methods will we helpful for planning of research teams for various scientific research tasks and provide more efficient and high-quality research results.

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ОНТОЛОГИЧЕСКИЙ ПОДХОД К СОПОСТАВЛЕНИЮ КОМПЕТЕНЦИЙ ПРЕДМЕТНОЙ ОБЛАСТИ ДЛЯ СПЕЦИАЛИСТОВ В НАУЧНО-ИССЛЕДОВАТЕЛЬСКИХ ПРОЕКТАХ

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Предложены объективные методы сопоставления компетенций для разработчиков научно-исследовательских проектов. Эти методы базируются на семантическом сравнении описания проекта с теми документами, которые характеризуют компетенции исследователей в той предметной области, к которой относится проект. Создана специализированная онтология научно-исследовательской деятельности, предназначенная для унифицированного описания терминологии, связанной с вопросами квалификации. Предполагается, что основным источником сведений о компетенция исследователях являются их научные пуликации, представленные в Web, а также их рейтинги в наукометрических базах данных.

Предлагается также извлекать онтологические знания из таких структурированных и естественно-языковых информационных ресурсов, доступных через открытую среду Web, как Wiki-ресурсы, базы данных и знаний, персональные блоги, официальные Web-сайтов учебынх и научных организаций, а также из метаданных и онтологий.

Sequential Presentation of Method for Integration the OWL DL and SWRL Using Protégé-owl API

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***Abstract*—This paper is devoted to the description of a method of integration of OWL DL and rules with sequential presentation. In article need of similar integration and semantics of OWL DL are analyzed; the method on integration of OWL and rules with use of language of the rules SWRL is provided.**

***Keywords*—OWL; Markup Language; SWRL; case based reasoning; reasoned; knowledge acquisition system; Protege ontology editor**

I. INTRODUCTION

In recent years, many formal ontologies were offered as the solution of problems of the description for difficult spheres of knowledge. Well thought over ontologies possess a row of the positive moments, including:

1) an opportunity to define controlled dictionaries of terms;
2) ability to inherit and expand the existing conditions;
3) an opportunity to declare correlations between the existing conditions;
4) an opportunity to add the new relations, on the basis of reasonings according to the existing terms.

By means of the technologies known under the general name Semantic Web, in particular the OWL [1] language, researchers can spread and be divided ontologies by all scientific community. Though there is a row of high-quality ontologies, scientists are far from implementation of all advantages of their use, and still there are opportunities for significant progress in this area, especially in application of the formal reasonings.

The unique force of the formal ontologies in the field of representation of knowledge is their ability to be accented on logical arguments. Such reasons are carried out with use description logicians (DL), forms of the logic developed for reasons about objects as separately and about classes of objects. The software under the name the moralist (Hermit, Pellet or Fact++) uses rules DL for execution of specific operations over knowledge bases [2]. The most important of them is:

1) coherence check: combining of ontological model with rules DL;
2) check of an consistency: ability for the described classes to be implemented by real copies;
3) classification: extension of the relations between objects which were brought out of the relations in an explicit form.

The OWL language offers rich property set, but apart from a set of relational properties of varieties of the OWL languages, they doesn't envelop all range of indicative opportunities for the relations of objects which can be constructed.

This article is devoted to the description of a method of integration of OWL DL and rules. For the solution of an objective, first of all, it is necessary to consider a question of feasibility of similar integration, then in details to analyze features of semantics of OWL DL. In the inference the method of integration of OWL and rules, SWRL (Semantic Web Rule Language) will be provided.

Frequent to model many processes in knowledge domain better with use of declarative approach and rules which results in interest in the systems based on rules. However, a possibility of interaction among a set of the existing systems based on rules limited. The SWRL technology [3] became the first step as based on the combining OWL with the rules Markup Language [4]. The combining OWL and SWRL gives opportunities of carrying out a logical output outside the opportunities of classification which are built in the description the logician, realized by OWL.

II. USE OF A COMBINATION OF OWL DL AND RULES

There are several reasons, for a choice of the OWL DL language as a formalism of model (legal) knowledge. First a key role is played by interchangeability and solubility. Secondly, among OWL family of languages, OWL DL is the most indicative dialect which remains solvable.

However there is one lack of OWL DL – limitation of its expressiveness, therefore, it needs to be expanded. One of methods consists in its extension using rules. The rule is a formula of a look:

$$\varphi_1 \wedge ... \wedge \varphi_k \rightarrow \psi$$

where $\varphi_1 \wedge ... \wedge \varphi_k \rightarrow \psi$ is a body, and ψ according to governed headed . The sense of the rule is that "every time when the body of the rule is true, the head will accept value truly too".

The choice governed as extension for OWL isn't accidental. First, integration of OWL (DL) into rules gives so indicative language as logic of first order (FOL – First Order Logic). Secondly, OWL DL well is suitable for expression of taxonomical, terminological or encyclopedic knowledge while rules can express configurations of concepts and properties which can't be reduced to taxonomical classification, and it is necessary to express these configurations which OWL DL can't express [1,5].

For example, we will consider (informally expressed) the rule:

If the judge condemns the innocent,
then he is unfair to this person

Which conversion to FOL looks as follows:

$$\forall x, y : Judge(x) \wedge condemn(x, y) \wedge Innocent(y) \rightarrow unjust(x, y)$$

The example contains a ratio between concepts and properties which are necessary, but which OWL DL isn't capable to express. The intuitive reason is rather simple: to clarify that someone is a judge, the innocent, etc. (atoms in a rule body), is a subject of taxonomical knowledge and reasonings.

From the formal point of view, the shortcoming is caused by inability of OWL to cope with variables. Because in the rule variables are higher x, at are transferred from a body to the head, and OWL DL isn't able to cope with such transmission. Unlike it, the rule, such, as

If someone made action which isn't authorized,
then he made violation

Which are represented to FOL as:

$$\forall x, y : Person(x) \wedge Action(y) \wedge Disallowed(y) \rightarrow commit(x, violation)$$

It can be expressed in OWL as:

$$Person \sqcap \exists perform.Action \sqcap DisallowedPerson \sqcap \exists.commit \sqcap Violation.$$

Let's pay attention that in the last example only one variable is separated between a body and the head of this rule. Thus, it is possible to make two preliminary remarks:

- if at least one variable is separated between a body and the head of the rule, then such rule OWL DL represented;
- if more than one variable are the general, then the rule can't be OWL DL represented [6].

Thus, it was shown that there are rules which can't be expressed in OWL DL. From here need in a research of how to integrate OWL and rules follows [7].

III. Syntax and Semantics of OWL DL

In OWL Dictionary

$$V ::= V_L \cup V_{URI}$$

where V_L represents a set of literals and V_{URI} URI great number of references. The set of V_{URI} is created as follows:

- V_I, a set of separate names, for example, $Pavlo$;
- V_O, a set of names of ontologies, as a rule, consisting of the URL addresses specifying where ontologies are stored;
- V_{IC}, a set (personal-) class names, for example, $owl : Thing$, $owl : Nothing$;
- V_{DC}, a set of class names of data types, for example, $rdfs : Literal$, $xsd : gDay$, $xsd : integer$;
- V_{IP}, a set (personal-) names of properties, for example, has the father;
- V_{DP}, a set of names of property of data types, for example, height in meters;
- V_{AP}, a set of names of properties of summaries, for example, $owl : label$, $owl : seeAlso$;
- V_{OP}, a set of names of properties of ontologies, for example, $owl : import$.

Symbolic circuit in this case following: for use of a C class; for property P; for data type D; for a personal object I; for summaries of A; for ontology O. For users, familiar with FOL, the great number of V_I represents a set of separate constants; V_{IC} and V_{DC} represent sets of unary predicates (classes); V_{DP}, the V_{IP}, V_{AP} represent sets from dyadic predicates (properties). The single complexity of the OWL DL dictionary is that one - and dyadic predicates are subdivided depending on whether they belong to copies/objects, data types, summaries or ontologies. Besides, OWL the logical dictionary consists of characters for creation of classes, i.e., $\sqcap$, $\sqcup$, $^{-}$, $\exists$, $\forall$, and also characters for a creation formula, i.e. $\sqsubseteq$ and .

Now we will pay attention to syntax of OWL, i.e. how to construct terms (atomic classes or difficult classes) and formulas (to OWL axioms and the facts).

The set of the classes OWL recursively is determined by the following rule:

$$QWL - Class ::= C|T| \perp |\bar{C}|C_1 \sqcap C_2|C_1 \sqcup C_2|\forall P.C|\exists P.C|\forall T.D|\exists T.D| \leq nPint| \leq nT|OneOf(i_1, ..., i_k)|OneOf(l_1, ..., l_k)$$

Where C designates a class (atomic or complex); $P \in V_I P$ atomic property, $D \in V_{DC}$ data type class; and $T \in V_{DP}$ property of data type. $Characters\>$ and $\perp$ aren't constrained by $owl : Thing$ and $owl : Nothing$. Pint means that property P isn't transitive property or isn't sub-property of transitive property. The predicate of $OneOf$ is a concept of the designer who provides lists of separate names i or literals of I.

Now we will provide OWL semantics. First, we will define the OWL model, namely function of interpretation for atomic classes, data types, properties, etc. Then we will continue this function of interpretation of difficult classes. And, at last, we will define truth conditions for OWL axioms and the relations of the logical investigation between ontologies.

OWL the M_{OWL} model represents a triple $\langle R, R_D, R_O, I_C, I_P, I_I, I_L \rangle$. The set of R is area of resources, with $R_O \subseteq R$ a set of objects or separate copies, and $R_D \subseteq R$ a set of data types or literal values. Let's pay attention that $R_D \cup R_O = \oslash$. Every I_I is interpretation of function for classes, properties of separate names and literals. More precisely:

- $I_C(owl:Thing) = R_O \subseteq R$;
- $I_C(owl:Nothing) = \subseteq R$;
- $I_C(owl:Literal) = R_D \subseteq R$;
- $I_C : V_C \to \rho(R_O)$;
- $I_C : V_D \to \rho(R_D)$;
- $I_P : V_{DP} \to \rho(R_O \times R_D)$;
- $I_P : V_{IP} \to \rho(R_O \times R_O)$;
- $I_P : V_{AP} \cup rdf:type \to \rho(R \times R)$;
- $I_P : V_{OP} \cup rdf:type \to \rho(R \times R)$;
- $I_I : V_I \to R_O$;
- $I_L : V_L \to R_D$.

Below in tab.1 the recursive extension of difficult classes is given.

Table I. THE RECURSIVE EXTENSION OF DIFFICULT CLASSES

Syntax	Semantics
C	$R_O \setminus I_C(C)$
$C_1 \sqcap C_2$	$I_C(C_1) \cap I_C(C_2)$
$C_1 \sqcup C_2$	$I_C(C_1) \cup I_C(C_2)$
$\forall P.C$	$\lvert o \in R_O : \langle o, o' \rangle \in I_P(P) \Rightarrow o' \in I_C(C)$ for all $o' \rvert$
$\exists P.C$	$\lvert o \in R_O : \langle o, o' \rangle \in I_P(P) o' \in I_C(C)$, for some $o' \rvert$
$n \leq P$	$\lvert o \in R_O : \lvert o' : \langle o, o' \rangle \in I_P(P) \rvert \leq n \rvert$
$\forall T.D$	$\lvert o \in R_O : \langle o, d \rangle \in I_P(T) \Rightarrow d \in I_C(D)$ for all $d \rvert$
$\exists T.D$	$\lvert o \in R_O : \langle o, d \rangle \in I_P(T) d \in I_C(D)$, for some $d \rvert$
$n \leq T$	$\lvert o \in R_O : \lvert d : \langle o, d \rangle \in I_P(T) \rvert \leq n \rvert$
$OneOf(i_1, ...i_k)$	$\lvert (I_I(i_1), ..., I_I(i_k) \rvert$
$OneOf(l_1, ...l_k)$	$\lvert (I_L(l_1), ..., I_L(l_k) \rvert$

Consistencies and logical consequence fitting ontology are defined as follows: considering the dictionary V and ontology of $O ::= T - axioms \cup A - axioms$, we have

$M_{OWL}| = O$ iff $M_{OWL}| = \psi$, for all $\psi \in O$

and any linguistic element in O is supported in V

$O| \neq \perp$ iff $M_{OWL}| = O$, for some M_{OWL}

$O| = O'$ iff $M_{OWL}| = O \Rightarrow M_{OWL}| = O'$, for all M_{OWL}

IV. SYNTAX AND SEMANTICS OF SWRL

A. OWL DL and ML Rules

In this section it will be a question about distribution of OWL DL on SWRL which represents a combination from OWL DL and ML Rules (Rule Markup Language). Rules are defined as: prior and posteriori. If all operators in the previous expression are defined as truthful, then all statements in a further expression applicable. Thus, new properties can be appropriated to copies, in the ontology based on a current status of the knowledge base. SWRL also defines library of embedded functions which can be applied to copies. They include numerical comparing, simple arithmetical actions and manipulation with lines, temporal functions.

Semantics is based by SWRL on OWL DL so doesn't support direct reasons about classes and properties. The rule SWRL contains the previous part which is mentioned as a body, and the following part which is mentioned as the head. Both the body and the head are formed from the positive conjunction of atoms:

$$atom \wedge atom... \Rightarrow atom \wedge atom$$

While SWRL doesn't support objections of atoms or an objection as a failure or a disjunction, it supports a classical objection. For example, programmer ($?P$) represents atom where the programmer is the class name OWL, and $?P$ is replaceable that represents OWL an individual. Informally the rule SWRL can be read that if all atoms in a prior part truthful, then, the following part, also be truthful. There are seven types of atoms, a constant look $P(arg_1, arg_2...arg_h)$, that is predicate P_i his arguments:

- class atoms;
- atoms of properties of individuals;
- atoms of properties which are transferred on values, data;
- atoms of different individuals;
- atoms of similar individuals;
- built-in atoms;
- data span atoms.

DLP because it saves complete expressiveness of DL in addition with language of rules is suitable for obtaining bigger expressiveness, SWRL more, than. For this reason, strongly safe subset of SWRL as the best combination of OWL and rules as it saves solubility in case of minimization of losses in expressiveness is represented.

B. SHOIN (D)

Syntax of SHOIN (D) – DL is equivalent to syntax of OWL DL, and is finite, isn't sufficient to write rules. Thus, there is a need to rely on syntax of FOL. However, considering that SWRL is own extension of the OWL DL language, it doesn't make any sense to express SWRL of a formula partially in syntax of DL and partially in syntax of FOL. Fortunately, there is a simple transformation between the DL formulas and formulas of FOL [8]. Further we will assume that everything SWRL of a formula express in syntax of FOL, according to the equivalence given in [9,10].

The SWRL dictionary is OWL DL of the dictionary V with adding of sets:

- V_{IX} for the separate variables designated through x, y, z;
- V_{DX} for the variables of data type designated through m,n;
- $V_{built-in}$ for the built-in names.

Any variable in V_{IX} or a name in V_I will be called the term an object, and we will designate through t with indexes if it is necessary. The term data type, we will designate through V, either a literal in V_L or a variable of data type in V_{DX}.

The logical SWRL dictionary expands OWL logical the dictionary with the help $\rightarrow$ and $\wedge$.

As SWRL is approved in FOL, its logical lexicon is equivalent to FOL, namely the functional sheaves ($\wedge, \vee, \rightarrow, \neg$) and quantifiers ($\exists, \forall$).

The set of SWRL atoms is determined by the following rule:

$$SWRL - atom ::= C(t)|D(v)|P(t_1, t_2)|T(t, v)|t_1 = t_2|t_1 \neq t_2$$

where With represents the class OWL (atomic or complex); $P \in V_{IP}$ OWL atomic property, $D \in V_{DC}$ class OWL data type; and $T \in V_{DP}$ property OWL data type.

The rule set of SWRL is the smallest set constructed of SWRL atoms, such where each element has the form:

$$A_1 \wedge ... \wedge A_2 \rightarrow A$$

where A_i and A SWRL atoms. And the head governed; and (perhaps empty) finite connection $A_1 \wedge ... \wedge A_k$ is a rule body. We will designate rules through r. There is k universal quantifiers which determine volume by all rule and it connects variables in the rule. X it is possible to set somehow as they are only universal quantifiers, and their changeover won't enter errors.

- classes OWL (i.e. their FOL conversion);
- OWL axioms and facts (i.e. their FOL conversion);
- SWRL of rules.

The SWRL model is designated through M_{SWRLg} expands the M_{OWL} models with function of assignment of

$$g ::= g_I \cup g_D$$

where:

- $g_I : V_{IX} \rightarrow R_O$;
- $g_D : V_{DX} \rightarrow R_D$.

The relations of SWRL expand OWL relations as follows:

$M_{SWRLg}| = C(t)$ iff $g_I \cup I_I(t) \in I_C(C)$

$M_{SWRLg}| = P(t_1, t_2)$ iff $g_I \cup I_I(t) \in I_C(C)$

$M_{SWRLg}| = t_1 = t_2$ iff $\langle g_I \cup I_I(t_1), g_I \cup I_I(t_2) \rangle \in I_P(=)$

$M_{SWRLg}| = t_1 \neq t_2$ iff $\langle g_I \cup I_I(t_1), g_I \cup I_I(t_2) \rangle \notin I_P(=)$

$M_{SWRLg}| = C(v)$ iff $g_D \cup I_L(v) \in I_C(C)$

$M_{SWRLg}| = T(t, v)$ iff $\langle g_I \cup I_I(t), g_D \cup I_L(v) \rangle \in I_P(D)$

$M_{SWRLg}| = A_1 \wedge ... \wedge A_2 \rightarrow A$

iff $M_{SWRLg}| = A_1 \wedge ... \wedge A_2 \Rightarrow M_{SWRLg}| = A$

C. Protege-owl API

Such popular development environment of ontologies as Protégé includes plag-in Swrltab, for creation and processing of the rules SWRL [3,10]. SWRL is supported by the moralist of Pellet to the place where rules can be defined as "Dl-safe".

Protégé [11] represents a flexible platform which prepares for development of arbitrary models of managed applications and components. It has an open architecture which allows programmers to integrate $plag_n$ which can appear in the form of separate inserts, specific components of the interface of the user ($v_d zheta$), or carry out any other tasks on the current model.

Protege provides several extension points where developers can dynamically add components as so-called plug-ins. The following fig.1 illustrates the types of plug-ins that you can create for the Protege-OWL editor.

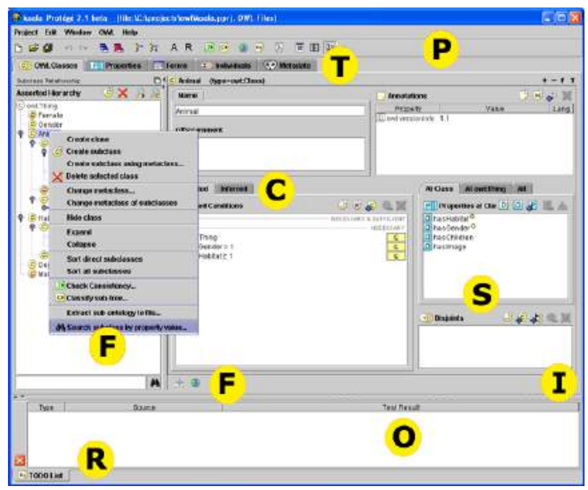

Figure 1. Plug-ins that can be created for the Protege-OWL editor

- S - Slot widget plug-ins are a Core Protege feature. A slot widget is a plug-in that can display and edit a property value on a form. Examples of default slot widgets include the list of disjoint classes, the conditions widget, and the annotation properties widget. You can create your own slot widgets and add them to the forms using the Forms tab.
- P - Project plug-ins are a Core Protege feature. They allow programmers to execute arbitrary code when a project is created, loaded, or closed. In particular, they can be used to add menus or toolbar buttons. They can also be used to attach arbitrary listeners to a knowledge base, such as agents.
- F - Resource action plug-ins can appear in the right-click menu of a selected class, property, or individual, or in the lower left corner of a form (as shown by the second 'F' above). A resource action plug-in must be a subclass of ResourceAction and you need to add an entry "ResourceAction=True" to your manifest file. Then, the ResourceAction is able to decide whether it wants to appear in the context menu, or also in the icon bar at the bottom left corner of a form.

- I - Resource display plug-ins can be used to add arbitrary components to the lower right corner of each form. You need to subclass ResourceDisplayPlugin and add an entry "ResourceDisplayPlugin=True" to your manifest file. Then you get a reference to a resource, e.g., an owl:Class, and a JPanel in which you can add buttons or other small components.
- O - Ontology test plug-ins are plug-ins that will be executed when the user presses the test ontology buttons. Each test must be a subclass of OWLTest and requires a manifest entry (check the Protege-OWL editor's manifest file for examples). The tests can return a test result object, which is then used to display results to the user.
- R - Result panel plug-ins are arbitrary components that can be displayed as a tab at the bottom of the screen. Examples include the "Find Usage" results, the classification output, and the ontology test results. You must subclass ResultsPanel and can then use some standard services such as selecting a highlighted object from there. You can add or remove your result panels as a result of some action using the ResultsPanelManager.
- C - Conditions widget extension plug-ins can be installed by a project plug-in to add additional tabs to the conditions widget. This is currently in its infancy, but you can call ConditionsWidget.addNestedWidgetFactory to add your panel, e.g., to display the abstract syntax.

The Protege Programming Development Kit (PDK) has a lot of general information on how to write, package, and distribute plug-ins. The best way to get started is to examine existing plug-ins that were written for the Protege-OWL editor, e.g., OWLViz, OWLDoc, Protege Wizards, etc. Pay particular attention to the manifest and protege.properties files for these plug-ins. The latter is needed for your plug-in to declare a dependency on the Protege-OWL editor.

Protege-owl API [12] is open source code of Java library for OWL and RDF(S). API provides classes and methods for loading and saving the OWL files, requests and handling the OWL models of data, and also for execution of reasons on the basis of the mechanism DL. Besides, API is optimized for implementation of the user graphic interfaces.

Jena [13] is one of the most widely used by the Java API, for RDF and OWL, providing services for representation of model, parse, persistence of the database, execution of requests and some instruments of visualization. Protege-owl API (v 3.4) and lower versions integrated with Jena, and the Jena ARP analyzer is used by Protégé-owl parcer.

The Jena inference subsystem is designed to allow a range of inference engines or reasoners to be plugged into Jena. Such engines are used to derive additional RDF assertions which are entailed from some base RDF together with any optional ontology information and the axioms and rules associated with the reasoner. The primary use of this mechanism is to support the use of languages such as RDFS and OWL which allow additional facts to be inferred from instance data and class descriptions. However, the machinery is designed to be quite general and, in particular, it includes a generic rule engine that can be used for many RDF processing or transformation tasks.

The overall structure of the inference machinery is illustrated at Fig.2.

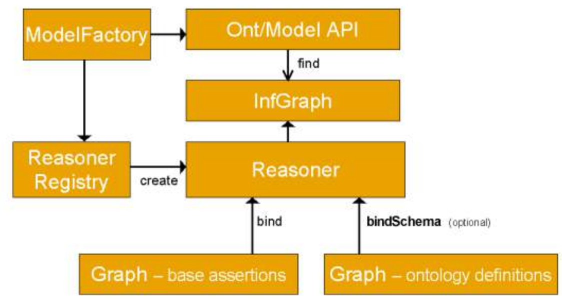

Figure 2. Overall structure of inference machinery

Applications normally access the inference machinery by using the ModelFactory to associate a data set with some reasoner to create a new Model. Queries to the created model will return not only those statements that were present in the original data but also additional statements than can be derived from the data using the rules or other inference mechanisms implemented by the reasoner.

As illustrated at the Fig. 2 the inference machinery is actually implemented at the level of the Graph SPI, so that any of the different Model interfaces can be constructed around an inference Graph. In particular, the Ontology API provides convenient ways to link appropriate reasoners into the OntModels that it constructs. As part of the general RDF API we also provide an InfModel, this is an extension to the normal Model interface that provides additional control and access to an underlying inference graph.

The reasoner API supports the notion of specializing a reasoner by binding it to a set of schema or ontology data using the bindSchema call. The specialized reasoner can then be attached to different sets of instance data using bind calls. In situations where the same schema information is to be used multiple times with different sets of instance data then this technique allows for some reuse of inferences across the different uses of the schema.

To keep the design as open ended as possible Jena also includes a ReasonerRegistry. This is a static class though which the set of reasoners currently available can be examined. It is possible to register new reasoner types and to dynamically search for reasoners of a given type. The ReasonerRegistry also provides convenient access to prebuilt instances of the main supplied reasoners.

Interfaces of the Protégé-owl model are located in an inheritance hierarchy. The review of available interfaces can be found in [14], with the basic interface of all RDF resources from which the received sub-interfaces for classes, properties and copies (objects).

There is an accurate discrepancy in model between the named classes and anonymous classes. The named classes are used for creation of separate copies while anonymous classes are used for determination of logical characteristics (restrictions) from the called classes. Classes which are logically defined can be used for creation of difficult expressions from restrictions of a class and the named classes. As well as restrictions, logical classes make a sense only if they are connected to the defined named class or property.

In SWRL, predicate characters can include the classes OWL, properties or data types. Arguments can be separate copies or value of the data OWL, or replaceable, related. All replaceable in SWRL are considered as universal quantifiers, from them by restriction of volume of this rule.

The $built-in$ SWRL are predicates which recognize that they undertake this one or several evaluated arguments. A row of the basic embedded functions for mathematical and urgent operations contain in SWRL Proposal. These built-in modules are defined in the $swrlb.owl$ [15] file. By agreement, basic SWRL $swrlb$ space name qualifier can precede all.

V. Conclusion

The article discussed issues related of integration of OWL DL and rules were considered. The explanation of semantics of OWL DL with determination of the OWL model, namely – interpretation functions, and with determination of conditions of truth for OWL axioms and the relations is given. And in the inference the method of integration of OWL and rules with SWRL is provided.

Advantages of use of SWRL were given in article that at the moment is the most widely used language of rules in community Semantic Web. It is described possibilities of Protégé-owl AP I as the popular development environment of ontologies of Protégé includes plag-in Swrltab, for creation and processing of the rules SWRL. There was analyzed that SWRL is supported by moralists of Protégé to the place where rules can be defined as "Dl-safe".

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ПОСЛЕДОВАТЕЛЬНОЕ ИЗЛОЖЕНИЕ МЕТОДА ДЛЯ ИНТЕГРАЦИИ OWL DL И SWRL С ИСПОЛЬЗОВАНИЕМ PROTÉGÉ-OWL API

Хала Е.А.

Эта статья посвящена описанию метода интеграции OWL DL и правил, с последовательным изложением. В статье описывается необходимость подобной интеграции, и анализируются семантики OWL DL, а также приводиться метод по интеграции OWL и правил с использованием специального языка правил SWRL.

Web-based Software for Automating Development of Knowledge Bases on the Basis of Transformation of Conceptual Models

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***Abstract*—The paper describes the web-oriented software designed for the development of intelligent system software packages (modules) intended for the code generation of knowledge bases based on the transformation of conceptual models. Software can be positioned as a framework for the development of knowledge bases also. It provides network access to a shared pool of knowledge bases projects and means for the visual design of knowledge bases.**

***Keywords*—web-based software, knowledge acquisition, knowledge bases, conceptual model, model transformation, code generation.**

I. Introduction

Currently the complexity of development process of intelligent systems is caused, mainly, by the features of the development phase of the knowledge bases (KB) which traditionally has been considered as a "bottleneck" [1]. The efficiency of this phase can be improved through the use of specialized software.

This paper describes the prototype of web-based software called the Knowledge Base Development System (KBDS). The KBDS implements the approach to the development of software components (modules) for the program code generation for KBs based on conceptual models presented in the XML format (the most common format for the exchange and storage of the different conceptual models) [2]. The C Language Integrated Production System (CLIPS) [3] and the Web Ontology Language (OWL 2) [4] were selected as the targeted knowledge base programming languages. This software is also an environment (framework) for the KBs development and it provides network access to a shared pool of KB projects and means for the visual design of KBs.

The KBDS prototype was implemented in PHP using the Yii2 Framework and JQuery, jsPlumb libraries. PostgreSQL was used as the object-relational database management system.

II. Knowledge Base Development System

The main purposes of the developed software are:

- the support of the development of software components for the program code generation for KBs based on different conceptual models;
- the support of the development of KBs (with the use of the developed software components).

Further we present the main functions and the architecture of KBDS in detail.

A. Functions

The main functions of KBDS in the context of the development of the software components are the following:

- the creation (import) of a meta-model of the source conceptual model on the basis on the XML schema (XSD) of this model, or by analyzing the model (Reverse Engineering);
- the visual representation and modification of the obtained meta-models;
- the visual design of a transformation model (in the form of a set of transformation rules) and the automatic TMRL (Transformation Model Representation Language) [2] code generation. In this case, a transformation rule is a description of how one or more constructs in the source language can be transformed into one or more constructs in the target language;
- the generation (assembling) of the software component based on the developed transformation model and the analyzer and generator units selected (depends on the type of the software component).

The KBDS provides the following main functions for the design of the KBs:

- the code generation for KBs on the targeted knowledge base programming language (CLIPS or OWL) using the software components developed;
- the automated synthesis of an ontological and a rule-based model (the internal representation of knowledge in the KBDS) based on the analysis of conceptual models;
- the storage and representation of obtained knowledge with the use of these models;
- the use of the special graphic notation - Rule Visual Modeling Language (RVML) [5] for the representation and modeling the logical rules;
- the visual representation and modeling knowledge in the form of ontological model.

B. Architecture

The KBDS has the client-server architecture (Figure 1) which allows to implement the main factions.

The client part of the KBDS includes the following main modules:

- the RVML editor that provides a visual representation and editing the logical rules with the aid of RVML;
- the ontology editor that provides a visual representation and editing knowledge in the form of a graph (ontological model);
- the meta-model editor that provides a visual representation and editing the meta-model elements;
- the transformation model editor that provides a visual representation and editing the transformation rules.

The server part of the KBDS includes the following main modules:

- the administration module that provides an user interaction with the KBDS (the limitation of user rights, the collection and analysis of various statistical information, etc.);
- the knowledge bases management module that provides a creation and managing KB projects;
- the meta-level management module that provides an internal representation of knowledge in the KBDS in the form of the rule-based and ontological models. These models allow us to abstract form the features in elements descriptions of various knowledge representation languages which are used in the implementation of KBs (for example, CLIPS, Jess, Drools, RuleML, OWL, SWRL, etc.) and to store knowledge in own independent format;
- the software components development module that provides the creation and managing software component projects, as well as code generation of the software components based on the developed transformation model and the analyzer and generator units selected;
- software components that provide a synthesis of the KB model (ontological or rule-based models) based on the analysis of conceptual models and a program code generation for a KB (CLIPS or OWL) based on the analysis of the KB model or the source conceptual model.

The architecture of a typical software component and a conceptual KBDS architecture are discussed in [2], [6] in detail.

C. Types of the software components

The KBDS allows to develop the following types of software components depending of transformations:

- the integrated components for the analysis that provide a formation of the rule-based or the ontological models based on the transformation of a conceptual model;

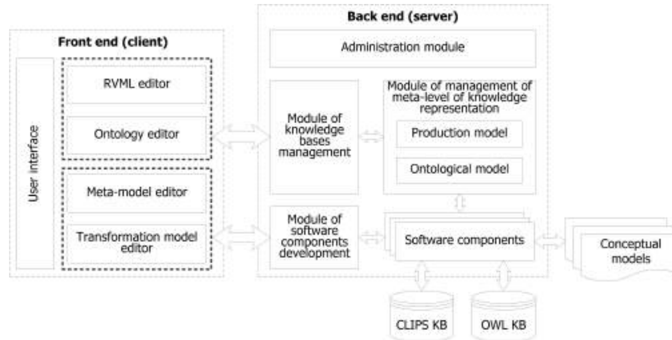

Figure 1. The client-server architecture of the KBDS

- the autonomous components for the program code generation that provide a program code generation for a KB on CLIPS or OWL based on the transformation of a conceptual model.

At the same time, the previously developed integrated software components for the code generation for CLIPS and OWL are provided to the user by default.

Description of the components is discussed in [2] in detail.

D. User roles

The developed prototype of web-based software (KBDS) is focused on the non-programmers (experts, knowledge engineers, analysts, etc.).

The KBDS supports the following user roles:

1) "guest" is a unregistered user, which can develop the KBs only (has limited access rights);
2) "developer" is a registered user, which can develop the KBs and software components, create user groups (has extended access rights);
3) "administrator" is a registered user who have access to all functions of the KBDS (has full set of access rights).

E. User interface

The user interface of web-based software (KBDS) is composed of five main elements (Figure 2):

1) the main menu that contains the main KBDS sections ("Account", "My projects", "Contacts" and "Administration");
2) the navigation chain (breadcrumbs) that is a path through the KBDS pages from the root to the current worksheet;
3) the right additional submenu contains all the possible actions that are available to the user within the section selected;
4) the workspace that is an basic element of the user interface that contains the semantic content of the selected page (section);
5) the bottom block (footer) that contains contact information and copyright.

Figure 3 shows the meta-model editor form (the meta-model for the XTM CmapTools concept maps is opened).

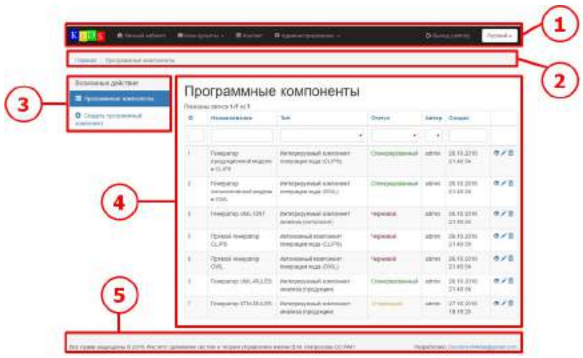

Figure 2. The main element of the KBDS user interface

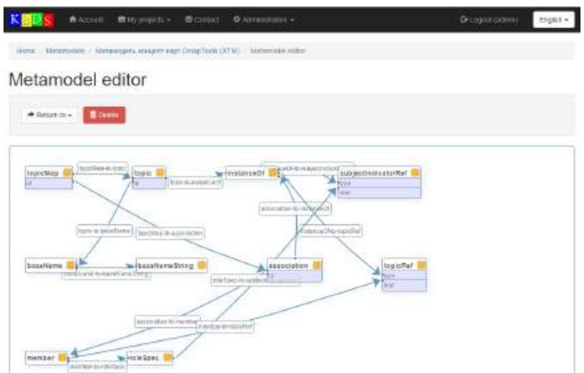

Figure 3. The meta-model editor form

Figure 4 shows the transformation model editor form (the scenario for transformation of the XMI UML class diagrams to rule-based model is opened).

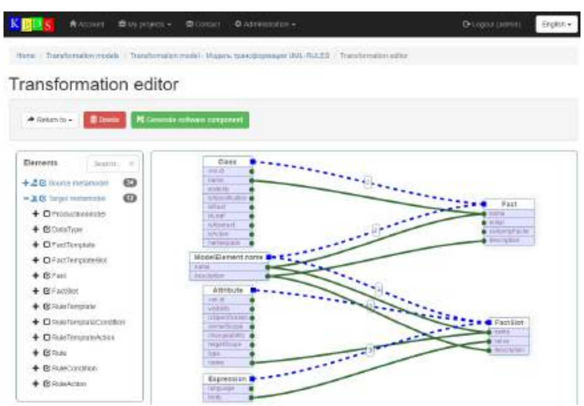

Figure 4. The transformation model editor form

Figure 5 shows the form of of generated transformation model code.

Figure 6 shows the RVML editor.

III. An illustrative example

Let's consider an illustrative example of a knowledge base design fragment using the proposed approach and software. IBM Rational Rose Enterprise was used as the UML-model source. The example analysed UML class diagram is presented in Figure 7.

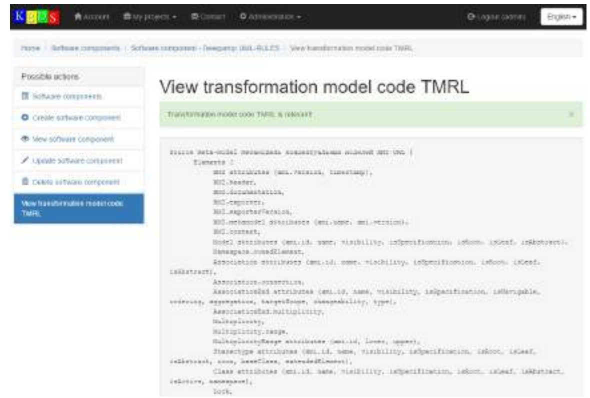

Figure 5. The form of generated transformation model code

Figure 6. The RVML editor

The following XML document fragment corresponds to the UML-model is obtained:

```
...
<UML:Stereotype xmi.id = 'S.339.1116.39.0'
    name = 'assert' visibility = 'public'
    isSpecification = 'false' isRoot = '
        false'
    isLeaf = 'false' isAbstract = 'false'
    icon = '' baseClass = 'Association'
    extendedElement = 'G.13' />
<UML:Class xmi.id = 'S.339.1116.38.1'
    name = 'Sole' visibility = 'public'
    isSpecification = 'false' isRoot = '
        true'
    isLeaf = 'true' isAbstract = 'false'
    isActive = 'false' namespace = 'G.0' >
  <UML:Classifier.feature>
    <UML:Attribute xmi.id = 'S
        .339.1116.38.2'
        name = 'Material' visibility = '
            private'
        isSpecification = 'false'
            ownerScope = 'instance'
        changeability = 'changeable'
            targetScope = 'instance'
        type = 'G.16' >
        <UML:StructuralFeature.
            multiplicity>
```

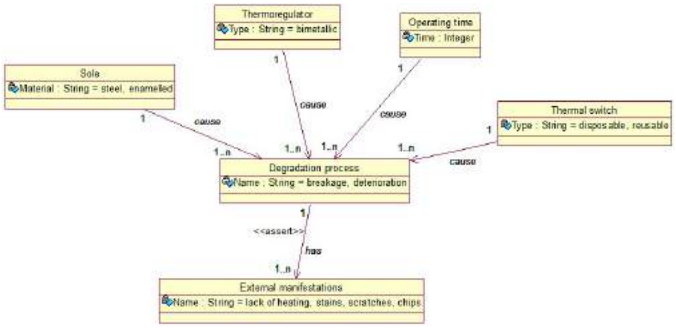

Figure 7. The analysed UML class diagram

```
            <UML:Multiplicity >
              <UML:Multiplicity.range>
                <UML:MultiplicityRange xmi
                   .id = 'id.3400316.11'
                  lower = '1' upper = '1'
                      />
              </UML:Multiplicity.range>
            </UML:Multiplicity>
        </UML:StructuralFeature.
            multiplicity>
        <UML:Attribute.initialValue>
            <UML:Expression language = ''
                body = 'steel, enamelled'
                   />
        </UML:Attribute.initialValue>
    </UML:Attribute>
  </UML:Classifier.feature>
</UML:Class>
<UML:DataType xmi.id = 'G.16'
      name = 'String' visibility = 'public
      '
      isSpecification = 'false' isRoot = '
         false'
      isLeaf = 'false' isAbstract = 'false
         ' />
...
```

Furthermore, the user creates a new KB project and imports conceptual model of a subject domain (in our case, the industrial safety examination of petrochemical facilities).

The concepts and relations extracted from this XML document and mapped to the production model can be presented using the RVML notation for further modification and validation (Figure 8).

The following generated CLIPS KB code fragment corresponds to the RVML model is obtained:

```
...
(defrule Sole+Thermoregulator+Operating
    time+Thermal
  switch->Degradation process
    (declare (salience 2))
    (Sole (Material "steel, enamelled") )
    (Thermoregulator (Type "bimetallic") )
    (Operating time (Time "") )
    (Thermal switch (Type "disposable,
        reusable") )
```

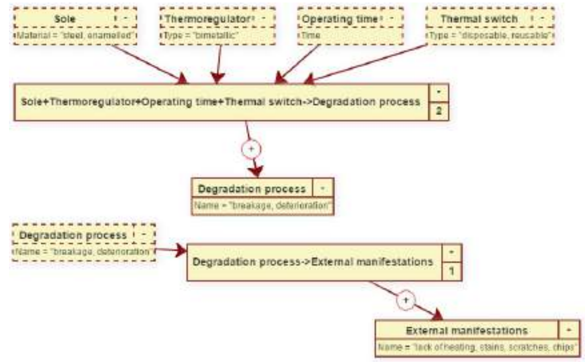

Figure 8. The obtained RVML model

```
    =>
    (assert
        (Degradation process (Name "
            breakage, deterioration") )
    )
)
(defrule Degradation process->External
    manifestations
    (declare (salience 1))
    (Degradation process
        (Name "breakage, deterioration")
    )
    =>
    (assert
        (External manifestations
            (Name "lack of heating, stains
                , scratches, chips")
        )
    )
)
```

IV. Discussion

The efficacy evaluation of the use of the developed software (KBDS) is carried out within a case study. The main objective of the case study was to assess the complexity of the development of KBs for expert systems with the use of the proposed approach and software (a UML-modeling tool + the KBDS, let's denote this approach as A1) and compare it with the complexity of other approaches:

- a UML-modeling tool [7] + the other software for the KB design, in particular, ClipsWin [9] (let's denote this approach as A2);
- without any a UML-modeling tool, but with the use of software for the KB design, in particular, ClipsWin (just a pure programmer's approach, let's denote this approach as A3).

IBM Rational Rose is chosen as a UML-modeling tool [8].

There are 20 variants (tasks) for the design of static expert systems for solving problems of diagnosing or prognosis in different subject areas (Table 1). Some constraints were imposed on the characteristics of subject areas models and KBs (on the tasks), in particular:

- the number of subject area entities: 5-10;
- the number of properties of subject area entities: 3;
- the number of connections between subject area entities: 5-10;
- the number of cause-effect relations (generalized rules): 3-4;
- the number of instances of cause-effect relations (possible concrete rules): 10-15.

Using the constraints provides the possibility of multiple repetitions of the tasks and their time compactness.

Table I. VARIANTS OF TEST TASKS

Variant	Domain entities	Connections	Cause-effect relations	Rules
1	6	5	3	10
2	5	6	3	10
3	8	5	3	10
4	5	8	4	11
5	8	7	3	12
6	9	5	3	10
7	5	6	3	14
8	8	7	4	14
9	6	5	3	15
10	7	10	3	12
11	5	6	3	11
12	5	6	3	12
13	7	7	3	14
14	8	5	3	11
15	7	6	3	18
16	6	8	3	14
17	6	5	3	11
18	8	7	3	12
19	7	8	3	10
20	5	7	3	12

The time criterion used (the time required to perform certain stages of development of expert systems) to assess the complexity. The assessment was carried out in the following stages [1], [10]: conceptualization, formalization, realization.

The main results of the conceptualization and formalization stages are the conceptual models of the subject areas presented in the form of UML class diagrams. The main results of the implementation stage are a syntactically corrected program codes of the KBs, checked on the adequacy and consistency.

For each variant (task) 3 results describing the time used are obtained, the average of their values are presented in Figure 9.

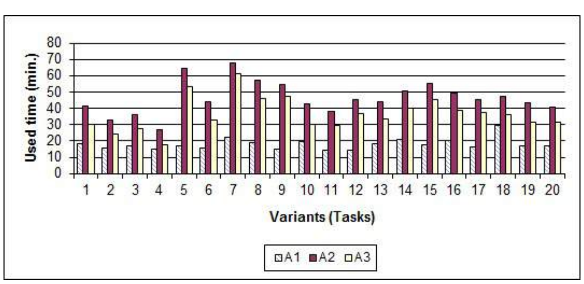

Figure 9. The results of the evaluation

Let's note features of performing the work at various stages for different approaches:

- A2: This approach provides the greatest time performance and uses IBM Rational Rose Enterprise for conceptual modeling of the subject area. The greatest time performance is caused by the hand transfer of the conceptual models obtained to ClipsWin (due to the absence the function of automatic code generation for the KB on the basis of conceptual models);
- A3: Functional limitations of the ClipsWin in the part of editing typing codes caused the application of the additional text editor (Programmer's Notepad) at the stage of realization. In particular, first, the description of the code in an external text editor (using the copying and pasting of individual blocks of a code) is carried out, and then the resulting code is imported into ClipsWin, which carries out the syntax check. In practice, using this scheme, the creation of KBs took 1.5 time less.

Analysis of the effectiveness of the proposed approach and software (KBDS) by the time criteria showed that the effectiveness of the development of KBs by the A1 can be increased 60.3% vs. A2 and 48.2% vs. A3 in an average due to automatic code generation based on conceptual models, which in turn allows:

- to increase the effectiveness of using the results of the conceptualization and formalization stages in the form of UML class diagrams, considering them not as static images, but as a basis for the automatic formation of the program codes in accordance with the ideology of a model-driven approach [11]. A Model-Driven Approach (Model-Driven Engineering or Model-Driven Architecture) is a software design approach which uses the conceptual (information) models as the major artifacts for software development [12], [13];
- to reduce the risk of design errors by enabling rapid prototyping KBs and getting their program codes;
- to eliminate programming errors (hand coding errors) by automatically transferring the elements of the conceptual models in CLIPS language constructs.

In addition to test cases designed to demonstrate the principal possibility of the application of the approach and its advantages, this approach was used to design the KB of the decision-support system for the industrial safety examination of petrochemical facilities [14], in the part of the definition the degradation processes and recommendations to reduce their rate.

V. CONCLUSION

The development of KBs for intelligent systems can be improved by acquiring subject domain knowledge presented in the form of conceptual models. This paper describes the prototype of web-based software called the Knowledge Base Development System (KBDS). This software implements the approach proposed by the authors [2].

The description of main functions, the client-server architecture, the user interface, user roles and types of software components are presented. The efficacy evaluation of the use of the developed prototype of web-based software (KBDS) is also given.

There are some features of the KBDS:

- the program code generation for CLIPS or OWL based on the transformation of conceptual models presented in the XML format. This feature significantly reduces the creation time for KBs. The proposed approach does not eliminate errors due to inaccurately or incompletely analysed conceptual models, however, the automatic model-based program code generation uses the principles of rapid prototyping to implement KBs;
- the modularity: the ability to expand the KBDS by adding new software components;
- the visual construction of the transformation rules and the automatic TMRL code generation;
- the use of the rule-based and ontological models for generalized representation and storage of acquired knowledge that, in turn, allows to support the code generation for various knowledge representation languages (eg, CLIPS, OWL, etc.);
- the non-programmers orientation. This feature is implemented by a set of editors that provide the description of the logical rules in the RVML and ontological (conceptual) knowledge in the form of a graph. The implementation of this feature expands the community of the KBDS users by experts, knowledge engineers, analysts;
- the possibility to support the collective, distributed work of specialists in the process of creating the KBs.

At present, the prototype of software is used in the learning process in Irkutsk National Research Technical University (IrNRTU) with in "CASE-tools", "Means of information technologies" and "Programming technologies" courses.

Future work will focus on improving the software support for the OWL2 as another target knowledge representation language and the algorithms support for the analysis of fuzzy conceptual models.

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ВЕБ-ОРИЕНТИРОВАННАЯ ПРОГРАММНАЯ СИСТЕМА АВТОМАТИЗАЦИИ РАЗРАБОТКИ БАЗ ЗНАНИЙ НА ОСНОВЕ ТРАНСФОРМАЦИИ КОНЦЕПТУАЛЬНЫХ МОДЕЛЕЙ

Дородных Н.О.

Рассмотрена веб-ориентированная программная система (Knowledge Base Development System, KBDS) автоматизации разработки программных компонентов (модулей) интеллектуальных систем. Создаваемые с помощью системы компоненты предназначены для генерации кода баз знаний (представленных в формате CLIPS и OWL) на основе трансформации концептуальных моделей (представленных в формате XML). Система позволяет не только создавать программные компоненты, но она также является средой для разработки баз знаний, обеспечивая сетевой доступ к общему пулу проектов баз знаний и предоставляя средства для визуального проектирования баз знаний. Разработанная система обладает клиент-серверной архитектурой и ориентирована на непрограммирующего специалиста. Приведено ее описание и оценка эффективности.

About the Specialization of Model-Driven Approach for Creation of Case-Based Intelligent Decision Support Systems

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Abstract—**The paper describes the specialization (modification) of the model-driven approach in the context of the development of case-based intelligent decision support systems. The specialization includes: the redefinition of the basic steps of the process of the software creation (their structure and content) and the models used. It is proposed to use: ontology as the computation-independent model (CIM), which will provide a complete and consistent description of the concepts and relations of the subject domain and their visual representation in the form of a graph; XML-like specification as a platform-specific model (PSM), which takes into account features of the description of cases.**

Keywords*—*model-driven approach, cases, knowledge bases, decision support systems, code generation.

I. Introduction

The problem of improving the efficiency and quality of development of problem-oriented intelligent systems (including knowledge bases (KB) and expert systems (ES)) is still relevant. This problem can be solved in different ways: from improving the development approaches (methodologies) up to creating and using specialized software [1]. Thus, there are some tendencies in this area:

- the development and application of software for ontological and cognitive modeling and CASE-tools (Protégé, FreeMind, Xebece, TheBrain, XMind, IBM Rational Rose, StarUML, ect.). These systems allow to create graphical conceptual models corresponding to the key abstractions of software;
- the development and application of specialized editors and shells for ESs (Expert System Designer, Expert System Creator, ARITY Expert Development Package, CxPERT, Exsys Developer, ect.). These systems allow to implement a formalized description of domain concepts and KB structures on a certain programming language (knowledge representation language), but have the low integration ability with CASE-tools, in most cases they support the one a particular language;
- the use of integrated development environments (frameworks) and unified approaches, which provide coverage of all stages of the life cycle of knowledge based systems and integration of the first two tendencies [2], [3], [4], [5].

In general, the existing solutions (results of mentioned directions) allow to improve the effectiveness of the intelligent systems development process, but don't solve the problem of portability of the developed systems to another technology or software platform (the operating system or the programming language).

One of the solutions for this problem is to use approaches based on Generative Programming [6], in particular, a model-driven approach, which provides the ability to develop multi-platform software.

II. Model-Driven Approach

A Model-Driven Approach (Model Driven Software Development or Model-Driven Engineering, MDE) is a software design approach which uses the information models as the major artifacts that, in turn, can be used for obtaining another models and generating programming codes [7].

Thus, the core ideas of the model-driven approach are:

- a model is the key artifact during the development process of software (a formal specification of the function, structure and behavior of a system within a given context);
- the software development process is a sequence (a chain) of transformations of models (from the more abstract to the less abstract).

Some of the better known MDE initiatives are the following:

1) Model-Driven Architecture (MDA), which is a registered trademark of Object Management Group (OMG) [8], [9], [10]. The main idea of the approach is to build an abstract meta-model for the management and exchange of metadata (models) and setting the ways of their transformation into a software-supported technology (Java, CORBA, XML, etc.). MDA specifies three default viewpoints on software: computation independent, platform independent and a platform specific. The viewpoint is an abstraction

technique for focusing on a particular set of concerns within a system while suppressing all irrelevant detail. The viewpoint can be represented via one or more models;

2) Eclipse Modeling Framework (EMF) is an Eclipse-based modeling framework and code generation facility for building tools and other applications based on a structured data model [11]. EMF provides the foundation for interoperability with other EMF-based tools and applications. The heart of EMF is Ecore. Ecore is the special language for description of meta-models (implementation of OMG's Essential Meta-Object Facility, EMOF). The basic tools to work with meta-models and skeletal code generation of software (programming skeletons) are EMF.Core, EMF.Edit, EMF.Codegen;
3) Model-Integrated Computing (MIC) has been developed over two decades at ISIS, Vanderbilt University for building a wide range of software systems. MIC focuses on the formal representation, composition, analysis, and manipulation of models during the design process. It places models in the center of the entire life-cycle of systems, including specification, design, development, verification, integration, and maintenance [12]. MIC providing three core elements: the technology for the specification and use of the domain-specific modeling languages (DSML); the fully integrated metaprogrammable MIC tool suite, and an open integration framework to support formal analysis tools, verification techniques and model transformations in the development process; the three-level representation of the system development process (Application Level, Model-Integrated Program Synthesis Level, Meta-Level).

In the context of the development of case-based intelligent decision support systems, MDA is selected as the primary approach, as the most standardized version (initiative) of the MDE.

III. Model-Driven Architecture

A. The main MDA elements (specifications)

MDA itself is not a new OMG specification but rather an approach to software development [9] which is enabled by existing OMG specifications such as:

- MOF (Meta-Object Facility) – OMG's standard for model-driven engineering. Its purpose is to provide a type system for entities in the CORBA architecture and a set of interfaces through which those types can be created and manipulated. MOF is designed as a four-layered architecture (a conceptual modeling space). Every model element on every layer is strictly in correspondence with a model element of the layer above. MOF provides a means to define the structure, or abstract syntax of a language or of data [13];
- UML (Unified Modeling Language) – the OMG's standard for an object modeling in software development. UML is not the programming language, but the UML-based models allow to generate codes of software [14];
- XMI (XML Metadata Interchange) – the OMG's standard for exchanging metadata information (UML-based models, etc.) via Extensible Markup Language (XML). XMI is also commonly used as the medium by which models are passed from modeling tools to software generation tools as part of MDE [15];
- Query/View/Transformation (QVT) – the standard set of languages for model transformation (model to model transformation, M2 [6]) defined by the OMG. The QVT standard defines three model transformation languages (QVT-Operational, QVT-Relations and QVT-Core). All of them operate on models which conform to MOF meta-models. The QVT standard integrates the OCL (Object Constraint Language) 2.0 standard and also extends it with imperative features [16];
- MOF Model to Text Transformation Language (MOFM2T) – the OMG's specification for a model transformation language [17]. Specifically, it can be used to express transformations which transform a model into text (M2T) [6].

B. Software development stages

MDA specifies three default models of a system corresponding to the three MDA viewpoints defined above. These models can perhaps more accurately be described as layers of abstraction, since within each of these three layers a set of models can be constructed, each one corresponding to a more focused viewpoint of the system (user interface, information, architecture, etc.). Thus, MDA defines the software development process as a sequential transformation of these models. Consequently, the development process can be represented as a set of following stages:

- building a computation-independent model (CIM). It presents the system requirements, i.e. exactly what the system is expected to do, but hides all information technology related specifications to remain independent of how that system will be (or currently is) implemented. CIM plays an important role in bridging the gap which typically exists between these domain experts and the information technologists responsible for implementing the system;
- building a platform-independent model (PIM). PIM is a model of software that is independent of the specific technological platform used to implement it;
- building platform-specific models (PSM). PSM is a model of software that is linked to a specific technological platform (for example, a specific programming language, operating system, database, etc.). Thus PSM specializes PIM for a specific platform based on its model (Platform Description Model, PDM);
- generating program codes and/or specifications (using the generator) based on PSM.

As a result, we propose to adapt (modify) and apply the MDA/MDD approach for building the case-based intelligent decision support systems, including clarification and redefinition of the main elements and stages taking into account specifics of the developed software.

IV. PROBLEM STATEMENT

MDA can be formalized as follows:

$$MDA = \left\langle \begin{array}{l} L, CIM, PIM, PSM, PDM, \\ F_{CIM-to-PIM}, F_{PIM-to-PSM}, \\ F_{PSM-to-CODE} \end{array} \right\rangle \quad (1)$$

where an L – visual modeling languages, $L = \{UML\}$; CIM, PIM, PSM, PDM – corresponding models; $F_{CIM-to-PIM} : CIM \to PIM$, $F_{PIM-to-PSM} : PIM \to PSM$, $F_{PSM-to-Code} : PSM \to Code$ – model transformation rules.

Thus, the main purpose of this paper is to adapt (to specialize) the MDA methodology in the context of the development of case-based intelligent decision support systems, i.e. to define an MDE^{CBR}:

$$MDA^{CBR} = \left\langle \begin{array}{l} L^{CBR}, CIM^{CBR}, PIM^{CBR}, \\ PSM^{CBR}, PDM^{CBR}, \\ F^{CBR}_{CIM-to-PIM}, F^{CBR}_{PIM-to-PSM}, \\ F^{CBR}_{PSM-to-Code} \end{array} \right\rangle \quad (2)$$

V. MDA SPECIALIZATION

The MDA specialization includes:

- to use the original author's notation - RVML (Rule Visual Modeling Language [18]) as the additional visual modeling language: $L^{CBR} = \{UML, RVML\}$;
- to use the ontologies as computation-independent models (CIM), which provide a complete and consistent description of the domain concepts and relations, and also their visual representation in a graph;
- to use the original XML-like specification as a platform-specific model (PSM), which provide the description of cases (particularly: possible fuzzy property values and description for a membership function) and the formation of an operational level to work with the Data Based Management Systems (DBMS).

The development process of the case-based intelligent decision support systems is presented by the following sequence of stages (Figure 1):

Stage 1. Description of the subject domain that contains the main concepts and relations. At this stage, the user creates a computation-independent model (CIM). This model can be implemented in the form of an ontology or an UML-model (in particular, as a class diagram). In addition, the main architectural elements of system (such as the "input form", the "output form", the "inference engine" and etc.) is also produced at this stage.

The efficiency of this stage can be improved by reusing (transformation) the existing conceptual models created using various ontological and cognitive editors, such as CASE-tools (e.g., IBM Rational Rose, etc.) [19].

Most of the software that supports the MDA/MDD approach does not realize this stage and only allows one to develop the software starting at the next stage. In this case, the conceptual model of a subject domain (even presented in the form of an ontology) is considered as a platform-independent model (PIM) that describes the main concepts and business logic (that is acceptable for databases).

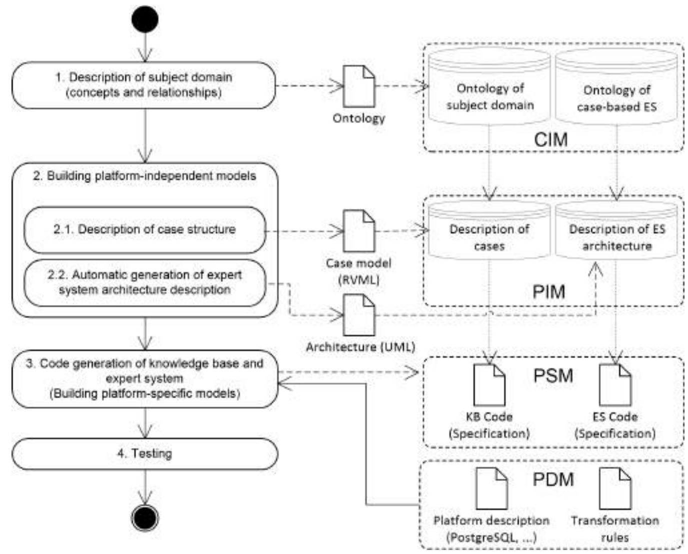

Figure 1. Stages and models of the specialized MDA

In the case of developing intelligent systems, this stage is necessary and corresponds to the stage of the conceptualization of knowledge. This stage allows one to pass from a general conceptual model of a subject domain to a knowledge representation model (with logical rules).

Stage 2. Building a platform-independent model (PIM) that describes the case structure with a clear separation of the "problem description" and "solution" parts. This model is obtained as a result of the automated transformation of a CIM with the subsequent clarification.

Visual modelling is one of the main aspects of the MDA approach. MDA traditionally uses a unified modelling language (UML) for building models. It should be noted that applying the MDA approach to develop specific software requires the use of UML extensions [20] that allow one to take into consideration some features of a subject domain (e.g., telecommunication or health.), architectures (e.g., real-time access and reliability), and programming languages and formalisms (e.g., CORBA or Prolog). So, it is proposed to use RVML as an additional visual modeling tool.

Stage 3. Building a platform-specific model (PSM) that is linked to a specific technological platform, in particular, DBMS.

Stage 4. Generating the codes for a KB and the case-based intelligent decision support system. At this stage, the interpretation of the UML-class diagram (that describes the software architecture) and RVML diagrams is performed. The main results of the interpretation are the program codes and specifications for an interpreter. In the process of interpretation and code generation, the platform description model (PDM) and rules for the transformation of models are used. In this case, a PDM describes the syntax and semantics of the programming languages for which program code is generated.

Stage 5. Testing. At this stage, the obtained program codes are tested in special software (in the interpreter).

It should be noted that the end user (an expert or a system analytic) only designs a CIM, a PIM and part of a PSM. All of the transformations of the models and the generation of program codes (with the possibility of modifications) are implemented with specialized software that includes a PDM.

The described sequence of stages almost coincides with a "standard" MDA approach, but the stage's content is redefined based on the designs of the case-based intelligent decision support systems.

VI. Conclusion

Efficient creation of KBs for solving problems in various areas requires the development and use of specialized methodical, algorithmic and program means. This paper describes the modification (adaptation) and application of the MDA/MDD approach for the development of the case-based intelligent decision support systems.

The modification includes: the use of the ontology as the CIM, the use of the RVML notation to create the PIM, and the use of XML-like specification as a platform-specific model (PSM) that takes into account the particular case descriptions, including description of fuzzy property values and a membership function.

The proposed approach will be the basis for the development of software.

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О СПЕЦИАЛИЗАЦИИ МОДЕЛЬНО-УПРАВЛЯЕМОГО ПОДХОДА ДЛЯ СОЗДАНИЯ ИНТЕЛЛЕКТУАЛЬНЫХ СИСТЕМ ПОДДЕРЖКИ ПРИНЯТИЯ РЕШЕНИЙ ПРЕЦЕДЕНТНОГО ТИПА

Дородных Н.О., Юрин А.Ю.

Рассмотрена специализация (конкретизация) модельно-управляемого подхода в контексте создания интеллектуальных систем поддержки принятия решений прецедентного типа. В частности: уточнены основные этапы процесса построения программных систем (их состав и содержание) и используемые модели. В рамках специализации предложено использовать: онтологии в качестве вычислительно-независимой модели (CIM) и XML-подобную спецификацию в качестве платформо-зависимой модели (PSM). Использование онтологии обеспечивает полное и согласованное описание понятий и отношений предметной области и их визуальное представление в виде графа; а предложенная спецификация учитывает особенности описания прецедентов.

The Semantic Space in Factorial of the Theory of Automatic Generation of Knowledge Architecture (TAGKA-2)

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***Abstract*—Combinatorial possibilities of TAGKA-2 [1] in Natural Language Processing, Natural Language Understanding, Inventive Problem Solving are presented by 696 192 modifications of 112 classes of actions in base calculation multiplied by 31 roles of individuals in each Field of Knowledge. Thus, the total number of TAGKA-2 formalisms is 21 581 952, while the Dictionary of Modern Russian Literary Language (in 17 volumes) contains 120 480 words. The amount claimed by authors of Russian Large Academic Dictionary is 150 000 words and the available electronic resources of the Institute of Linguistic Studies of Russian Academy of Sciences contain about 5 million Russian-speaking words of XVIII-XXI centuries based on 1,4 billion word usages [2].**

Keywords*—semantic code, semantic primitive, calculus of fields of knowledge, modification of action; recursion, artificial intelligence.

I. Introduction

T. Winograd in his research understood what is required from semantics: "converter working with the parser and providing data suitable for a logical deductive system. If you have the English grammar parser and the deductive system on the basis of knowledge about a particular subject, the role of semantics is reduced to filling the space between them" [3]. However, how to achieve that no one knew.

To the credit of the Belorussian science, V.V. Martynov reached essential progress in this area in creating a semantic coding approach [4]. He proposed a list of tasks to equip computer with encyclopedic knowledge consisting of five components:

1) To calculate semantic primitives, i.e. semantically irreducible kernel words and define rules of their combinatorics.
2) To define the necessary and sufficient set of formal characteristics constituting 'dictionary entry'.
3) To define a set of semantic operations for calculating a subject domain of any kind.
4) To propose heuristic teaching rules to work with the system.
5) To build a system of mutual references based on semantics [5].

In 1994, under the supervision of V.V. Martynov, A. Hardzei [6] proposed the first procedure of calculating the subject domains in the form of a directed graph of complex strings.

Use of the procedure has required to establish one-to-one (vector) transition between actions in basic semantic classifier and has led to creation of the Theory of Automatic Generation of Knowledge Architecture (TAGKA) founded on: the formal theory, the semantic counterpart, the table of actions as semantic elements, the algorithm defining roles of individs, and the graph of search of hyponyms through hypernyms [7].

In 2014 the new version – TAGKA-2 was developed. TAGKA-2 differs from the previous in: simplified algebraic apparatus, increased number of rules of interpretation of the standard superposition of individs, and minimized semantic calculus.

The number of operations with the strings of semantic code reduced to two. Now it is the algebra of the type:

$$A =< M, \star, ^{-} > \text{ [1].}$$

Where: M is a set of elements, '$\star$' is the operation of superposition, '$^{-}$' is the operation of extension.

II. Semantic Coding Evolution

A practical example of notation evolution for the semantic formula of the action "compress":

USC-1: $S(a)A_1\bar{S}(a)AO/O$ [8]

USC-6: $((XY)Z)((ZW)W')$ [9]

TAGKA-2: $Z((\bar{Z}\bar{W})W)$ [1]

Theoretically, there is a set of changes:

- A geometric model is introduced and consistency of the algebra is verified. Constructions leading to mathematical and semantic paradoxes are forbidden:
  XX
  XYX
  $XYZZWZ$
  $XYZZWZ(x)$
  A strict rule of right margin extension of multipliers is established:
  $X \rightarrow Y \rightarrow Z \rightarrow W$
- Algebraic operations are refined.

- Rules of creation, restriction, reduction, and transformation of algebraic expressions are presented in an explicit form.
- Now, there is only one rule of transformation – transposition.
- Non-commutative one-to-one (vector) transitions between algebraic expressions and their arguments are established:

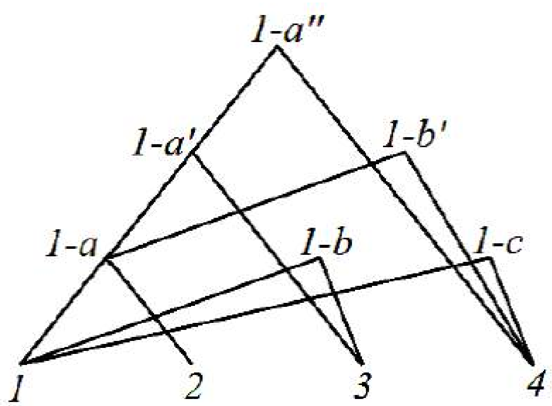
$$((X*\overline{X})*\overline{\overline{Y}})*\overline{Y} \rightarrow (X*(\overline{X}*\overline{\overline{Y}}))*\overline{Y} \rightarrow$$

attract: Y_2 imp X_2; cumulate: Y_2 imp X_2

$$X*((\overline{X}*\overline{\overline{Y}})*\overline{Y}) \rightarrow X*(\overline{X}*(\overline{\overline{Y}}*\overline{Y})) \rightarrow$$

constrict: Y_2 imp X_2; connect: Y_2 imp X_2

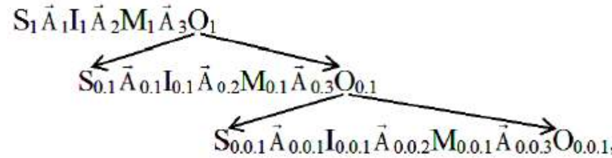
- The procedure to calculate subject domains and its semantics in the view of an oriented graph is defined:



- The algorithm of roles of individs (macro objects) is developed.
- 112 semantic primitives (abstract actions or classes of actions) are computed and grouped in the table as rows of semantic elements.
- All micro-actions are considered as modifications of class actions. The number of micro-actions only on the first modification level is $112 \cdot 111 = 12432$. On the second level it reduced in the progression n-1 for the second multiplier $112 \cdot 110 = 12320$. So the number of micro-actions almost doubles $12432+12320 = 24752$. It means the power of the system lays in the interval of factorials (9!; 10!), that is very large but finite [1].

[1]The precise number of micro-actions is calculated by C. Rykovski with the formula:
$S_n = \frac{2a_1+d(n-1)}{2} \times n$, where $L = 112$, $a_1 = L-1$, $d = -1$, $n = L-1$;
$S_n = \frac{2(L-1)+(-1)(L-1-1}{2} \times (L-1) = \frac{2L-2-L+2}{2} \times (L-1) = \frac{L(L-1)}{2}$;
$\sum = 112 \times S_n = \frac{L^2(L-1)}{2} = 696\,192$
Because of 31 roles of individs for each subject domain there is a final number of semantic formulas in TAGKA-2 is 696 19231 = 21 581 952.

- Were defined the interpretation rules of regular superposition of individs to define semantic counterparts for algebraic expressions, for example:
$\bar{\bar{\alpha}}_1 * \bar{\alpha}_1$ after $\alpha_1 * \bar{\alpha}_1$ (superposition of the surroundings of α_1 with its shell as a result of physical effect on the surroundings of α_1) – *mold* α_1;
$\bar{\bar{\alpha}}_1 * \bar{\alpha}_1$ after $(\alpha_1 * \bar{\alpha}_1) * \bar{\bar{\alpha}}_1 \simeq \alpha_1 * \bar{\bar{\alpha}}_1$ (superposition of the surroundings of α_1 with its shell as a result of informational effect on the surroundings of α_1) – *predispose* α_1;
$\bar{\alpha}_1 * \alpha_1$ after $\alpha_1 * \bar{\alpha}_1$ (superposition of the shell of α_1 with α_1 as a result of physical effect) – *form* α_1;
$\bar{\alpha}_1 * \alpha_1$ after $(\alpha_1 * \bar{\alpha}_1) * \bar{\bar{\alpha}}_1 \simeq \alpha_1 * \bar{\bar{\alpha}}_1$ when $\alpha_1 = \alpha, \beta$ (superposition of the shell of α_1 with α_1 as a result of informational effect) – *bring up* α_1.
- Was defined a procedure of consequent extension of multipliers in algebraic expressions when recursively expanding the geometric model:



where: S – subject, A – action, I – instrument, M – mediator, O – object.
- Compound strings are excluded and a description of the event is represented as non-commutative superposition of actions or as their non-commutative preposition. Moreover, superposition or preposition of actions covers the same superposition or preposition of micro-actions in recursion.

Let us consider some examples for superposition. The action "carry" is not considered as a combination of actions "hold" and "move" (see USC-6 [9]), but it is considered as a modification of the action "move" in the microsystem of the compound instrument and for the action "transport" of the action "move" in the microsystem of the compound mediator.

In that case, the action "fix" is in superposition to the action "move" because it is possible to hold without moving but it is not possible to move without fixing. It is impossible to move a motor car from the parking if a handbrake relatively to the ground fixes the car. It is necessary to release the brake and fix the car relatively to the hands by pressing them to the car.

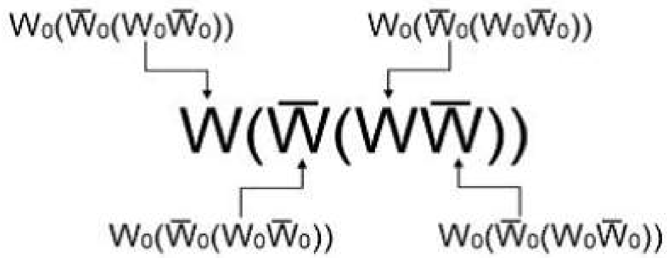
One more example: it is impossible to move a wall from the standing point because it fixed relatively to the ground. To do that, under the wall, let say, a sled should be inserted to unfix it relatively to the ground and creating a condition to push the wall by hands. So, "fixation" is a preliminary condition for any kind of movement. There is obvious superposition of actions: **fix** $\rightarrow$ **move**.

The next example is for preposition of the action. When you are cooking, it is not important what to do first: to place a pan on a gas stove and then to light it or to light the gas stove and then to put the pan. However, for the purpose of safety, it is preferable to put the pan and then to light the stove, or preposition: **put** $\rightarrow$ **light**.

The last example is about superposition of actions in recursion. To drill a titan plate it is necessary to cool a drill by a cooling liquid to save a drill. The process starts from pouring the liquid to a drilling point and then drilling is implementing. We can say that drilling is implemented on the condition of pouring the liquid: pour $\rightarrow$ drill.

So, to create the event a vector transition between actions has to be implemented.

Here is the example of recursion of the action “normalize” in TAGKA-2:



A canonized text, for the example, is "A doctor by means of a medicine treats a patient".

III. An Inventive Problem

How to remove the shell of an egg? According to the TAGKA-2 table of semantic elements, three possible solutions can be generated [1]:

1) In the subgroup “surroundings – shell” the solving action is “fractionize” form outside.
2) In the subgroup “shell – core” the solving action is “dissolve” (inset a dissolving reagent under the shell).
3) In the subgroup “core – shell” the solving action is “unclamp” from inside by expanding a volume of the core.

IV. Conclusion

TAGKA-2 is one of possible models of calculation of semantics and it demonstrates essential progress in semantic coding development especially in subject domain calculation. However, TAGKA does not claim to be exclusive and complete.

Semantics of natural language is versatile and allows different ways of formalizing. However, all methods, like Euclidean and non-Euclidean geometry, should be consistent and effective in its problem solving, and those who argue with that, as Reichenbach aptly said, only "confuse a rigor of the method with a limitation of a goal" [10].

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СЕМАНТИЧЕСКОЕ ПРОСТРАНСТВО В ФАКТОРИАЛЕ ТЕОРИИ АВТОМАТИЧЕСКОГО ПОРОЖДЕНИЯ АРХИТЕКТУРЫ ЗНАНИЙ (ТАПАЗ-2)

А. Н. Гордей

Комбинаторные возможности ТАПАЗ-2 в компьютерной обработке данных на естественном языке, понимании естественного языка, решении изобретательских задач представлены в виде 696 192 модификаций 112 макропроцессов базового исчисления с умножением на 31 роль индивидов каждой предметной области. Таким образом, общее количество формализмов ТАПАЗ-2 составляет 21 581 952, тогда как Словарь современного русского литературного языка в 17-и томах содержит 120 480 слов, заявленный объём Большого академического словаря русского языка – 150 000 слов, а имеющиеся электронные ресурсы Института лингвистических исследований РАН на 1,4 млрд словоупотреблений содержат около 5 млн русскоязычных слов XVIII–XXI вв.

Semantic Coding for Semantic Knowledge Inference

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***Abstract*—A pressing task of developing the effective knowledge inference tools attracts researchers of different interests in Computer Science. Semantic coding is a main component of computational semantics for knowledge inference on a semantically formalized basis. Universal semantic code (USC) of professor V.V.Martynov is a tool of semantic coding for meaning representation and inference. USC converts knowledge in the semantic code, implement axiomatic inference, and convert the semantic code into natural language. Independence of the semantic code from any kind of natural language is a tool of real-time multilingual knowledge generating and knowledge exchange through computer.**

Keywords*—*universal semantic code, knowledge representation, knowledge inference, formal semantics, natural language processing, semantic coding, verb classification.

I. Introduction

Can we explain how our long-time memory works? For instance, you just have listened the scientific report and memorized it. Later, on your department meeting, you retold the report to your coworkers. However, try to compare the initial text of the report with what you retold and you notice the essential difference between two verbal representations of the same report. If every listener of the report retells it after you, you will get many different verbal representations of the same text or the same knowledge.

Human memory determines the verbal perception. However, it is a question, in what form does our mind record the initial text? This is impossible to remember the content of the text without some expression tool. A psychologist Hoffman [8] writes, "… the information in the memory can be kept only in the form of the specific code." Repeating this idea several times, he assumes - some internal semantic code works between human information input and output.

Modeling the internal semantic code for the meaning representation and inference in the informational computer systems is a crucial problem of artificial intelligence.

USC defines semantic criteria in the following way [12], [13]:

1) Every semantic string of symbols corresponds to only one meaning and every string conversion corresponds to only one meaning conversion.
2) Declarative knowledge represented as procedural. Each object in the system considered not from the point what it is but what function it performs.
3) A USC verb classifier defines names of the classes and gives their symbolic representation paired with natural language interpretation

It seems expedient to determine the place USC occupies within the scope of formal knowledge representation models designed for artificial intelligence (AI) systems. Formal grammars generated based on a Chomsky [4] conception could be used for creating programming languages, but absence of semantic interpretation does not allow them to become knowledge representation languages with one to one correlation between syntactic and semantic elements.

As per Amarel [1] and Schank [17] priority in intellectual problem solving is given to knowledge representation, thus the necessity of developing language system has been predetermined. Natural language in its non-canonized form cannot meet this requirement [19]. A formal system with full semantic interpretation is embodied in Montague [16] grammar. However, Montague semantics is defined on the natural language word level without exposing its inner semantic structure. We could say by analogy that in this case the research covers only a molecular level (an atomic structure is missing), and easy to imagine what the level would have reached our technology if physics had shared the same fate.

The interpretation of Rene Tom [18] has the partial similarity of signs with their spatial analogues. For example, $\rightarrow$ is the conjunction, $\leftarrow$ is the separation, $\vdash$ is the start, $\dashv$ is the end. Unfortunately, it is impossible to convert one interpretation into another without formal representation of the notions.

Frames of Minsky [15], associative nets and semantic networks, first order predicates logic or modal logic are the most traditional models [9]. Several conventions for knowledge modeling are determined including production rules [5], structured objects [7] and logic programming [10]. The main disadvantage of them is the absence of tools of the word meaning representation. The understanding of the problem had initiated the development of the fuzzy and pseudo-physical logics [6].

There are three projects to create a language with formalized semantics, besides USC: the model of conceptual dependence proposed by Schank [17] the "meaning-text" model of Melchuk [14], and the theory of automatic generation of knowledge architecture (TAGKA) of Hardzei [21]. The basis of the first two are some primitives (semantic elements): primitive actions in Schank's model and lexical functions in Melchuk's, which form semantic notation of utterances. The primitives of the given models do not claim to be complete, independent and consistent in the strict sense of the word because of their empirical elaboration. USC is the first project of the language deductive theory of knowledge representation.

Hardzei proposes the theory having in the foundation semantic formalisms for knowledge representation and knowledge inference as well. The theory is based on USC of prof.

V.V. Martynov where were proposed semantic primitives, i.e. semantically irreducible kernel words, and the rules of their combinatorics were defined. In general, semantic coding is a process of converting natural language phrases to a chain of semantic primitives or semantic formulas and back. The author sees the essential difference of TAGKA vs USC in the method of defining a structure of the semantic formula and operations of conversion of semantic formulas to each other. Semantic coding has a crucial difference with Semantic Web where is no semantic formulas but semantic tags represented not formally but by means of natural language.

II. Linguistic interpretation and inference

There is in USC a formulated set of semantic axioms within the scope of some algebra. Each axiom represents a regular conversion of sense in explicit form. No kind of artificial intelligence systems can exist without semantic explication of sense.

For example, it is natural enough for a human to come to the following conclusion: 'The engineer has seen the device before that is why he would recognize it' or in a more general form, X has seen $Y \rightarrow X$ would recognize Y. If our system would be intellectual, it would know how to draw this immediate inference. In other words, the developer of AI system has to know the way of teaching a computer to draw such a kind of inference. Regretfully he does not know how to do it. Moreover, he cannot perceive how the human does it.

Here is another case of deduction: 'He has already played Rossini's "Tarantella" that is why he would play it' or in a more general form, X has played $Y \rightarrow X$ can possibly play Y. A human identifies the verb 'play' in spite of grammatical differences. Though the first deduction is reducible to the same postulate, we do not know how to. The human pure intuitionally easily uses such deduction [13].

Formalization of lexical semantics cannot solve AI problems because of the natural language vagueness that follows from the discrepancy between the complexity of the syntactic and semantic structures. Such discrepancy arises due to the ellipticity of natural language phrases. Thus the following phrase "Your child eats with his hands" is reconstructed in full as "Your child eats with his mouth, holding food with his hands" [19].

Making comparative analysis of the following phrases "John beats Jim" and "John expects Jim" we figure out that in spite of their full syntactic coincidence they have important semantic distinction. Asking the question "what does John do to Jim?" we get a regular answer "He beats him" and meaningless, in this case, "He expects him". Actually, the phrase "John beats Jim" has an "atomic" semantic structure while the phrase "John expects Jim" has a "molecular" one. Semantic reconstruction of the second phrase is: "John is staying where he expects Jim to come soon" [13].

III. USC verb classifier

In the semantic verb classifier, each verb stays in some class. USC operates with 54 verb classes of physical and 54 verb classes of informational strings [20].

Each verb is coded by the USC string defining a number of arguments of the string and their roles: X – subject, Y – instrument, Z – object, W – result.

How to use the classifier? Suppose, in the user's text there is a sentence "The master restores a painting". The verb "restore" is a name of the class and according to its USC string ((XY)Z)((ZW)W') we can construct a phrase: X by means of Y affects Z so that W is restored. The user can specify the role of the variables like that: "An artist by means of a brush affects on the paint so that the painting is restored".

Having assigned names of performers of the action, represented by the verb, and tools, that are being used, to the variables the user determines the initial situation (he does not realize that now he is developing a knowledge base) and the target situation. The user just has to fill out a form of the following type: who "X" by means of what "Y" acting on what "Z" gets what "W" and computer provides possible ways of changing from the initial to the final state.

IV. USC axiomatics

Using axioms of conversion, we demonstrate how to generate and convert USC strings and show how this knowledge representation and inference language can become a solver of intellectual problems.

The KB operates with the axioms of the USC algebra and formed as an oriented graph. The nodes of the graph are the USC strings, the arcs are the USC axioms. The solution of the intellectual problem is implemented as a route of the arcs. The inference algorithm is based on the successive drawing of the route from the target situation to the initial one.

A. Axiom of diffusion

The axiom defines transferring the variable from one position to another in the right part of the string.

1) Transferring the variable from the first position to the second:
$((XY)Z)((ZY)W) \rightarrow ((XY)Z)((ZZ)W)$
2) Transferring the variable from the second position to the third:
$((XY)Z)((ZY)W) \rightarrow ((XY)Z)((ZY)Y)$
3) Transferring the variable from the first position into the third if and only if variables are not repeated inside the initial string: $((XY)Z)((ZY)W) \rightarrow ((XY)Z)((ZY)Z)$

On the Fig. 2 see the graph for physical strings conversion with the axiom.

B. Axiom of transposition

The axiom defines shifting of internal parenthesis in the right part of the string and transition from 'active' to 'passive' verb:

$((XY)Z)((ZZ)W) \rightarrow ((XY)Z)(Z(ZW)).$

On the Fig. 3 see the combined graph for physical strings conversion with the axiom of diffusion and transposition.

1.1	(ZW)Y	**Connect** - make joined or united X bmo Y connects Z and W	2.1	(ZY)W	**Disconnect** - make disconnected, disjoined X bmo Y disconnects Z and W
3.1	(ZW)Z	**Insert** - put or introduce into something X bmo Y inserts Z in W	4.1	(ZZ)W	**Extract** - force to leave or move out X bmo Y etracts Z from W
5.1	(ZZ)Y	**Squeeze** – press firmly *X bmo Y squeezes Z*	6.1	(ZY)Z	**Expand** - make bigger or wider in size, volume, or quantity X bmo Y expands Z
7.1	(ZY)Y	**Destroy** - damage irreparably X bmo Y destroys Z	8.1	(ZW)W	**Produce** - create or manufacture X bmo Y produces W from Z
9.1	(ZZ)Z	Change - cause a physical transformation X bmo Y changes Z			

Figure 1. The example of physical classes

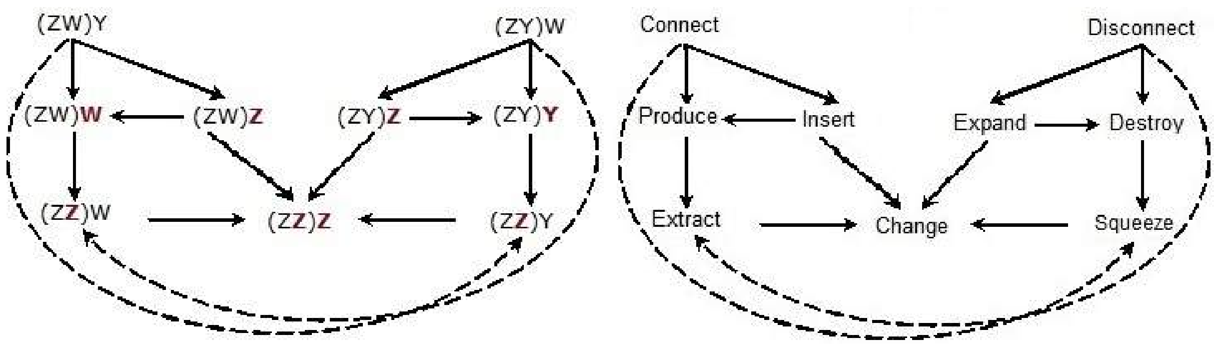

Figure 2. Axiom of diffusion

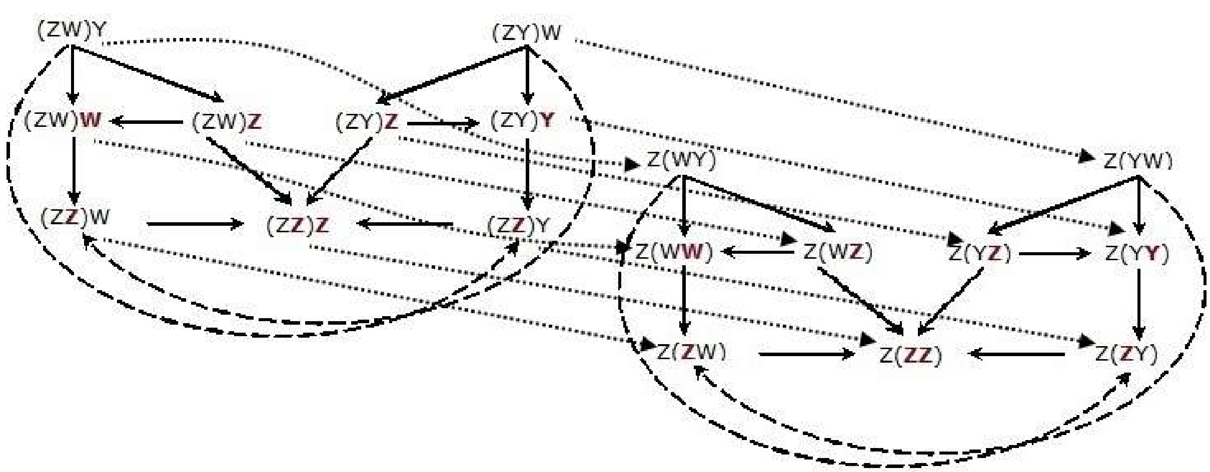

Figure 3. Axioms of transposition and diffusion

C. Axiom of complement

The axiom defines converting one string into another, in the right part of the string, according to the spatial relation:

$$((XY)Z)((ZZ)W) \rightarrow ((XY)Z)((ZZ)W') \rightarrow ((XY)Z)((ZZ)W_{\text{J}})$$

On the Fig. 4 see the graph for physical strings conversion with the axiom.

The complete graph of USC conversion is on the Fig. 5.

V. Conclusion

Inference is a main procedure of intellectual problems solving including inventive problems. Inventive solution comprises consequence of technical operations. Any technological process is a consequence of the technical operations, where every operation is represented by physical verb (charge, magnetize, bond, split, etc.).

Conversion of the USC strings, representing physical verbs, by means of the USC axioms generates string consequences where each of them can be considered as a technological process. Substitution the real objects in the positions of variables in the USC strings forms a technical solution [2].

Another possible application is a machine translation by converting phrases of one natural language into the USC strings and converting the strings into another natural language. During the translation, USC strings may represent verbs, nouns, and adjectives independently of the particular natural language [3].

Axiomatic conversions of strings represent inference of knowledge from knowledge on the abstract level of verb classes and then with specifying the knowledge by substitution of synonyms in the positions of the classes.

USC displays the situation when the set of semantic primitives is not postulated but recursively calculated, and primitives are displaced in the semantic field in the range of semantic nearness of meanings. Eventually, KB is semantically ordered.

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СЕМАНТИЧЕСКОЕ КОДИРОВАНИЕ ДЛЯ СЕМАНТИЧЕСКОГО ВЫВОДА ЗНАНИЙ

Бойко И.М.

Статья посвящена семантическому кодированию знаний на основе Универсального Семантического Кода (УСК), который был разработан профессором Виктором Владимировичем Мартыновым.

Семантический вывод знаний осуществляется с помощью набора УСК аксиом, которые задают правила последовательного преобразования знаний.

Семантический код скоординирован с языковым представлением через классификатор глаголов, представляющих действия.

Аксиоматический граф вывода знаний показывает конечность возможных преобразований одних глаголов в другие, тем самым определяя конечность количества возможных способов решения интеллектуальных задач.

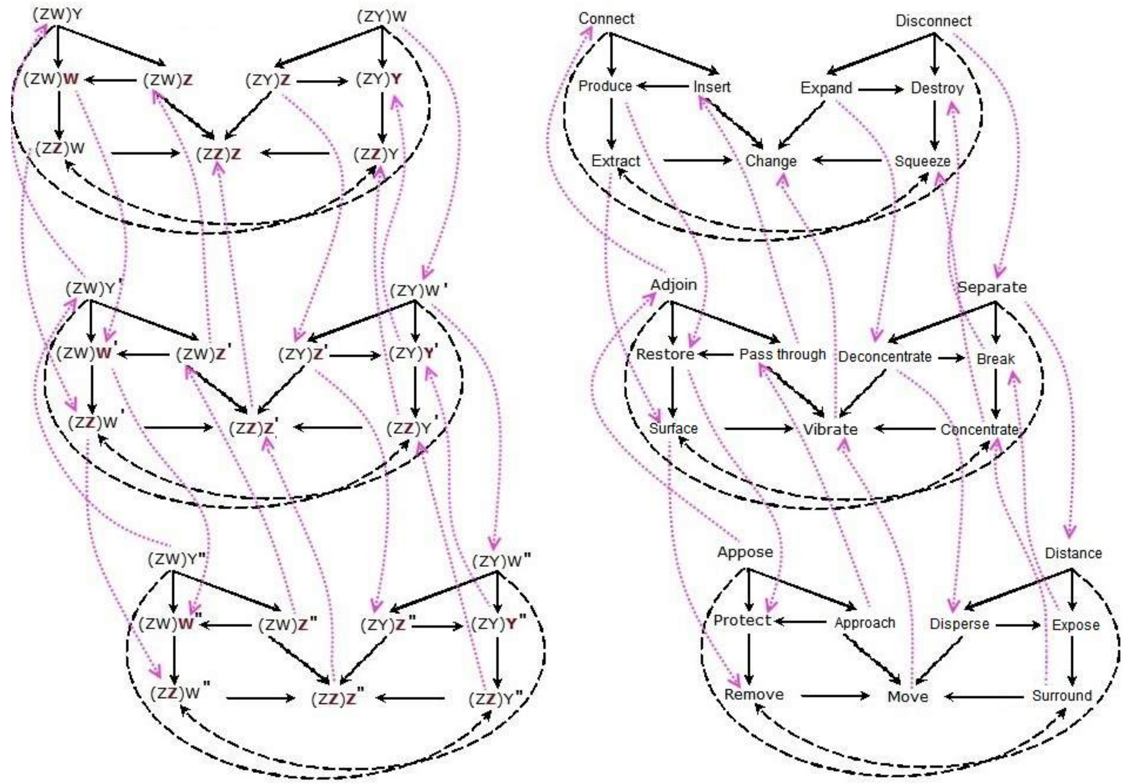

Figure 4. Axiom of complement

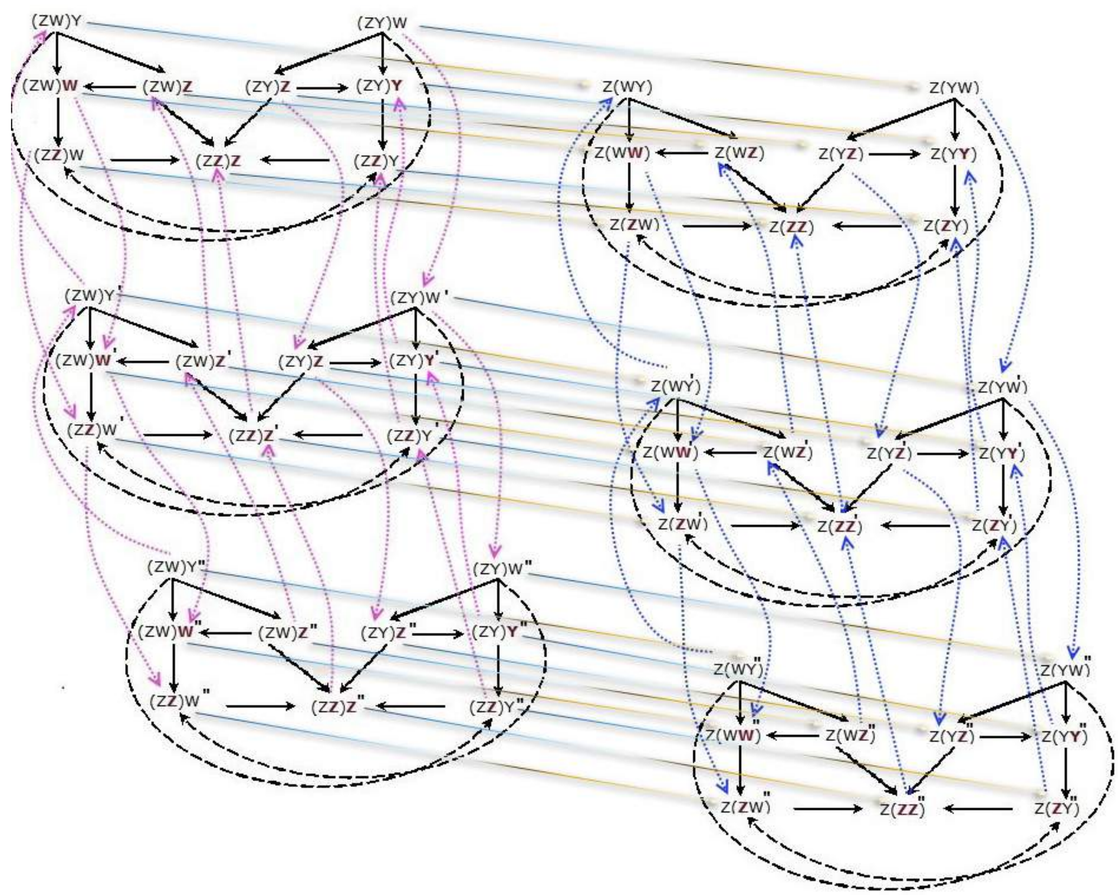

Figure 5. Complete graph of axioms: diffusion, transposition, and complement

A Prototype of the Computer System for Speech Intonation Training

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***Abstract*—In this paper we describe the importance of intonation in human comprehension of speech. We lay out fundamental principles of intonational theory of speech that is based on the concept of universal melodic portraits. In this paper we describe the main algorithms of analysis and interpretation of intonation in an utterance that underlie the developed computer-based system for teaching of speech intonation. We further show the system's output and discuss its usefulness in teaching foreign language intonation.**

Keywords—Intonation of speech, speech analysis and synthesis, melodic portrait, intonation analysis and interpretation, computer system for teaching, intonation training.

I. Introduction

Intonation plays significant role during speech comprehension. Without intonation, it's impossible to understand the expressions and thoughts that go with words.

Speech intonation shows a communicative intention of an utterance, its logical meaning, a prominence of the most significant theme in relation to general themes (actual division of a sentence), a distinction between semantically associated segments of speech, and an integration of speech elements within these segments. We can therefore think of intonation as referring to the way we use the pitch of our voice to express particular meanings and attitudes. The exact relation between intonational patterns and informational structure (as part of semantics) is still to be investigated.

A common linguistic idea is that foreign accent appears more evident in intonation, and therefore, prosodic aspects of speech should be explicitly taught to students who wish to communicate intelligibly in a foreign language. Foreign accent arises due to contact between two different language systems, namely, at bilingualism, because of language interference. Intonation is the most important aspect of speech that provides both linguistic and sociocultural information. Considering that functions of intonation in speech are various, and that deviations in this area can lead to significant semantic differences, incorrect intonation can make a wrong impression during the speech of a non-native language speaker [1].

In this view, is it very important to emphasize intonational aspects of speech while teaching foreign language. In [2] an automatic intonation assessment system for computer aided language learning is described. The similarity between reference and test intonation templates is evaluated on a frame-by-frame basis by using the DTW alignment by estimation of the correlation between both F0 curves. Previously [3 – 5], we've published several scientific results in the area of speech intonation analysis and synthesis which can serve as a foundation for the creation of innovative intelligent systems of automatic intonation assessment for computer aided language learning.

II. General information about speech intonation

In phonetics and physiology of speech, a phrase is considered to be a comparatively independent unit in speech intonation [6]. Phrase independence manifests itself in articulatory integrity, semantic and syntactical association of linguistic units, and in presence of objective traits that allow singling it out from a speech stream. Any punctuation mark can set a boundary of intonation phrase in a written text. However, quite often the number of phrases can be greater than the number of punctuation marks. Generally, a phrase is a combination of one to five words, with a three-word phrase being the most common. A particular place of a phrase boundary is determined by the optimal satisfaction of the semantico-syntactic, phonetic and physiological requirements. The first of the named requirements prescribes a union inside a phrase between semantically connected words that cannot be split into two phrases. The second requirement denotes the tendency of language phonetic systems for definite rhythmical construction, for example, a group of two to three words combined in one phrase. Finally, the third requirement prescribes the formation of a phrase with the number of words that could be physically pronounced during the time required for one act of exhaling.

After definition of a phrase, the next step in intonational speech analysis is determination of a phrase intonation type. The main intonation phrase types include: completed and uncompleted phrases, special and common questions, exclamation phrases, and some others types. The number of intonation subtypes of the main phrase intonation types could reach several dozens. The task of definition of an intonation subtype is achieved by the analysis of two factors: the position of a phrase in a text and by its semantic value. The first factor, a position in a text, is determined by the analysis of a phrase position in relation to the nearest punctuation marks. For example, its position at the beginning or the end of a text, its position before or after punctuation marks, and the type of punctuation mark in a sentence. The second factor, a semantic value of a phrase, is determined based on the meaning of a phrase and on its logically emphasized intonational center. In particular, it needs to be determined whether a phrase expresses intentions, explanations, follow up questions etc. The final decision on an intonation type and subtype of a phrase is made after considering both factors.

Speech intonation is physically realized by the set of acoustic means, named the prosodical parameters:

- melodics - the movement of the frequency of the main tone (F0);
- energetics - the current change of the force (amplitude) of the sound (A);
- rhythmics - the current change of the duration of the sounds and pauses (T).

Since melodics of speech is the most informative among these parameters, the main attention in this article is given to the melodics.

III. Block Diagram of the Suggested Computer System for Speech Intonation Training

Figure 1 contains a block diagram illustrating sequence of algorithms for analysis of speech intonation within the developed computer training system. The main goal of the system is to provide a student with a compact and easily interpretable image for the results of analysis of melodic and energy contours of phrases with different intonation. The system would also provide a visual, auditory and numerical evaluation of the quality of learning of a foreign speech intonation by a student.

Block 1 contains the database of phrase samples with different intonation patterns which is compiled from multimedia textbooks (see, for example, [7] for Russian language, or [8] - for English). Every sample phrase has preliminary placed prosodic marks that include phrase boundaries and placement of its nucleus.

Based on a given goal of intonation learning, a student chooses the needed sample phrase, hears it and pronounces it. The pronounced phrase is recorded on the buffer (block 2).

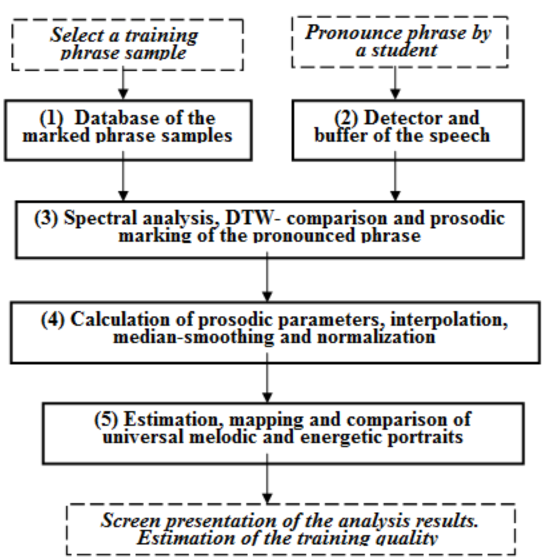

Figure 1. The block diagram of the computer training system of foreign speech intonation

In block 3, the signals from both sample and pronounced phrases are analyzed by calculating Mel-frequency cepstral coefficients (MFCCs) and then compared using the modified method of DTW – continuous dynamic time warping (CDTW) [9]. This is accompanied by determination the beginning and the end of the pronounced phrase, a transfer of prosodic marks (phrase boundaries and placement of its nucleus) and labeling of a pronounced phrase.

In block 4, prosodic phrase parameters of both sample and pronounced speech signals, such as F0 – frequency of the basic tone (pitch), and A0 – energy of the signal, are calculated. These parameters are further interpolated on the non-vocal areas of speech signal, and then they are median-smoothed and normalized on their minimum and maximum of phrase values.

In order to calculate the proper value of training quality, in block 5, an estimation and comparison of universal melodic and energetic portraits are produced.

Figure 4 presents illustration of system's output for the interrogative phrase: "Did Sasha eat the porridge?" The image shows successive processing F0 (t) and A0 (t) and a comparison of the sample phrase and the student-spoken phrase speech signals.

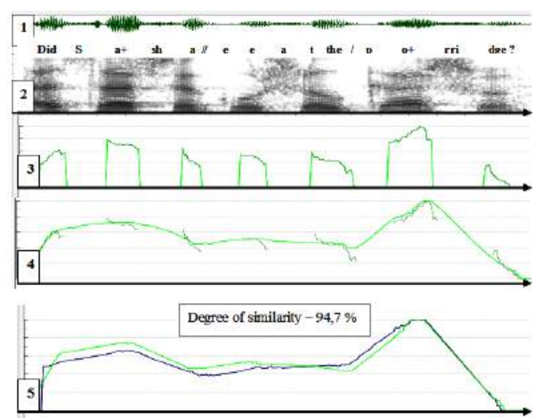

Figure 2. The illustration of speech signals processing: 1- oscillogram, 2 – spectrum, 3 – F0(t) (original), 4 – F0(t) (after interpolation and median smoothing), 5 – comparison of two melodic curves F0 (t) - sample and spoken phrases

IV. Software Realization of the Computer System Prototype

Software realization of the prototype is written on C++ programming code by using Qt framework. It can be compiled under Windows platform (from xp to 10 versions), also under Linux platform.

Application used following libraries:

- OpenAL - used for multimedia interaction (audio input/output). OpenAL is a cross-platform audio application programming interface (API). It is designed for efficient rendering of multichannel three-dimensional positional audio;
- MathGL - used for draw graphics. MathGL is a library for making high-quality scientific graphics under Linux and Windows;

- GNU Scientific Library (GSL) - used for data calculation and processing. GSL is a numerical library for C and C++ programmers. It is free software under the GNU General Public License;
- SPTK - used for audio data analyzing. SPTK is a suite of speech signal processing tools for UNIX environments, e.g., LPC analysis, PARCOR analysis, LSP analysis, PARCOR synthesis filter, LSP synthesis filter, vector quantization techniques, and other extended versions of them.

Application core divided into several modules that implement standalone functions. Such modules can implement audio signal recording, voice detection, DP processing and so on. As this modules a independent from each other, we can easily build different applications by replacing this modules for other one or integrate them in external systems.

For build main user interface used built-in web engine. User interface built on html5, css3 and js (ReactJs js framework). ”Developer mode” user interface build on standard Qt forms.

Main user interface is independent from application core and can be modified or even replaced by other one. Use html/css/js standard allow easy change application front-end for different purposes. For interaction with application core exists a number of special links formats that processed by application core. Such links can open different applications dialogs (like settings, developer mode and so on), process input audio signals and play audio files.

So we can easy build different training systems by replacing front-end and training data files.

The starting page of the User Interface is shown in figure 3. From this page, also possible to pass in “Developer mode”.

Figure 3. Starting page of the User Interface

After clicking the ”Start” button, a new window opens (see. Figure 4) in which a list of training phrases appears. When selecting one or another test phrase, there is an additional window where you can choose from 3 options: “Show pitch”, “Show energy” or “Show spectrum”.

When selecting the “Developer mode” one can see the full list of test phrases (see Figure 5). In this mode one can

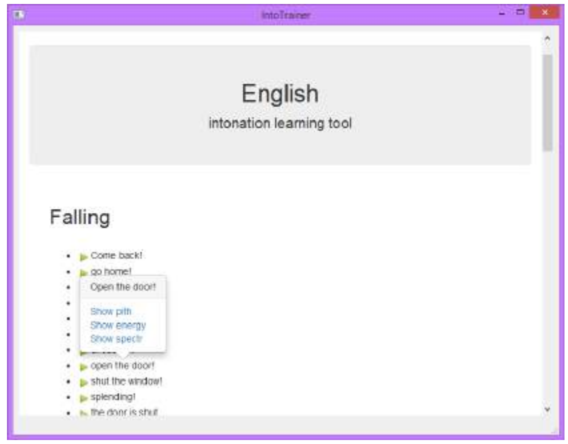

Figure 4. The page of the test phrases selection

choose additional options clicking the buttons: “Evaluation”, “Record”, “Play”, “Remove”, “Rename” and “Settings”.

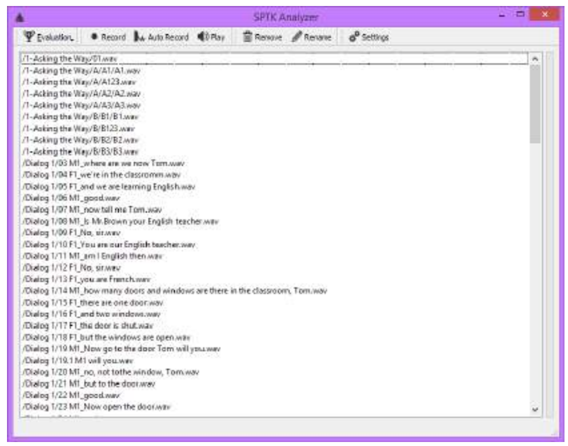

Figure 5. The “Developer mode” window

When selecting the “Evaluation” in the “Developer mode” window one can see the acoustic parameters of the test phrase (Figure 6), or the smoothed F0-parameter of the test phrase (Figure 7), or the F0-correlation between the test phrase and the same phrase pronounced by student (Figure 8).

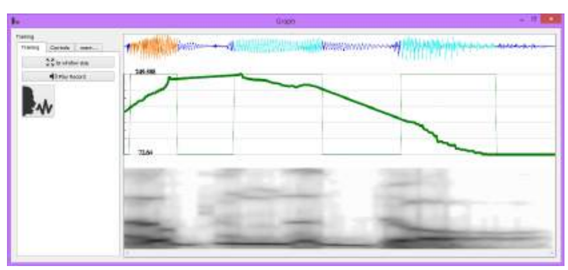

Figure 6. Showing of the acoustic parameters of the test phrase

When selecting the “Settings” in the “Developer mode” window one can change some speech analyzer parameters, such as: frame size, frame shift, type of frame windows, LPC order and others (see Figure 9).

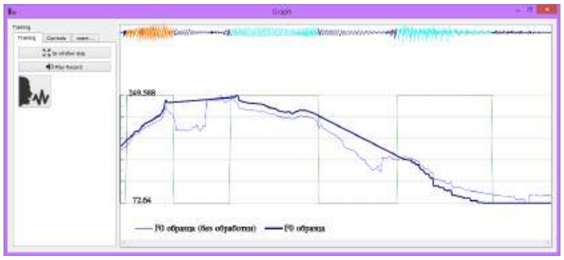

Figure 7. Showing of the smoothed F0-parameter of the test phrase

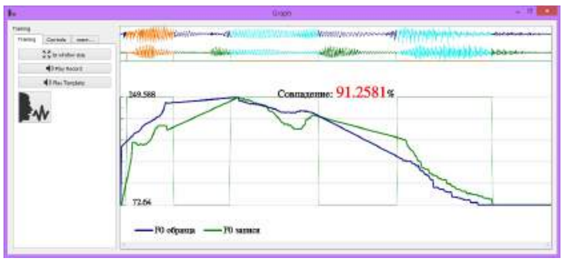

Figure 8. Showing of the F0-correlation between the test phrase and the same phrase pronounced by student

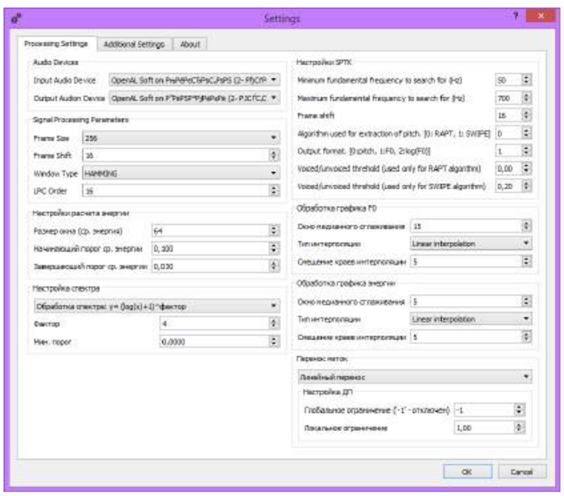

Figure 9. The “Settings” mode window

V. Conclusion

We believe, that there is a great potential in both domestic and international markets for a new and innovative product such as the proposed computer system for intonation training integrated into a foreign language educational courseware. To our knowledge, there is no satisfactory software available for such teaching system and, therefore, such system appears to be of great relevance. For example, there are considerable intonational differences between Russian and English languages. American English native speakers made the following interesting observation: “Ask an average American what they are thinking about the Russian accent, and the answer will be as follows: ”Russians don’t sound very friendly. I feel like they don’t like me at all. I am not sure whether it comes from their language or from their culture?” One of the reasons why native Russian speakers sound unfriendly in English is the so called “flat” tone. Native Russian speakers often do not use language-specific phonological representation of intonation during their conversation in English. Moreover, native Russian speakers tend to avoid using rising and falling intonations in English and, as a result, Americans may find their speech unfriendly and unpleasant.

Application of an intonation mapping analyzer as a part of a speech recognition system is expected to increase reliability of recognition through the prominence of accented words and intonational segmentation of a speech flow. Intonation analysis will also be helpful for subsystems of identification of individual and emotional factors of speaker’s speech. The use of intonation system in speech synthesis systems will give an opportunity to improve intonational prominence of synthesized speech so that it will positively affect listener’s comprehension.

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ПРОТОТИП КОМПЬЮТЕРНОЙ СИСТЕМЫ ОБУЧЕНИЯ РЕЧЕВОЙ ИНТОНАЦИИ

Лобанов Б.М., Житко В.А.

В статье обосновывается важность интонации для восприятия и понимания речи человеком. Описаны фундаментальные принципы интонационной теории речи, которая основывается на концепции универсальных мелодических портретов. В статье описываются основные алгоритмы анализа и интерпретации фразовой интонации, которые лежат в основе разработанной компьютерной системы, предназначенной для обучения речевой интонации. Показаны выходные характеристики системы и обсуждается её полезность в обучении интонации иностранного языка.

Multivoice Text-to-Speech Synthesis for Natural-Language Interfaces of Intelligent Systems

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***Abstract*—The paper considers the application of voice conversion technology for developing multivoice text-to-speech synthesis (MVTTS) in natural-language interfaces of intelligent systems. The main features of the proposed integrated architecture of MVTTS system are presented. Voice conversion model based on multiple regression mapping function and Gaussian mixture models, as well as the method of text-independent learning based on hidden Markov models and modified Viterbi algorithm are observed. Experimental evaluation of the effectiveness of the proposed solutions on the characteristics of naturality and similarity of synthesized speech has been done.**

***Keywords*—text-to-speech system, voice conversion, natural-language interface.**

I. Introduction

The natural-language interface is a form of interaction with an intelligent system. This method is optimal for users, because it is the most natural way for communication between humans. At present moment a considerable attention is given to issues connected with natural-language interfaces research and development within the intelligent systems. A text-to-speech synthesis subsystem (TTS), which provides an implementation of a feedback system to the person, takes an important place in the structure of the speech interface system. This type of systems development at the present stage has achieved a significant progress. They have the tasks of not only ensuring intelligibility indicators specified synthesized speech signal, but also requirements on the naturalness of speech, availability of a wide range of prosodic templates, support for multiple languages and different voices announcers. This last aspect is the most important and interesting to study, especially in the context of the transition from the synthesis to voice cloning systems of specific speaker [1]. To solve the task of implementing personalization properties for a speech synthesizer, different speech processing technologies, including voice conversion, are used.

II. Architecture of MVTTS

Voice conversion (VC) is a speech signal processing technology, which allows transforming voice characteristics of the source speaker (SS), contained in speech signal, in characteristics of target speaker (TS) without changing the meaning of the message [2,3]. Voice conversion objects primarily are timbre (spectral envelope) and prosodic (contour of main tone frequency, in another words - pitch) speaker features [4]. To solve the problem of building MVTSS based on VC an approach based on integrated system architecture of TTS and VC was formulated and suggested. We propose to incorporate functional blocks of voice conversion into the TTS composition with at the level of acoustic processor of the system. An information on the voice of the announcer, stored in the DB of acoustic fragments of synthesizer in the parameterized form is used in a function of original. The proposed approach allows to achieve greater cohesion between two types of systems. Multivoice TTS architecture is presented in figure 1.

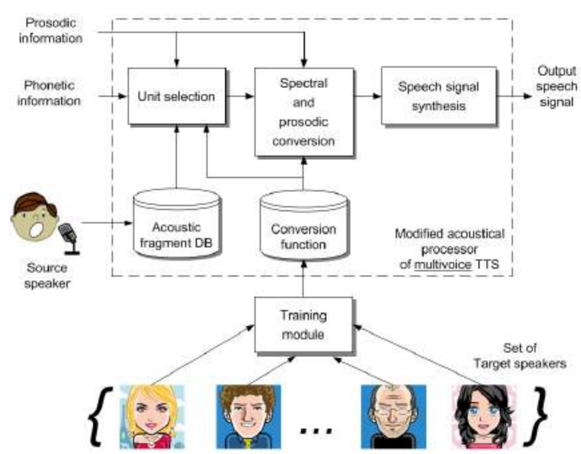

Figure 1. Integrated architecture of MVTTS

Integrated MVTTS architecture allows using available linguistic resources, which the database (DB) contains, acoustic fragments of speech signal kept in the synthesizer (in the parameterized form). A proposed approach permits to achieve greater cohesion between two types of systems. This structure reflects the stages of information processing: aspects of voice conversion are taken into account only while selecting units of compilation; transformation and conversion algorithms of timbral and prosodic information are executed atomically (i.e. signal characteristics are modified only once); compiled and synthesized speech reconstruction also run once immediately after phase conversion characteristics of SS in the TS that reduce the number of alternations of artifacts.

III. Analysis-synthesis speech model

During the review and comparative analysis of the literature on relevant methods of speech signal analysis-synthesis models [5], it was found that the most promising model is a hybrid harmonic plus noise model and its STRAIGHT implementation [6]. It allows decomposing a signal and manipulating independently with three components: main frequency contour (pitch contour), smoothed spectrogram (periodical part), noisy spectrogram (aperiodical part). The analysis of the speech signal is synchronized with the pitch contour and is performed in instantaneous harmonic parameters domain. Then, based on the average estimation between the two instant values of spectral envelope, smoothed time-frequency representation envelope spectrum are taken. Smoothed STRAIGHT-spectrogram is determined according to the expression:

$$P_T(\omega) = \frac{1}{N}\sum_{k=0}^{N-1}|S(\omega, \tau + \frac{kT_0}{N})|^2, \qquad (1)$$

where $P_T(\omega)$ – smoothed stable over time the power spectrum of the signal, provided that the centres localization time Windows are divided into $\frac{T_0}{N}$, N-number of Windows for calculation, $|S(\omega,\tau)|^2$-instant Fourier spectrum for time τ, $\tau + \frac{kT_0}{N}$ – time offset for spectrum analysis of the signal in time $|S(\omega, \tau + \frac{T_0}{2})|^2|$. This representation (1) allows determining accurately the value of periodic and aperiodic signal components best suited for transformation of the spectral envelope. At the later stage it gives the possibility to perform the conversion of each speaker-dependent signal characteristics (envelope spectrum for periodic and aperiodic component and parameter of prosodic in the form of pitch contour) in the simplest way and without additional errors. The method also permits to manipulate the source parameters of excitation, signal recovery of parametric region and provides a synthesis of the signal with low distortion.

IV. Voice conversion based on GMM

The most common paradigm in voice conversion researches now is a statistical model based on multiple Gaussian mixtures models (GMM), which was proposed in the original [7] and its modified versions are presented [8]. Systems based on this model have satisfactory results in terms of the characteristics of the similarities between the converted and the target speech signals.

Training is carried out on the basis of a set of parallel pairs of vectors of SS and TS parameters for which a joint GMM model is built. Expectation vector and covariance matrix available in GMM are used as parameters in the function of conversion, which is represented by the expression:

$$F(\mathbf{x}) = \sum_{q=1}^{Q} p_q(\mathbf{x}_i, \mathbf{y}_{i-1}, \mathbf{x}_{i+1})[\nu_q + \Phi_q\bar{\mathbf{x}}_i^q + \Psi_q\bar{\mathbf{y}}_{i-1}^q + \Omega_q\bar{\mathbf{x}}_{i+1}^q],$$

$$p_q(\mathbf{x}) = \frac{\alpha_q N(\mathbf{x}, \mu_q^x, \Sigma_q^{xx})}{\sum_{j=1}^{M}\alpha_j N(\mathbf{x}, \mu_j^x, \Sigma_j^{xx})}. \qquad (2)$$

where $\mathbf{x}$ – parameters vector of the source speaker, M – number of component mixture, μ_i^x and μ_i^y – expectations vector of the i-th components of the mixture, Σ_i^{xx} – covariance matrix of the source speaker of the i-th components,Σ_i^{yx} – crosscovariance matrix for source and target vectors 1st speaker components, $p_i(\mathbf{x})$ – posteriori probability vector $\mathbf{x}$ i-th component, N – multivariate Gaussian distribution.

Type conversion function (2) is widespread, thanks to a good practical results obtained on its basis [9]. However, it also has some disadvantages. When we try to increase strongly the similarity between speakers, effect of oversmoothing of the voice signal could be observed.

V. Text-independent training method

To build a SS conversion function in TS will a phase of training is required, which includes a stage of mapping vectors of parameters, characterizing the voices of announcers, derived from the analysis and parameterization of the signal. Training can be carried out on the basis of text-independent and text-dependent approaches.

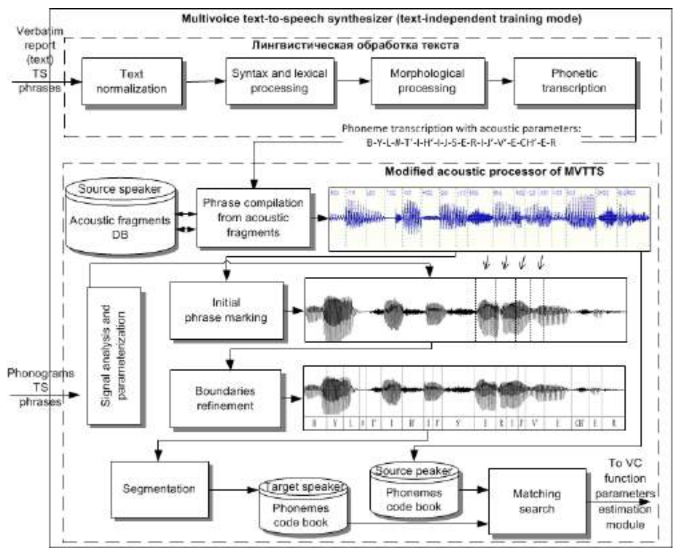

Figure 2. Text-independent training process in MVTTS

While learning, text-dependent SS and TS are required to recite the same text. Common text implies a common phonetic constituents, which vary within certain limits (depending on sex, age, mannerisms, etc. features of the speaker), but essentially the same in terms of phonetics. It gives an opportunity to hold a temporary mapping parameters, vectors and later compare the clusters of acoustic parameters of the subspaces. The downside of this approach is connected with coast of preparation of such parallel corpora.

In this case obvious temporary matching of vectors parameters can't be received by direct contrast. The key advantage of this approach is the convenience and simplicity of customization of the system with this type of training, for the end user. It does not require a certain texts database, you can use any available phonograms or even record the voices in the process of talking on the phone.

The method of text-independent teaching in the context of the MVTSS structure (figure 2.) involves extensive use of linguistic TTS units to undertake the following stages: the text normalization, its syntax, morphological processing, phonemic transcription, as well as further accessed synchronization markup with phone phonogram target speaker based on data obtained from SS, i.e. speech synthesizer. This fact gives the opportunity to convert subsequently phonemic recognition task units in the flow of speech audio synchronization task and phonetic markup and text blocks of a speech synthesizer. A detailed description of the method could be found in [10].

VI. Text-independent training algorithm

During the alignment stage of training, two concurrent processes are in progress: preparation and analysis of speech and text information on the phonetic and acoustic characteristics of the target speaker. A sequence of phonograms learning phrases $Wav = (w_1,\ w_2,\ \dots,\ w_n)$ and its corresponding recording sequence $Torpho = (t_1,\ t_2,\ \dots,\ t_n)$, are the main information for these processes, where n – is the number of phrases of the training set. Next over textual information processor conversion is carried out language spelling of text in an alternative type of L: $Torpho \rightarrow Tphono \in D^{s\times n}$, where s – is the number of phonetically distinguishable units in a single phrase, and then the phonetic transformation processor performs phonemic text, F: $Tphono \rightarrow Tallo \in D^{a\times n}$, where a – is the number of allophones (combinations of phonemes) in a single phrase, in a sequence of indices of allophones. It should be noted that the alphabet index data matches for all of the speakers, because their composition is strongly typed and is constant for members of a language group. Algorithms that implement the data transformations are described in detail in the literature [11].

Speech signal analysis unit performs over a sequence of phonograms W analysis , based on signal model STRAIGHT [4]. To reduce computational complexity of subsequent phases, and the resulting conversion model smoothed spectrum $P_R(w,t)$ for every moment of time is replaced with its envelope in parametric form using linear spectral frequencies (LSP). Thus, the transformation performed by block analysis of speech signal can be defined formally as $\hat{A}$: $Wav \rightarrow \Pr m \in D^{p\times m\times n} | \Pr m(m,n) = \{F_0, \Delta F_0, a_1, a_2 ... a_p\}$, where p – dimensionality of LSP parameters vector , m – number of signal frame, n – number of phnogram in training set Next sequence of allophones indexes $Tallo$ and vectors Prm of signal parameters simultaneously are transmitted to the entrances of the block defining the boundaries of allophones, that is establishing an optimal match between them.

This task can be solved efficiently using hidden Markov Model (HMM), in which the sequence $Tallo$ would be a sequence of states, and Prm – the sequence of observations. From the terms of HMM this process consists of linking the best sequence of states from the current sequence of observations for the model. The solution of this problem, formalized in the form of expression, is possible by using iterative Viterbi algorithm.

$$H : (Tallo,\ Prm) \rightarrow (Tallo^{opt},\ Prm),$$

$$\arg\max P(Tallo,\ Prm|\lambda), \lambda \in (A, B, \pi),$$

$$B^{trg} = \{\forall t | Tallo^{opt}(t)\} \Leftrightarrow P^{trg} = \{\forall p | Prm(p)\}$$

where λ – hidden Markov model parameters, A – matrix of states, B – matrix of observations, π– matrix of initial states. Further, by combining statistics all observations on each state, on all phrases training set, it is possible to find matching vectors of parameters relevant to a particular allofonu, thanks to the equality of allophones alphabets in terms of its composition $Ballo^{src}(i) = Ballo^{trg}(i) = Ballo(i) \Rightarrow Prm^{src}(i) \Leftrightarrow Prm^{trg}(i)$. Thus, all of the above steps as a result of the two phases, allow forming joint sequence of vectors of signal parameters on phonetic $Z = (\{Prm^{src}(i),\ Prm^{trg}(i)\}_i), \forall i \in N, i = 1, I$,(where I – number of allophones in the database) for its subsequent use in the search model parameters of conversion. More information on the learning stage is described in the works of authors and bibliography [5].

VII. Experimental results

To evaluate the effectiveness of the proposed methods a series of experiments to characterize the intelligibility and naturalness of synthesized speech by means of method of average opinions (mean opinion score-MOS) was conducted [12].

Experiments were perfomed on phonetically balanced set of phrases, including 90 on audio records of the same proposals for four speakers: two men and two women.In further experiments male speakers are nominally marked as M1 and M2, and female speakers as F1 and F2. The average duration of one phrase was 5-6 seconds. The scaling algorithm was used for temporary alignment based on dynamic programming.

Experimental results are presented in table 1.

Table I. Results of the experimental evaluation of MOS marks for naturality and similarity of synthesized speech

Naturality (MOS)					
	M-	M-F	F-	F-F	Mean
GMM	3,2	2,6	2,9	3,3	3,0
GMM*	3,5	3,2	3,3	3,4	3,4
FW	4,3	3,3	3,7	3,8	3,8
ANN	3,6	3,7	3,7	4,1	3,8
Similarity (MOS)					
	M-	M-F	F-	F-F	Mean
GMM	3,7	3,5	3,6	3,9	3,7
GMM*	3,7	3,6	3,6	3,7	3,7
FW	2,7	2,2	2,8	2,6	2,6
ANN	3,8	3,4	3,8	4,3	3,8

For illustration purposes, the results of the experiment are presented in the form of histograms for characteristics of naturalness (figure 3).

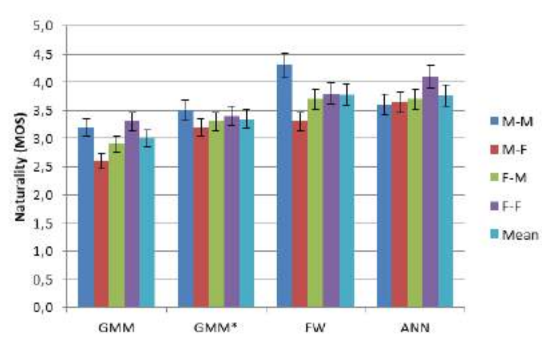

Figure 3. Similarity marks (MOS)

and similarity of synthesis speech (figure 4).

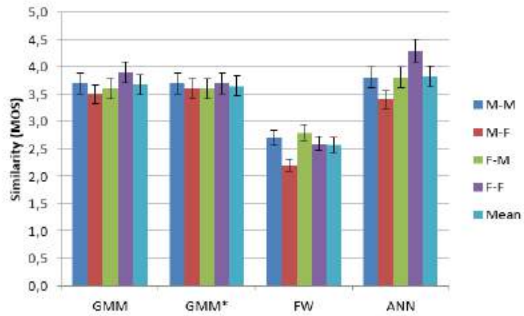

Figure 4. Naturality (MOS)

Experimental results suggest that the proposed method enables to improve the characteristics of naturalness in comparison with the classical method of conversion on the basis of an average of 10 MOS % according to the parameters of naturalness and 5 % according to similarity. Also according to the similarity parameter this method comes short of approach based on spectral weighting and artificial neural networks. This fact can be explained by the fact that proposed method (GMM*) allows to get a stronger, less than the average (more natural) representation of spectral envelope as a result of conversion, while classical statistical techniques (GMM) can significantly average this feature. However, according to degree of similarity, the proposed method exceeds the standard method based on frequency warping (FW) and only is slightly inferior to the method based on artificial neural networks (ANN),the listed methods in the process of achieving great simplicity in training and fewer resources on preparations. High performance of latest justified by a nonlinear mapping displaying features, but require a preliminary design of a neural network and its learning algorithm selection.

VIII. Conclusion

The report deals with aspects of practical implementation of multivoice speech synthesis systems. A new architecture based on speech synthesis systems integration and conversion of voice at the level of modified acoustic processor system synthesis is proposed.

A suggested method and the algorithm have the following advantages: allow to convert input text transcripts for obtaining spelling phonemic text; provide the ability to generate a training set for the original announcer on the basis of the target text of phonemic announcer; all necessary for learning information about SS is kept within the MVTTS as its acoustic resources (database of acoustic standards, dictionaries and rules), or can be obtained by synthesis within the MVTTS on information from TTS.

The proposed methods implemented in the form of software modules could be used as components for the construction of natural-language interfaces of intelligent systems.

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МУЛЬТИГОЛОСОВОЙ СИНТЕЗ РЕЧИ ПО ТЕКСТУ ДЛЯ ПОСТРОЕНИЯ ЕСТЕСТВЕННО-ЯЗЫКОВЫХ ИНТЕРФЕЙСОВ ИНТЕЛЛЕКТУАЛЬНЫХ СИСТЕМ

Захарьев В.А., Петровский А.А.

В докладе рассмотрены вопросы применения технологии конверсии голоса для построения мультиголосовых систем синтез речи по тексту (МГСРТ) для создания естественно-языковых интерфейсов интеллектуальных систем. Особенности предлагаемой интегрированной архитектуры МГСРТ на базе технологии конверсии голоса, функция конверсии голоса на основе модели Гауссовых смесей и множественной регрессионной функции отображения, а также метод текстонезависимого обучения на базе скрытых Марковских моделей и модифицированного алгоритма Витерби. Приведены экспериментальные оценки эффективности предлагаемых решений по характеристикам узнаваемости и натуральности синтезируемой речи

Linguistic and Acoustic Resources of the Computer System of Spoken English Intonation Training

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***Abstract*—This paper considers supra-segmental parameters as intonation, stress and speech rhythm, which are related not only to the correct articulation of sounds of the target language, but the correct pronunciation depends on prosodic structures presented by a standard intonation patterns. Linguistic and acoustic resources are needed for computer-aided intonation training because they are the basis for pronunciation instructions in and outside the classroom.**

***Keywords*—supra-segmental parameters, intonation, pronunciation, linguistic and acoustic resources, computer pronunciation training**

I. Introduction

Intonation is one of the first aspects of speech, to which the baby reacts, which perceives and makes attempts to reproduce itself. It was revealed that the child has few difficulties in developing a native speaker intonation. Thus, intonation seems more simple and it is taken for granted at the time of amplification of infant speech. It seems that an adult should remember and reproduce intonation much easier but they are making a lot of efforts by learning to intonation structure.

Proper pronunciation of the target language is associated with the correct articulation of sounds and also with supra-segmental parameters. Supra-segmental parameters are aspects of speech, referred to prosody.

By teaching prosody is important to understand and describe the supra-segmental parameters that are detected in the target language. It is also very important to describe the prosodic pattern of speech. The students often have issues producing correct intonation and they must learn to intonate the modalities, otherwise their speech is much less intelligible [1].

Anyway, by learning prosody is necessary to know an intonation contours palette to convey the diversity of thoughts in speech. Therefore, the intonation should be taught in the context of a well-structured dialogue or discourse.

Speech is a universal means of communication. It includes the processes of generation and perception (reception and analysis) messages for communication purposes in all languages of the world where leading thought or mental image is implemented in the speech by acoustic instruments.

The sentence is a combination of grammatically and phonetically structured performance of human thought during the speech. It is known that the sentence possesses definite phonetic features: speech melody, sentence-stress, tempo, rhythm, pauses and timbre. Each feature performs a definite task, and all of them work simultaneously [1]. An utterance consists of one or more phrases. The phrase has a semantic completeness and syntactic structure. The phrase is the largest unit with a complete phonetic intonation. The main distinguished unit in the phrase is the core, around which are concentrated its accompanying elements pre-nucleus and post-nucleus.

II. Intonation pattern of melodic portrait

The present work is a follow up study to the previously introduced model of universal melodic portraits (UMP) of accentual units (AU) for representation of phrase intonations in text -to-speech synthesis [2]. According to this model, a phrase is represented by one or more of AUs. Each unit, in turn, can be composed of one or more phonetic word. If there is more than one word in an AU, than only one word bears the main stress while other words carry a partial stress. Each AU consists of pre-nucleus (all phonemes preceding the main stressed vowel), nucleus (the main stressed vowel) and post-nucleus (all phonemes following the stressed vowel).

The UMP model assumes that topological features of melodic AU for particular type of intonation do not depend on a number or quality of phonemic content of a pre-nucleus, nucleus or post-nucleus, nor on the fundamental frequency range specific for a given speaker. The UMP model allows to represent intonation constructs as a set of melodic patterns in normalized space Time – Frequency.

Time normalization is performed by bringing pre-nucleus, nucleus and post-nucleus elements of AU to standard time lengths. This sort of normalization levels out the differences in melodic contours caused by the number of words and phonemes in an AU.

For fundamental frequency normalization F0 min and F0 max are determined within the ensemble of melodic contours produced by a certain speaker. This sort of normalization cancels out the differences of melodic contours caused by speaker's voice register and diapason.

The normalization is calculated by the formula

$$F_0^N = (F_0 - F_0 min)/(F_0 max - F_0 min). \qquad (1)$$

In certain cases, it may be beneficial to use statistical normalization instead of 1

$$F_0^N = (F_0 - M)/\zeta, \qquad (2)$$

where M is mathematical expectation, ζ is standard deviation. Note that M can be interpreted as a register and ζ – as a diapason of speaker's voice.

Therefore, the normalized space for UMP may be presented as a rectangle with axes (T_N, F_0^N) as schematically shown in Figure 1, while the interval [0 – 1/3] on the abscess T_N Structure of linguistic resource is a pre-nucleus, [1/3 – 2/3] is a nucleus, and [2/3 – 1] is a post- nucleus. The intervals on the ordinate F_0^N: [0 -1/3] – low level, [1/3 – 2/3] – mid-level, [2/3 – 1] – high level.

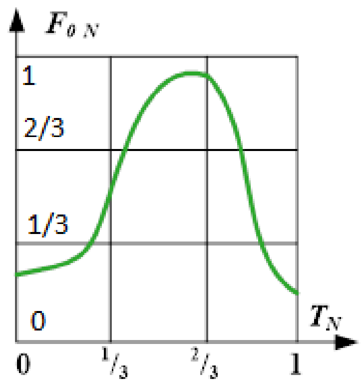

Figure 1. Main view of UMP

III. Structure of Linguistic and Acoustic Resources

In present research we use the resources of English texts and audio-files [3] which included:

- 44 everyday situations, each containing four dialogues in natural conversational English;;
- All dialogues consist 1051 sentences, including 704 affirmative sentences, 325 interrogative sentences and 22 exclamatory sentences, spoken by certain number of male and female speakers;
- Situations relevant to those studying or travelling in England, including eating out, entertainment and travel, as well as more general functions such as greetings, complaining and apologizing.

Each dialogue is structured by:

- the speaker (man and/or woman),
- the number of participants in the dialogue,
- the type of sentence: questions, statements and exclamations,
- the number of phrase units,
- number of AU in the phrase,
- the specification pre-nucleus, nucleus, post-nucleus.

In his "Advice to Foreign Learners" A.C.Gimson emphasizes necessity of learning "the English usage of falls and rises to signify the mood of the speaker, so that an over-use of rises will not give an unintentional impression of, for example, diffidence or complaint, and too many falls create an unwitting effect of impolite assertiveness" [4].

For that reason, the processing of acoustic materials was conducted according to the following intonation criteria:

- the falling tune;
- the rising tune;
- the falling-rising tune.

(a) The falling tune

The voice falls from a high to a low note on one stressed syllable. It is used in short complete statements, for questions beginning with a question word, for question tags when the speaker is sure that what he says is right or for orders and exclamations.

(b) The rising tune

The voice rises on the last stressed word or on the unstressed syllables following the last stress. It is used for statements intended to encourage, for questions which are answered by, for questions beginning with question words when the speaker wishes to show special interest, for question tags when the speaker is not sure that what he says is correct, for sentences ending with "please"; for "goodbye"; for "thank you" when it is used to show gratitude for a simple matter (passing the salt etc.)

(c) The falling-rising tune

The voice falls on the most important part of the sentence and rises again. It is used for apologies, for expressing tentative opinions.

According to the grammar rules of English there are two types of commonly used interrogatory sentences: general and special questions. The statistics below show how often are interrogatory sentences used depending on the situational moment during the interaction.

Statistic: General question

Is	16	Will	6	Need	1	Shall	2
Are	12	Do	26	Has	4	May	2
Am	1	Does	4	Can	23	Must	1
Was	2	Did	2	Could	17	Would	16
Were	1	Have	21	Should	1	TOTAl	140

Statistic: Special question

What	66	Who	2	Whose	0	Whither	0
When	13	How	52	Wherefore	0	Whence	0
Why	2	Which	8	Whatever	0	However	0
Where	14	Whom	0	Wherewith	0	TOTAL	157

Table 1 (English) and Table 2 (Russian) gives us a clear idea that the minimum (F0 min) and maximum (F0 max) of fundamental frequency - F0 differs in the entire ensemble of intonation patterns IKi in the utterance spoken by native English speaker and native Russian speaker. That makes obvious that the voice of pitch in English is higher than the voice of pitch in Russian.

Intonation type	Affirmative		Special		General	
F0 [Hz]	min	max	min	max	min	max
Sample 1	92	184	100	330	109	280
Sample 2	90	180	98	280	98	286
Sample 3	100	230	60	235	101	252
Sample 4	105	230	65	232	99	211
Mean value	96.75	206	80.75	268.25	101.75	257.25
Diapason	2.13		3.34		2.53	

Intonation type	Affirmative		Special		General	
F0 [Hz]	min	max	min	max	min	max
Sample 1	80	147	85	154	85	170
Sample 2	78	150	85	155	91	196
Sample 3	81	144	80	155	84	185
Sample 4	82	146	83	157	84	185
Mean value	80.25	146.75	83.25	157.5	86.25	182.25
Diapason	1.83		1.89		2.11	

Table 1. shows the minimum (F0 min) and maximum (F0 max) of fundamental frequency in English

Table 2. shows the minimum (F0 min) and maximum (F0 max) of fundamental frequency in Russian

IV. The overview of computer-aided language learning programs

Computers were used for language learning since 1960 in the last century [5]. The research in this area of computer-aided language learning can be divided into two equal sphere from technical point of view. The whole system has got three main fields: early systems, new voice input systems and dialogue based systems. On the one side, there are various systems that have a form of websites with fill in the gaps tasks, online chat, statistic multimedia programs, modifications of popular games or even a set of digital music files for playback. On the other side, systems are able to natural language understanding, voice synthesis, and high interactive 3D programs to teach a cultural norm and also a language. For example, there are programs just for vocabulary learning, but some are focused on grammar learning. Computer-aided pronunciation programs can be separated in two very small categories such as those which are used for speech segmentation learning, and those which gives instruction on phrase level or discuss level.

A. Early systems

The Programmed Logic for Automatic Teaching Operations (PLATO) [6] system was one of the early system of computer-aided language learning which was running on the largest and expensive mainframe. PLATO and other similar systems were based on text that was presented to students with task and advise to fill it with appropriate words. If the answers were wrong, the program informed them about that without explanation of the errors. The pejorative monikers were used to describe the monotonous aspect of systems of this type. IBM developed a specialized hardware and programmed material for German language learning in New York university with tasks aimed to fill in the gaps accompanied by pre-recorded audio tracks.

B. Modern systems

Modern systems as usual perform more opportunities for language learning which includes high quality audio, graphics and automated feedback. The content of the lessons is not static and is generated randomly as a response of student action.

Many systems use some forms of automatic system recover, speech synthesis, natural language understanding, or natural language generation. WebGrader [7] was a tool for pronunciation training which helps students of French to obtain an automatic pronunciation evaluation feedback based on calibrated machine scores. One of interesting results was that the students were disappointed with the scoring, sometimes it seemed to be wrong, but there wasn't opportunity for segmentation of sentences and sending a feedback.

The Voice Interactive Language Training System (VILTS) [8] used a task-based language learning approach. The learning activities were divided into three separated levels of category of activity (speaking, reading and listening). The graphic user interface suggested the way in which the lessons can take place, but students have chosen their own way for language learning. The study showed that students reacted positively to the system, finding, that the navigation is userfriendly, and natural language recognition occurs in interactive activities and pronunciation feedback were all important factors in positive program reception.

The Tactical Language Tutoring System (TLTS) is a good example of a rich multimedia system for language learning. The student is immersed in the 3D word of language using virtual tournament where he is instructed to fulfill the tasks. Speech recognition is performed using the Hidden Markov Model Toolkit and augmented with noisychannel models to capture mispronunciations [9]. The computer-aided language learning system created dynamic questions for practice on base of teacher's sentence pattern. Graphical representation of the parts of the sentences which are practice on a given moment were shown to prompt the student to generate the whole sentence. A grammar network was created to grab potential errors according to the greatest impact where the impact was estimate as a increase of grammar errors divided by the increase of nonagreement in the model.

C. Dialogue based training system

Dialogue based training systems are used to create a virtual environment in which students ca hold dynamic and natural conversations. Instead of a given specific sentence or limited script that can lead the student to memorise them in the learning process, students can hold conversations that are varied between practice sessions. The speech recognition technology is imperfect, there is continuous tension in the system of dialogue between allowing freedom in conversation and sufficient constraining way of acting to be held in the given parameters.

V. Computer-Aided Pronunciation Training

The system of computer-aided pronunciation training (CAPT) is created to evaluate and improve pronunciation in foreign language. The computer-aided pronunciation training system can be considered as an evaluation component and a feedback component. Pronunciation evaluation can take place at two general levels: holistic and pinpoint errors detection. A holistic evaluation considers a wide choice of speech and gives the whole evaluation of speaker's proficiency. A pinpoint errors detection attempts to detect the concrete mispronunciation on a word and subword level [10].

A. Methods of pronunciation evaluation

There are several methods suggested to holistic evaluation of pronunciation. All of them includes correlation of subjective human measures with based on machine measures. The acoustic and probabilistic measurements include total duration of read speech without any pauses, total duration of speech with pauses, mean segment duration, rate of speech, and log likelihood measurements. The human rating includes the quality of pronunciation, segmentation quality, fluency and rate of speech.

B. Techniques for feedback pronunciation

The techniques for feedback pronunciation can be divided into six types: explicit correction, recast, elicitation, metalinguistic feedback, clarification request, and repetition [11]. The effectiveness of methods is the object of the study. The automatic systems of computer-aided pronunciation training occupy the treacherous ground because of the novelty of the technology and continuously changes of computer systems. The findings of the study shows that there are severe pedagogical deficiencies in many available computer-aided language learning systems, the computer-aided speech recognition systems can be used effectively in learning process.

VI. Conclusion

A core principle of communicative language learning is that the knowledge of syntax and vocabulary form is only a part of a larger hierarchy. Evaluating student's communicative competence is a major research challenge.

By teaching English we often face the situations where a student who knows well grammar fails in managing every day situations in real world. The classroom activities should leads to the progress. Language instructions based on communicative principles are the best way to form student's ability to interact with each other and more comprehensive examinations must be performed to measure student progress [10]. Intelligible pronunciation is only one of the needed skills for speaking a foreign language, and it is often not emphasized in the classroom.

A foreign language learner will make a number of pronunciation errors at the phonemic (segmental) and prosodic levels when producing speech in a target language. Errors at the segmental level can be generally classified as substitution, insertion, deletion, and duration errors. Errors at the prosodic level are more difficult to categorize. There is some debate over whether phonetic or prosodic aspects of pronunciation have more impact on perceived pronunciation quality [12].

Practically, to know a foreign language means to generate the skills and develop the ability to think as a native speaker and to understand other people's thoughts. In order to sounds right and intelligible to the listener the utterance should be conveyed into correct intonational pattern. This means that the internal or external performance of speech should be presented with an appropriate dynamic acoustic connotation in accordance to the rules of the target language.

Computer-aided intonation training is specifically designed to evaluate and improve pronunciation in foreign languages. Due to computer-aided intonation training system the specific pronunciation mistakes will be identified at the word or subword level, providing an opportunity to improve pronunciation in and outside the classroom according to visual feedback.

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ЛИНГВИСТИЧЕСКИЕ И АКУСТИЧЕСКИЕ РЕСУРСЫ КОМПЬЮТЕРНОЙ СИСТЕМЫ ОБУЧЕНИЯ ДИАЛОГОВОЙ ИНТОНАЦИИ АНГЛИЙСКОЙ РЕЧИ

Здоронок Ю.А.

В этой статье рассматриваются супрасегментные феномены речи, с которыми связана не только правильная артикуляция звуков изучаемого языка, но и грамотное произношение, просодическая оформленность мысли в речи с помощью эталонных интонационных шаблонов. Лингвистические и акустические ресурсы необходимы для компьютерной системы обучения диалоговой интонации английской речи в пределах и за пределами учебной аудитории.

Voice User Identification in Access Control Systems

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***Abstract*—In view of the constant development of any business, we have a lot of data that must be protected. At the moment, the access control checkpoints are equipped with various types of access control. But most of the access control devices have a high price. Moreover, a large part of the costs fall on the allocation of personal identification for each user agent. The solution to this problem is voice recognition. The use of biometrics eliminates the chips and access cards. Avoid loss of means of identification and theft. And the use of the voice will eliminate the expensive equipment to read the data.**

Keywords*—*Voice, identification, neural networks.

I. Introduction

Currently, voice recognition and biometrics as a whole, already widespread. The simplest example - fingerprint scanners installed on almost every laptop.

"Biometrics" assumes people recognition system on one or more physical or behavioral traits. In the field of information technology, biometric data is used as a form of identifiers of access control. Also, biometric analysis is used to identify people who are under the supervision[1]. Just biometrics provides the behavioral analysis of the object. These include walking, gestures, etc.

Authorization process using biometrics is quite simple. Using an apparatus for varying the characteristics identified by the current data are scanned and compared with previous data.

Biometric systems have a number of important advantages: biometrics uses characteristics of the human body and its behavior, which makes the data unique (give someone else a fingerprint or make the iris of your eye like a someone else's It requires quite rare and sophisticated technologies); Unlike paper-based IDs (passport, driving license, identity card), by a password or personal identification number (PIN), biometric characteristics can not be subjected to theft, can not be lost or forgotten. Quite a long time, fingerprints are used to identify criminals and prevent theft or fraud. Some people are able to imitate the voice, but it requires special skills that are not often met in everyday life.

The latter include voice, gait, gestures, handwriting, etc. Until recently, little behavioral characteristics in identification systems used in connection with the obvious drawbacks. Over time, the human gait can vary. The voice may change as a result of the disease, age-related changes or the environment (for example, high noise level). Currently, however, with the advent of effective methods of digital signal processing interest in this subject has increased significantly in the world.

We propose to use voice recognition to control access to devices on the premises. The advantage of this solution is the simplicity of the hardware and software implementation. For voice print only requires a microphone and an analog-digital converter. These devices are equipped with almost all modern desktop and mobile computers.

Task voice recognition or speaker recognition voice boils down to, to identify, classify and appropriately respond to human speech from the input audio stream. It is usually divided into three sub-tasks: receiving a voice print, identification and verification.

Receiving voice imprint - the process of obtaining the sample, representing the vector characteristics of the speaker's voice. Identification - the process of determining the identity modeled voices by comparing the sample template files saved in the database.

Verification - a process in which by comparing the submitted sample template stored in the database the requested identity is verified. The result is a proof of identity or a negative response system. Implementation of these procedures takes quite a long time, so difficult simultaneous identification of several persons.

The aim is to reduce the time of receipt of voice prints, as well as a decrease in the time of identification and verification of the voice print. To achieve this goal is proposed to use the Kohonen self-organizing map (SOM - Self-Organized Map), where the processing speed has been increased through the provision of neurons with maximum activity, while receiving minimal loss of accuracy.

II. Voice recognition principle

To implement voice recognition is necessary to make a specific course of action.

With microphone voice recording turns out to be identified and sent to the computer. It is to obtain the optimal WAV file, since ease of handling.

The resulting voice recording must be divided into frames. Separation of the footage shown in Figure 1.

This action is necessary for easier work with the recorded soundtrack. Further, all calculations will be made with each frame individually.

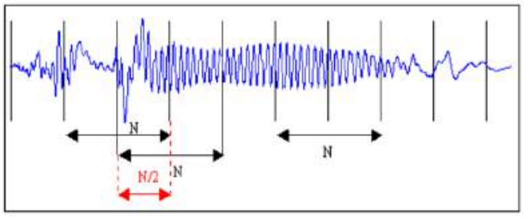

Figure 1. Audio wave

The next step is to remove noise and unwanted effects. This is necessary in order to record obtained at various times correspond to each other, regardless of external factors. There are many ways by which you can reduce the noise effects. I used the multiplication of each frame on the weighty special feature – "Hamming window":

$$\omega(n) = 0.53836 - 0.46164 * cos(\frac{2\pi n}{N-1}) \quad (1)$$

where n – ordinal number of the element in the frame for which the new value of the amplitude is calculated,

N – frame length (number of signal values measured for the period).

The resulting footage is converted to its frequency response using a sweep through the "Fast Fourier Transformation":

$$X_k = \sum_{i=0}^{N-1} x_n e^{-\frac{2\pi i}{N}kn} \quad (2)$$

where N – frame length (number of signal values measured for the period)

X_n – the amplitude of the n-th signal

$X_k - N$ – complex amplitudes of the sinusoidal signals composing the original signal.

Today the most successful voice recognition system using knowledge about the hearing aid. They are based on the fact that the ear interprets sounds not linearly but in a logarithmic scale. In view of these features is necessary to bring the frequency response for each frame "mels". The dependence is shown in Figure 2.

To go to the "mel" characteristics following relationship is used:

$$m = 2595 log_{10}(1 + \frac{f}{700}) = 1127 log_e(1 + \frac{f}{700}) \quad (3)$$

where m – frequency Melachim, F – frequency in hertz.

This last action is required for the subsequent conversion to vector characteristics which, subsequently, is compared with the database of voice records. The vector will comprise mel-cepstral coefficients, which can be obtained by the following formula:

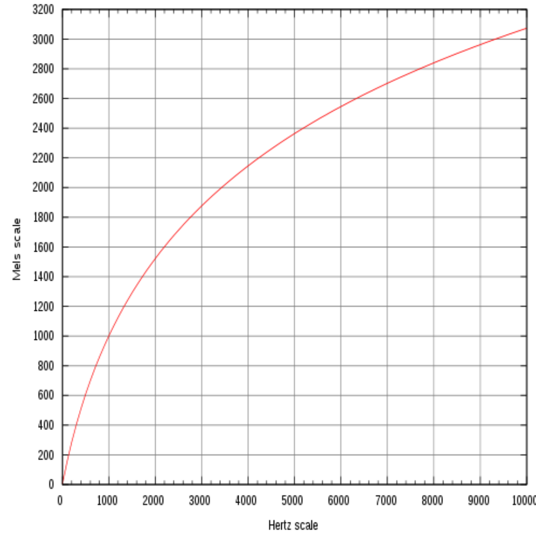

Figure 2. Audio wave

$$c_n = \sum_{k=1}^{K} (log S_k)[n(k - \frac{1}{2})\frac{\pi}{K}] \quad (4)$$

where c_n – mel-cepstrum coefficient at number n,

S_k — amplitude of k item in mel frame,

K – prescribed number of mel-cepstral coefficients $n\varepsilon[1, K]$.

The resulting feature vector is added to the database for comparison with it.

It is recommended to use multiple entries of the same voice. Then, the resulting vector is presented as the arithmetic mean vectors characterizing individual frames of speech. To improve recognition accuracy just need to average the results not only between shots, but also take into account the performance of several speech samples. With a few voice recordings, it is reasonable not to average performance to one vector, and spend clustering, for example using the method of k-means.

III. Neural network comparison

The self-organizing map (SOM) (Kohonen, 1982) is one of the most important neural network architecture. Since its invention it has been applied to so many areas of Science and Engineering that it is virtually impossible to list all the applications available to date (van Hulle, 2010; Yin, 2008). In most of these applications, such as image compression (Amerijckx et al., 1998), time series prediction (Guillen et al., 2010; Lendasse et al., 2002), control systems (Cho et al., 2006; Barreto and Araújo, 2004), novelty detection (Frota et al., 2007), speech recognition and modeling (Gas et al., 2005), robotics (Barreto et al., 2003) and bioinformatics (Martin et al., 2008), the SOM is designed to be used by systems whose computational resources (e.g. memory space and CPU speed) are fully available. However, in applications where such resources are limited (e.g. embedded software systems, such as mobile phones), the SOM is rarely used, especially due to the cost of the best-matching unit (BMU) search (Sagheer et al., 2006). Essentially, the process of developing automatic speech recognition (ASR) systems is a challenging tasks due to many factors, such as variability of speaker accents, level of background noise, and large quantity of phonemes or words to deal with, voice coding and parameterization, among others. Concerning the development of ASR applications to mobile phones, to all the aforementioned problems, others are added, such as battery consumption requirements and low microphone quality. Despite those difficulties, with the significant growth of the information processing capacity of mobile phones, they are being used to perform tasks previously carried out only on personal computers. However, the standard user interface still limits their usability, since conventional keyboards are becoming smaller and smaller. A natural way to handle this new demand of embedded applications is through speech/voice commands. Since the neural phonetic typewriter (Kohonen, 1988), the SOM has been used in a standalone fashion for speech coding and recognition (see Kohonen, 2001, pp. 360-362). Hybrid architectures, such as SOM with MultiLayer Perceptrons (SOM-MLP) and SOM with Hidden Markov Models (SOM-HMM), have also been proposed (Gas et al., 2005; Somervuo, 2000). More specifically, studies involving speech recognition in mobile devices systems include those by Olsen et al. (2008); Alhonen et al. (2007) and Varga and Kiss (2008). It is worth noticing that Portuguese is the eighth, perhaps, the seventh most spoken language worldwide and the third among the Western countries, after English and Spanish. Despite that, few automatic speech recognition (ASR) systems, specially commercially available ones, have beendevelopedand it isavailable worldwidefor the Portugueselanguage. This scenario is particularly true for the Brazilian variant of the Portuguese language, due its large amount of accent variation within the country. Scanzio et al. (2010), for example, report experiments with a neural network based speech recognition system and include tests with the Brazilian Portuguese language. Their work is focused on a hardware-oriented implementation of the MLP network. In this context, the current paper addresses the application of self-organizing maps to the Brazilian Portuguese isolated spoken word recognition in embedded systems. For this purpose, we are particularly interested in evaluating several software strategies to speedup SOM computations in order to foster its use in real-time applications. The end-user application is a speaker-independent voice-driven software calculator which is embedded in smartphones.

We used learning without a teacher, because it is much more plausible model of learning in the biological system. Kohonen developed and many others, it does not need to output the target vector and therefore, does not require comparison with predetermined ideal responses, and learning set consists only of the input vectors. The training algorithm adjusts network weights so as to produce consistent output vectors, ie, to sufficiently close the presentation of input vectors produce the same outputs. The learning process, therefore, highlights the statistical properties of the training set and groups similar vectors in the classes. Presentation of the input vector of this class will give a certain output vector. The spread signal in such a network is as follows: input vector is normalized to 1.0 and applied to the input, which distributes it on through the matrix of weights W. Each neuron in layer Kohonen calculates the sum at its input and depending on the condition of the surrounding neurons becoming active layer or inactive (1.0 and 0.0). Neurons in this layer operate on the principle of competition, ie. E. As a result of a certain number of iterations is still an active one neuron or a small group. This mechanism is called lateral. Since testing of this mechanism requires significant computing resources, in my model it replaced by finding the maximum neuron activity and awarding him the activity 1.0, and 0.0 all other neurons. Thus, the neuron is activated for which the input vector closest to the vector of the weights. As a sigmoid activation function is used, which is as follows:

$$f(x) = 1/(1 + e^{-a*x}) \tag{5}$$

where a – slope parameter.

Geometrically, this rule shows next picture:

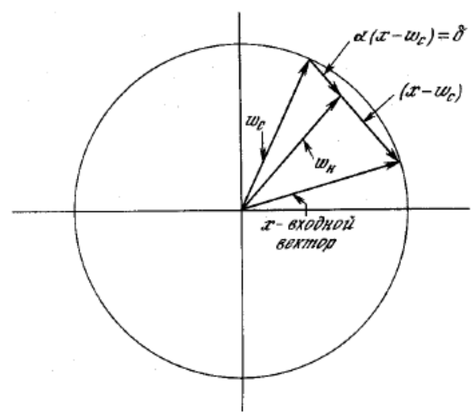

Figure 3. Correction weights of Kohonen neuron

Since the input vector x is normalized, ie. E. Is on a hypersphere of unit radius in the space of weights, then the correction weights on this rule is rotated vector weights toward the input that allows to produce statistical averaging of input vectors, which reacts active neuron. Thus, the study was replaced lateral approach leading to the activation of neurons.

IV. Results

The effectiveness of the proposed approach to the identification of the employee's voice, implemented in the access control system in the room, was estimated on the basis of techniques proposed in [20]. word composed of figures were recorded for the experiment. The data set includes the voice data of 14 speakers. 30 words (10 different words, on 3 samples each) were recorded for each speaker. Table 1 shows the selected words.

Table I. The words, taken for the experiment

One	Two	Three	Four	Five
Six	Seven	Eight	Nine	Zero

Just as in the study described in the article, all the words have been written to the indoors, and used as a source of noise conditioner. Attracted by the speakers (11 men and 3 women) spoke freely, while maintaining their respective accents and pronunciation defects. It was necessary for the complexity of classification problems, since even the same statements have different durations after detecting the endpoint. Were used for simulation and SOM TS-SOM, sluduet configuration having 10 inputs and 256 neurons located in the 16 * 16 array.

Analysis of results shows that the resulting modification has improved the effectiveness of the implementation is two times as compared to SOM: PDS, a fall of 3 per cent accuracy.

V. Conclusion

The result of this study was to modular application performing voice user authentication. The program consists of three main parts. The first carries the addition of users, the second and the third carries the identification sends information to identify the user.

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ГОЛОСОВАЯ ИДЕНТИФИКАЦИЯ ПОЛЬЗОВАТЕЛЯ В СИСТЕМАХ КОНТРОЛЯ ДОСТУПА

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Задача голосовой идентификации или распознавания диктора по голосу сводится к тому, чтобы выделить, классифицировать и соответствующим образом отреагировать на человеческую речь из входного звукового потока. При этом обычно выделяют три подзадачи: получение голосового отпечатка, идентификация и верификация. Используя самоорганизующуюся карту Кохонена, с небольшими модификациями, вместо простых алгоритмов сравнения, можно значительно ускорить данные операции.

The Enlargement of Electronic Lexical Database by Computational On-line Free System

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***Abstract*—The article describes the urgency of electronic vocabularies' update. It also depicts the principle of electronic Belarusian grammar dictionaries composing by means of computational program "Word Paradigm Generator" which is the main source of Belarusian lexical database enlargement for natural language processing in computational and linguistic platform "corpus.by" [2].**

***Keywords*—computational linguistics, lexical databases, text and speech platform.**

I. Introduction

Lexicography is a branch of linguistics which studies a process of dictionary compiling and dictionaries themselves. The lexicography accomplishes different functions: it describes normalized language, teach the language, provides interlanguage communication. But the main function of the brunch is the scientific study of vocabulary. A vocabulary is in a certain way organized collection of words, usually with the addition of notes, which provides information about the features of their structure and / or their function. Today many scholars pay attention to the new scientific field – computational lexicography for many reasons: it's a new way of compiling and collecting dictionaries. Electronic dictionary is a dictionary stored as machine (computer) data instead of being printed on paper. Many researches have pointed out that these dictionaries have a number of distinctive peculiarities In contrast with printed. Electronic format:

1) accelerates the process of finding a required vocabulary unit;
2) extends the capabilities of a unit description;
3) electronic format makes it possible;
4) allows adding extra information: additional illustrations, diagrams, pictures, use recording or live-sounding speech, etc;
5) allows adding extra information: additional illustrations, diagrams, pictures, use recording or live-sounding speech, etc;
6) gives an opportunity of quick renewal of new lexicology

In this paper the author represents the program for creating new electronic grammar dictionaries for the Belarusian language and demonstrates the mechanism of its functioning on the example of her own dictionary which composes 1500 lexemes.

II. Word paradigm generator

Service Ẅord Paradigm Generator[̈1] is a computational program which processes unknown words. It analises the structure of a word, defines its possible grammatical features and outputs the whole paradigm and a tag of this word (see figure 1). The tag is an annotation of a word which describes all grammatical features of a word depending of a part of speech to which it belongs to. The necessity of the tags is the next: morphological information is widely used in scientific and normative grammars, as they simplify the description of the language and reflect its systemic nature. Paradigms of one part of speech in most cases have the same features, the same structure and a set of endings for the same type of declension or conjugation, combine sets of similar words stems, and often characterized by similar stresses and / or morphonological phenomena.

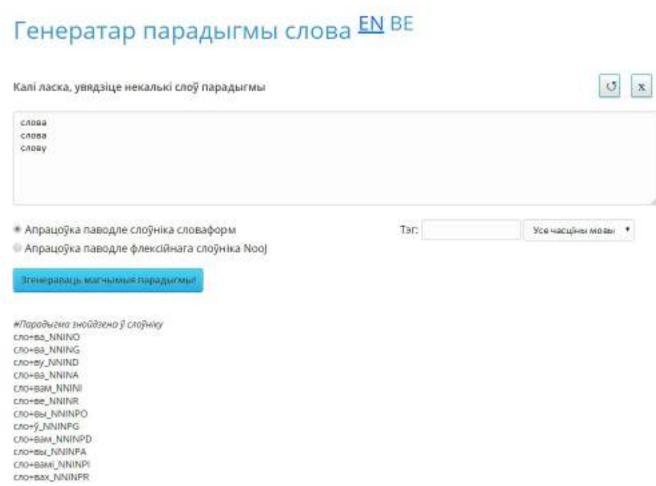

Figure 1. The lexeme which is found in the dictionary of the system

The system works on the principle of formal pattern: for a necessary word it chooses words from the database with the same grammatical characteristics and structure and outputs a list of the variants for this word. The user by himself chooses the right paradigm for this word. There are two main dictionaries which are built in the system: the dictionary of word forms and a dictionary of NooJ-format [4]. If any of these dictionaries contain a testing word, the system outputs the whole paradigm with tags (see figure 1). Otherwise it searches words corresponding to the query and outputs all possible variants (see figure 2). In other words, the algorithm searches for the nearest paradigm(s) matching the last letters of the word, to which the user needs to get the paradigm. As it is the program for grammar dictionaries enrichment, the service processes only changeable parts of speech (noun, verb, adjective, participle, pronoun, numeral). For auxiliary parts of speech the system outputs their annotation [3].

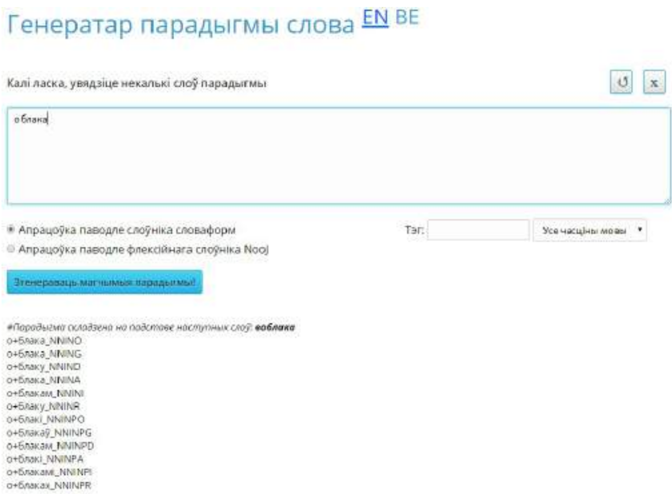

Рис. 2. The output of processing unknown word «Облака»

III. The composition of lexical database

Any dictionary is built according the next principles:

1) the nature of the dictionary;
2) the information they contain;
3) the language of the explanations;
4) an intended user.

While preparing our own Belarusian grammar dictionary, we have taken into account some other criteria for its compiling:

1) The meaning of lexical units upon which the lexicographer concentrates his attention presents very special difficulties of its own.
2) A lexicographer searches new words for the users whose needs are more practical.
3) Each entry must be self-contained, as we consult a single entry in a dictionary.
4) an intended user.

To correspond to all these points it was decided to analyze the vocabulary of the authors of 20th century both Belarusian and foreign (translations of foreign authors), such as Uladzimir Karatkevich (Dzikae paliavanne karalia Stakha), Vasil Bukaw (Zhurawliny kryk, Kar'er, Vawchynaia iama), Anton Adamovich (Tryvoha), Hohal (Vechary na khutary bliz Dzikanki), Daniel Defo (Zhytstsio i dziwnyia pryhody marakhoda Rabinzona Kruza) and so on. As a result, it was examined nearly 600 pages of different books, where nearly 5 thousand of words are unknown for the system [2].

The author has chosen 1600 lexemes in a haphazard way and divided all these words into the next groups:

1) Non-obscene words (the dictionary contains these words).
2) The words that are absent in the dictionary of the system.

The main attention is paid to the last group as all these words are unknown, therefore they are the core of a new dictionary. They are also subdivided into:

1) Proper Nouns (Анеліна, Менск, Яніна, etc.);
2) Dialectisms (дамо, йшла, etc.);
3) Russisms (начаць, дзэйстві+цельны, палучацца etc.);
4) Authorial words (кашчуннічайце, коця, дрыкганты, бомкнуцца etc.);
5) Words written in Tarashkevitsa - unofficial variant of Belarusian orthography (разьбованымі, купальле, губэрнатар, госьць, дысэртацыя).

To fall under these criteria, we have created a Belarusian grammar dictionary which contains the paradigms of a lexeme with its annotation. The dictionary composes 1500 separate lexemes, including changeable and unchangeable parts of speech (see figure 3).

Figure 3. An electronic database of 1500 separate lexemes

According to developed dictionary the author has prepared the algorithm of lexical database enlargement which consists of 5 steps:

1) Vocabulary selection.
2) Words processing by Word Paradigm generator.
3) Manual editing of output data.
4) Implementation it the system.
5) Vocabulary approbation.

IV. The specification of the program

While working with Word Paradigm Generator, the user should take into account the next points:

1) It processes one word at once (the user needs to input only single word).
2) It partially arranges stresses (some words have stress arrangement, some – no).

3) A user needs a manual editing for verification.

In the process of composing new grammar electronic dictionary the author has used Word Paradigm Generator as the main system which processes unknown words and on their basis generates grammar dictionaries. It was marked some more peculiarities of the program functioning which is necessary to correct. They are presented below. The system:

1) gives an incomplete verb paradigm (the future or present tense form is absent, depending on the verbal aspect + not all forms of participle) (see figure 4);
2) gives an incomplete paradigm of the adjective (without short and comparative forms) (see figure 4);
3) outputs participle II paradigms (in Belarusian "дзеепрыслоўе", which is unchangeable part of speech and has only aspect);
4) outputs a paradigm for unchangeable nouns (for example, са+ні, ка+ва, etc.);
5) outputs an incomplete paradigm of female nouns with endings –сць, -сьць);
6) outputs a full paradigm for complex words, where the first word is unchangeable and the second is changeable, and doesn't output a paradigm for both changeable parts of a complex word;
7) doesn't output a paradigm for changeable parts of speech in Tarashkevitsa.

There are also some mistakes with tags:

1) It outputs tags of common nouns for proper nouns.
2) Very often it outputs tags of participle I (in Belarusian "дзеепрыметнік") for adjectives and vice versa.
3) It can confuse verb aspects, therefore output incorrect tag for verbs.

+	+
цярпець_VPC	бязглузды_JJMO
цярплю_VPIF1	бязглуздага_JJMG
церпіш_VPIF2	бязглуздаму_JJMD
цярпіш_VPIF2	бязглузды_JJMA
церпіць_VPIF3	бязглуздага_JJMU
цярпіць_VPIF3	бязглуздым_JJMA
церпім_VPIF1P	бязглуздым_JJMR
цярпім_VPIF1P	бязглуздая_JJFO
церпіце_VPIF2P	бязглуздай_JJFG
церпіце_VPIF2P	бязглуздай_JJFD
церпяць_VPIF3P	бязглуздую_JJFA
цярпяць_VPIF3P	бязглуздай_JJFA
цярпі_VPM2	бязглуздаю_JJFS
цярпіце_VPM2P	бязглуздай_JJFR
цярпеў_VPIPM	бязглуздае_JJNO
цярпела_VPIPF	бязглуздага_JJNG
цярпела_VPIPN	бязглуздаму_JJND
цярпелі_VPIJJ	бязглуздае_JJNA
цярпеўшы_VPB	бязглуздым_JJNA
	бязглуздым_JJNR
	бязглуздыя_JJPO
	бязглуздых_JJPG
	бязглуздым_JJPD
	бязглуздыя_JJPA
	бязглуздых_JJPU
	бязглуздымі_JJPA
	бязглуздых_JJPR

Рис. 4. The output of verb "Цярпець"(on the left) and the adjective "Бязглузды" (on the right)

Among this list of program disadvantages we should distinguish two main points: the system problems, connecting with program incompleteness, and problems, connecting with unfilled database of the whole system which works only on the basis of one dictionary of word forms. All in all, the system works on 86% and this is a rather high level [3]. In future it is planned both to improve the capability of the program on the basis of this research and enlarge the lexical database of corpus.by.

V. Conclusion

The article covers the problem of electronic Belarusian grammar dictionaries composing by means of electronic program "Word Paradigm Generator" on the example of electronic lexical database consisting of 1500 lexemes. It is a little dictionary which contains different lexical groups including unofficial vocabulary. It provides two types of information: grammatical (the whole word paradigm) and morphological (a word annotation). Word Paradigm Generator is described as the means of electronic grammar dictionaries enrichment. The mechanism and principles of its functioning are also pointed out as well as all it deficiencies which need to be improved.

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ПОПОЛНЕНИЕ ЭЛЕКТРОННОЙ ЛЕКСИЧЕСКОЙ БАЗЫ ДАННЫХ ЧЕРЕЗ КОМПЬЮТЕРНУЮ СИСТЕМУ “ГЕНЕРАТОР ПАРАДИГМЫ СЛОВА”

Зеновко Е.С.

Данная статья описывает проблему создания и пополнения электронных словарей. Она также отражает принцип пополнения электронных белорусских грамматических словарей с помощью компьютерного сервиса в открытом доступе "Генератор парадигмы слова". Программа является основным источником расширения белорусской лексической базы данных для обработки естественного языка в области компьютерной и лингвистической платформы "corpus.by"[2].

Введение

Лексикография является разделом лингвистики, изучающим процесс составления словарей. Лексикография выполняет различные функции: она описывает нормированный язык, обучает языку, обеспечивает процесс коммуникации. Но основная ее функция - научное изучение лексики. Сегодня многие ученые обращают внимание на новое научное направление - компьютерную лексикографию по многим причинам: это новый способ сбора и пополнения словарей. Многие исследователи отмечают, что электронный формат словарей имеет ряд отличительных особенностей, таких как ускорение процесса поиска необходимой единицы словаря, расширение возможности описания единиц словаря, добавление дополнительной информации по словарных единицах, быстрое пополнение словарей и т.д. В данной статье автор представляет программу для создания новых электронных белорусскоязычных грамматических словарей и демонстрирует механизм его функционирования на примере своего собственного словаря, который составляет 1500 лексем.

Описание программы «Генератар парадигмы слова»

В данной главе описывается сервис "Генератор Парадигмы Слово"[1], который представляет собой компьютерную онлайн программу, которая обрабатывает неизвестные слова. Она анализирует структуру слова, определяет его возможные грамматические особенности и выводит всю парадигму и тэг этого слова. Система работает по принципу формального шаблона: для необходимого слова он выбирает из базы данных слова с одинаковыми грамматическими характеристиками и структурой и выводит список вариантов для этого слова.

Принцип и механизм создания лексической базы данных

В данном разделе описывается процесс подбора лексики для белорусскоязычного грамматического словаря, демонстрируются его особенности и механизм пополнения через Генератор Парадигмы Слова.

Особенности функционирования «Генератара парадигмы слова»

Третья падглава отражает особенности функционирования онлайн ресурса "Генератор Парадигмы Слова описывает все недостатки программы, которые должны быть исправлены, и пути их исправления.

Заключение

В статье рассматривается проблема составления электронных белорусских грамматических словарей, которые могут пополняться с помощью электронной программы "Генератор Парадигмы Слова». Данный механизм демонстрируется на примере электронной лексической базы данных, которая состоит из 1500 лексем. Это небольшой словарь, содержащий различные лексические группы слов, в том числе ненормативную лексику. Он дает два типа информации: грамматическую (вся парадигма слова) и морфологическую (аннотацию слова). Генератор Парадигмы слово описывается как средство электронного обогащения грамматических словарей. Отмечены механизм и принципы его функционирования, а также все недостатки, которые должны быть улучшены.

Implementation of Reinforcement Learning Tools for Real-Time Intelligent Decision Support Systems

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***Abstract*—The paper describes implementation of multi-agent reinforcement learning tool based on temporal differences. The possibilities of combining learning methods with statistical and expert methods of forecasting for subsequent integration into the forecasting subsystem for use in long-term intelligent decision support system of real-time were considered. The work is supported by RFBR and BRFBR.**

Keywords*—*artificial intelligence, intelligent system, real time, reinforcement learning, forecasting, decision support.

I. Introduction

Reinforcement learning methods (RL) [1], based on the using large amount of information for learning in arbitrary environment, is one of the most rapidly developing areas of artificial intelligence, related with the development of advanced intelligent real-time systems (RT IS) typical example of which is a real-time intelligent decision support system (RT IDSS) [2,3].

One of the most promising in terms of use in RT IS, related to the class of dynamic intelligent systems [4,5], is a learning, based on the temporal differences (TD) [1]. TD-learning process is based directly on experience without preliminary knowledge about the environmental behavior of the model environment. TD-methods intending for multi-dimensional time series can update the estimates, including other received estimates without waiting for the final result. Thus, TD-methods are adaptive. The latter property is very important for the IS of semiotic type abled to adapt to changes in the controlled object and environment [3].

Using the multi-agent approach for dynamic distributed control systems and data mining systems, including RT IDSS, that are capable of improving the efficiency and reliability of such systems is the fastest growing and promising approach [6].

When modern RT IDSS are developing, important consideration should be given to means of forecasting the situation at the object and the consequences of decisions, expert methods and learning tools [7]. These resources are necessary for modification and adaptation of RT IDSS with regard to changes in object and external environment, and for enhancing the application field and improving system performance.

II. Principles of reinforcement learning

We assume, that the uncertainty of information entering the RT IDSS‘s database about the problem area current state of the object and environment, mainly associated with the erroneous operation of the sensor (sensors) or errors from dispatching personnel. The functions of the RL-learning contains of the non-Markov decision model‘s adaptation to the situation by analyzing the history of decision and improving their quality [1,8,9].

The RL-learning decision-making module adjusting the decision-making strategy by interacting with the environment and the analyzing the evaluation function (payment function), called the agent. Agent target is to find an optimal (for a Markov process) or acceptable (for not-Markov process) decision-making strategies, also called the policies, in the process of learning. Intelligent agents must be able to support multiple learning paths and adapt to experience changes in the environment.

The target of RL-learning is to maximize the expected benefits R_t, which is determined as a function defined on the sequence of rewards:

$$R_t = r_{t+1} + r_{t+2} + ... + r_{t+T}, \quad (1)$$

where T - the final time step, r_t - reward at the time step t. This approach can be used in applications where the final step can be defined by natural way, from the kind of the problem, i.e., when the interaction of the agent-environment can be divided into a sequence, called episodes.

The main problem of RL-learning, is to find compromise between learning and application by agent. Agent must prefer actions that he had already applied and found that they are effective in terms of getting more reward. On the other hand, to detect such actions, the agent must try to perform actions that were not previously performed. Thus, agent should be use the actions that are already known, and explore new actions to be able to have the best choice in the future. An important characteristic of RL-learning is getting delayed compensations that occur in complex dynamic systems. This means that the action produced by the agent can affect not only the current award, but also all subsequent.

In terms of the use in RT IDSS, TD-methods can solve several problems: the problem of prediction the values of certain variables within a few time steps and management problem based on the how RL-agent's learning affects the environment. Thus, the agent should predict the future environment state and use these values to change the environment in order to maximize the received reward.

In despite of the problem of finding a compromise between learning and application, RL-learning has a number of important advantages for use in RT IDSS:

- using simple feedback on the basis of scalar payments;
- rapid response in supporting mode when the agent needs to adapt to changes in the environment quickly;
- interactivity and the ability to change (replenishment) analyzed data (history);
- effectiveness in non-deterministic environments;
- efficiency in conjunction with the temporal models for problems of finding consistent decisions;
- openness to modification and the comparative simplicity of inclusion in intelligent systems for various purposes (planning, management, training, etc.).

III. Scheme of Reinforcement Learning Methods Based on Temporal Differences

Let's consider RL-methods based on temporal differences (TD-methods) in terms of their use in the RT IDSS [1, 10, 11]. TD-methods using experience to solve the prediction problem. Given some experience following a policy TD-methods update their estimates. If nonterminal state S_t is visit at time t, then methods update their estimates $V(S_t)$, based on what happened after that visit, i.e. for the valuation adjustment to wait only the next time step is necessary. Directly at time $t+1$ target evaluation value is formed and necessary adjustment to existing reward r_{t+1}, and evaluation $V(S_{t+1})$ is produced. The simplest TD method, known as TD(0), is:

$$V_{S_t} \leftarrow V(S_t) + \alpha[r_{t+1} + \gamma V(S_{t+1}) - V(S_t)], \qquad (2)$$

where γ - the valuation of the terminal state. The target value will be $r_{t+1} + \gamma V(S_{t+1})$ during adjustment. TD-methods are partly based on current estimates in their adjustments so they are self-adjusting. One of the advantages of TD-methods is that they do not require knowledge of the environment model with its rewards and the probability distribution of the next states.

While using the TD-methods, estimate (benefit) becomes known at next time step. This advantage of TD-methods often crucial when using in RT IDSS, because as episodes in some situations can be so lengthy that the learning process delay related to the necessity to complete the episodes are too large.

TD-methods are learning on the basis of each transition, regardless of the ongoing actions in the future and, accordingly, are not sensitive to situations where it is necessary to ignore episodes or reduce the significance of the episodes which can greatly slow down the training. TD-methods can be divided into two main categories - on-policy and off-policy approaches. In the on-policy approach, the strategy used to control, similar to the evaluation strategy that improved during learning. In the off-policy approach, control strategy has no relationship with the evaluation strategy.

SARSA – on-policy TD control method. For an on-policy method we must estimate $Q^{\pi(s,a)}$ for the current behavior policy π and for all states s and actions a:

$$Q(s_t, a_t) \leftarrow Q(s_t, a_t) + \alpha[r_{t+1} + \gamma Q(s_{t+1}, a_{t+1}) - Q(s_t, a_t)], \qquad (3)$$

where α - constant step length; γ - the valuation of the terminal state. This update is done after every transition from a nonterminal state s_t. If s_{t+1} is terminal, then $Q(s_{t+1}, a_{t+1})$ is defined as zero. This rule uses every element of the quintuple of events, $(s_t, a_t, r_{t+1}, s_{t+1}, a_{t+1})$, that make up a transition from one state-action pair to the next. As in all on-policy methods, we continually estimate Q^π for the behavior policy π, and at the same time change π toward greediness with respect to Q^π .

Q-learning - off-policy TD control method that finds the optimal value of Q function to select the follow-up actions and at the same time determines the optimal strategy. Similarly to method TD(0) in each iteration there is only knowledge of the two states: s and one of its predecessors. Thus, the values of Q allow to get a glimpse of the future actions quality in the previous states and to make the decision task easier.

For this method, we need to evaluate the function of the value of the action $Q^\pi(s,a)$, for the current policy π and for all states s and actions a, where the episode consists of a sequence of alternating states and state-action pairs. One-step Q-learning is characterized by the following relationship:

$$Q(s_t, a_t) \leftarrow Q(s_t, a_t) + \alpha[r_{t+1} + \gamma max \alpha Q(s_{t+1}, a) - Q(s_t, a_t)], \qquad (4)$$

where α - constant step length; γ - the valuation of the terminal state. In this case, the desired function Q directly approximates Q^π - optimum function values of action, regardless to the applied strategies. The strategy determines which state-action pairs are visited and adjusted. In Q-learning update rule is always based on the greedy and deterministic strategy which improved. At the same time, the actions selected for control, based on a different strategy (not depending on $Q(s,a)$). For example, for generating action, the strategy can be used with uniform distribution in space operations.

To ensure the necessary convergence all couples must continue to adjust. This is the minimum requirement in the sense that each method is guaranteed to finding the optimum course of action. It was found [1] that function converges to Q^π with probability 1 in case of stochastic approximation for the step length sequence of values Q_t.

TD (λ) - method in which a time difference contains of the n-steps. There is an additional memory variable associated with each state, its eligibility trace. The eligibility trace for state s at time t is denoted $e^t(s)$. On each step, the eligibility traces for all states decay by $\gamma\lambda$, and the eligibility trace for the one state visited on the step is incremented by 1:

$$e^t(s) = \begin{cases} \gamma\lambda e_{t-1}(s) & \text{if} \quad s \neq s_t \\ \gamma\lambda e_{t-1}(s) + 1 & \text{if} \quad s = s_t \end{cases} \qquad (5)$$

where γ – the valuation of the terminal state, λ – trace-decay parameter. These traces show the acceptability of each state at the changes taking place in learning if there is corroborating event. Thus, for method TD (λ):

$$V_{S_t} \leftarrow V(S_t) + e(s)\alpha[r_{t+1} + \gamma V(S_{t+1}) - V(S_t)], \quad \forall s \in S : e(s) \neq 0 \tag{6}$$

While using eligibility traces, all states must be updated at each step (choosing of actions a at the state (s_t) and receive reward r at the state (s_{t+1})). At the same time, current reward information is propagated back to the states with higher values of eligibility traces. It can be shown that with value $\lambda = 0$, the algorithm becomes similar to the algorithm TD (0), updating only state s_t at step $t + 1$. With a value $\lambda = 1$, the algorithm finds a solution equivalent to full-passing method that makes sense only to occasional problems in the assessment of value after getting all rewards and counting final benefit.

IV. Multi-agent case in reinforcement learning

It is known that multi-agent systems are groups of autonomous interacting entities (agents) having a common integration environment and capable to receive, store, process and transmit information in order to address their own and corporate (common to the group of agents) analysis tasks and synthesis information [9]. The structure of the multi-agent system for RL-training is influenced by several agents at the same time and accordingly the action of each agent may depend on the actions of other agents system.

The advantages of multi-agent systems in the RL-learning:

- the possibility of parallel computing, as it uses the distributed type of the agents interaction in order to increase system performance;
- exchange of experience between the agents, by means of learning and simulation, that allows to help RL-agents with similar tasks to learn faster and achieve higher productivity;
- resiliency - system continues to operate even after failure of one or more agents;
- scalability - inclusion or exclusion of the agent from the system does not affect the operation of the system;

In addition, there are few disadvantages of multi-agent systems:

- complexity setting of learning targets;
- unsteadiness of learning problems arising from the fact that all agents are learning at the same time and each agent faces the challenge of changing the learning targets. So the basic strategy can vary with changes in strategies of other agents. Thus, RL-agent needs to find a compromise between the use of current knowledge and research environment to gather information and improve this knowledge;
- necessity of coordination;
- exponential growth in discrete state-action space. The basic Q-learning algorithm estimates the values of all possible pairs of the state-action, which leads respectively to an exponential increase in computational complexity;

V. Implementation of reinforcement learning tool for the forecasting subsystem

On the basis of statistical and expert methods of forecasting was suggested combined (integrated) prediction method [7,10], which contains of an averaging the results obtained on the basis of the moving average method and the Bayesian approach, based on weighting coefficients. Then, resulting prediction corrected by values of series obtained by the method of exponential smoothing. After that, forecast adjusted by results of the expert methods: ranking and direct evaluations. The probability of each outcome acquired by statistical methods, increased or decreased depending on the expert assessment values for these outcomes.

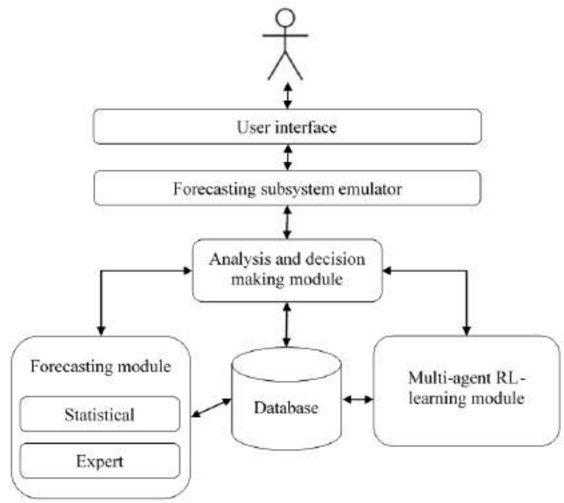

Fig. 1. Architecture of forecasting subsystem

Proposed architecture (Fig. 1) of prediction subsystem includes:

- emulator, which simulates the state of the environment with using of various system parameters change algorithms (linear and random) in the online database;
- prediction module based on statistical methods (extrapolation method of moving average, exponential smoothing and the Bayesian approach) and forecasting expert methods (ranking and direct evaluation);
- multi-agent RL-learning module consist of the group of independent agents each of which is trained on the basis of a developed TD-methods (TD (0), TD (λ), SARSA, Q-learning) as well as used for the accumulation of knowledge of the environment and able to adapt and modify this knowledge. The generalized scheme of multi-agent reinforcement learning module (MARL) is shown on Fig. 2;
- decision-making module designed for the data analysis coming from the prediction module and multi-agent RL-learning module, making decisions on follow-up actions and adjusting management strategies;

Software implementation of a subsystem prototype of forecasting using statistical and expert modules to meet the challenges of the expert diagnosis of complex technological

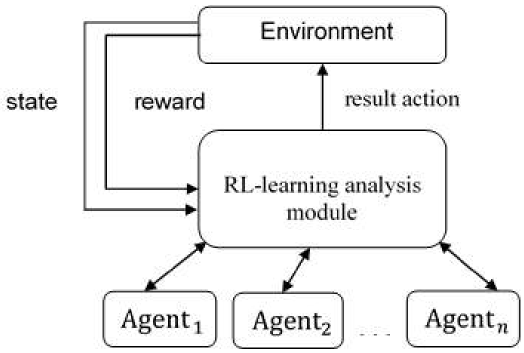

Fig. 2. Structure of multi-agent reinforcement learning module

objects (one of the nuclear power plant subsystem) were made [10,11]. The test results revealed that there is necessity to raise additional methods: RL-learning methods based on temporal differences that reveal the existing regularity by analyzing the history of the process and reduce the influence of random phenomena.

Various algorithms of TD-methods (TD (0), TD (λ), SARSA, Q-learning) have been developed and examined in order to analyze the possibility of their application in an integrated tool in order to comparing the prediction results using different techniques and their combinations [11] and maximize rewards from the environment. The main research problem of the paper is designing multi-agent RL-learning analysis module based on temporal differences methods, its integration into the forecasting subsystem, finding the most preferred methods of RL-learning and prediction in order to inclusion in the RT IDSS and evaluation of the efficiency of multi-agent systems in terms of use in RT IDSS.

VI. Conclusion

In this paper were analyzed various methods of RL-learning and implemented the relevant algorithms in terms of their further integration into the forecasting unit of RT IDSS. Particular attention was paid to the methods based on temporal differences (TD-methods). A combined forecasting method based on statistical and expert methods was proposed and algorithms for the combined method were implemented. The architecture of forecasting subsystem consist of forecasting module (includes statistical and expert sub-modules), the multi-agent RL-learning module (comprises of different agents that communicates with RL-learning analysis submodule which collect result from the agents, find optimal result action, send overall result to the environment and pass current reward and state to agents from the environment) and the module of analysis and making decisions (which collect data from other modules, analyse received information and form final effect on the environment) were suggested.

Currently, the multi-agent RL-learning module and separate agents, that working with different algorithms based on temporal differences are developing in terms of creating an integrated tool and its following inclusion in an integrated environment that focuses on the use in RT IDSS of semiotic type, in order to expand the scope, improve productivity and efficiency of the modern RT IDSS.

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РЕАЛИЗАЦИЯ ИНСТРУМЕНТОВ ОБУЧЕНИЯ С ПОДКРЕПЛЕНИЕМ ДЛЯ ИНТЕЛЛЕКТУАЛЬНЫХ СИСТЕМ ПОДДЕРЖКИ ПРИНЯТИЯ РЕШЕНИЙ РЕАЛЬНОГО ВРЕМЕНИ

Еремеев А.П., Кожухов А.А.

В статье описываются алгоритмы методов обучения с подкреплением на основе темпоральных различий. Оцениваются преимущества мультиагентной технологии в рамках применения в интеллектуальных системах реального времени. Рассматривается реализация многоагентного инструмента обучения с подкреплением на основе темпоральных различий. Представлены способы комбинирования методов обучения со статистическими и экспертными методами прогнозирования. А так же рассматриваются возможности их последующей интеграции в подсистему прогнозирования для использования в интеллектуальных системах поддержки принятия решений реального времени.

About Focusing on Relevant Information Used by Agents in Reasoning in Intellectual Systems of Hard Real-Time

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***Abstract*—We consider questions about focusing only on relevant information used by agents reasoning in intellectual systems of hard real-time. We offer the method to find the relationship of relevance between agent's knowledge and tasks solved by this agent and we also offer the method to focus attention of agent on relevant information providing his stability to anomalies using metareasoning, metaknowledge and cognitive modeling.**

Keywords*—*hard real-time, relevant information, focusing, metareasoning, stability, active logic.

I. Introduction

As we know for systems of hard real-time, it is important to be able to estimate the amount of time for solving tasks that these systems have for thinking until moment when it is late for thinking. For this, you must be able to correlate in time steps and results of reasoning with events happening in external domain. Reasoning of this type called reasoning situated in time.

To formalize reasoning situated in time different versions of active logic were suggested. As rule, traditional epistemic logics give us possibility to reason about process of reasoning of agent as a whole after its actual implementation. Active logic gives us a possibility to witness process of reason-ing of agent while this process is implementing.

The general concept of the active logic set forth in [Elgot-Drapkin, 1998]. As a model of deduction, logic is characterized by an active language, lots of deductive rules, as well as the set of "observations". If we assume that the agent says, being in a static environment, many observations can be considered as part of the initial knowledge base of a deductive system, i.e., as a set of statements that sup-port the deductive process by which new knowledge generated. However, the use of the surveillance function allows us to simulate the dynamic environment information about this environment is sup-plied to the agent as this environment changes.

Time reasoning is characterized by performing cycles of deduction, called steps [Purang et al., 1999]. Since the basis of the active logic model is a discrete-time, these steps serve as the interim standard - time is measured in steps. Agent's knowledge is associated with step index on which they were first get. The principal difference between the active logic and other temporal epistemic logics is that the temporal arguments introduced in the language of their own agent theories. Thus, the time parameter is associated not only with each statement (the formula), which is explicitly known by the agent, but also a deductive inference rules. That the agent learned at step t (t-knowledge) is used to form a new knowledge for output in step (t + 1).

II. Relationship of relevance between agent's knowledge and tasks solved by this agent

Determination of relationship of relevance between agent's knowledge and tasks solved by this agent is a key factor in the simulation of dynamic systems; it gets particular relevance for hard real-time systems. Developing a method to define relationship of relevance following assumptions were made.

The agent at each time point solves exactly one problem.

Each of the possible solved by agent tasks corresponds to exactly one of the possible modes of his work, one of which is a standard ("regular"), and the others correspond to the different classes of possible contingencies, which, in the general case, can be several . Change of operation modes of agents is irreversible: the normal mode may be replaced by an unexpected, but not vice versa; one of the non-standard modes can be replaced by another and in the future it will no longer be used.

Agent's knowledge represented as a first-order logic formulas or any of its conservative expansion. Each formula can be relevant in relation to all possible modes of operation of the agent or can be obviously irrelevant to some (but not all) of them.

Agent's reasoning for solving the current task it can be represented as a cyclic process of successive generation of sets of the so-called explicit knowledge, with each such set is associatively connected with the time it was generated. Generation of new set of explicit knowledge is a result of execution of next deductive cycle generally consisting of the following stages:

- focusing attention of agent on knowledge relevant to the current mode of operation;

- the use of inference rules.

The first step is executed only when changing the operation mode of agent. At this stage, the current set of explicit knowledge (obtained as a result of the previous deductive cycle) is filtered, which resulted in agent's focus includes only the knowledge that, in accordance with the strategy used by the agent, are relevant to the current mode of operation. This filtering allows in many cases significantly reduce the execution time of deductive cycle. Note that the change of operation modes of agent occurs when abnormal situations appear jeopardizing the implementation of the agent of its primary function in the allotted for this time, and this is due to the need to change its mode of operation.

At the stage of the application of rules of inference there is a comparison with the information that is fallen in the focus of attention of the agent during the execution of the deductive cycle, result-ing in form of the so-called set of special cases (specific instances) of inference rules obtained by substituting metavariables included in these rules of inference, by specific values (they are formulas, trapped in the focus of the agent at the beginning of its operation in this mode). Note that in the gen-eral case each inference rule as a result of comparison may have from zero to more than one concrete instance. Next comes the application of specific instances of inference rules, which result in form a set of formulas, the union of which with a lot of explicit knowledge gained as a result of the previous deductive cycle (the elements of this set are also formulas), results in a new current set of explicit knowledge. Note that the knowledge acquired by the agent as a result of observation for the external environment, including those get from other agents in the form of messages that do not stand out in a special class, and for ease of review, shall be deemed as received by the application of rules of inference, the only condition of applicability of which are points in time when the relevant observations were made. Although the formulas, once got in a set of explicit knowledge of the agent, are struck out in the future, their use for the generation of specific instances of inference rules can be blocked if they come into direct conflict with other formulas, located in the same set of explicit knowledge.

Thus, the results of the deductive cycles execution depend on how the relationship of relevance is determined between the formulas, which are the elements of explicit knowledge sets and possible modes of operation. In the simplest case it is assumed that all available explicit knowledge of agents is relevant to any possible mode of its operation. This approach has the obvious advantage, consisting in the fact that this excludes the possibility of losing information due to an error at step of focusing attention of agent the focus doesn't get knowledge important from the point of view of the current situation. On the other hand, the current explicit knowledge of the agent may have a very large volume, and not all of them may be relevant in every moment of time and current mode of operation appropriate to this time. In this case, with correct focus of attention due to the refuse of considering irrelevant information a significant amount of time can be saved, which is of great importance when working in hard real-time. Note, however, that such a situation occurs only when using the concept of time as an external entity. In other systems of active logic the length of deductive cycles serves as a time model, one is the inner entity and assumed to be constant, making it pointless to focus attention of the agent on information relevant to the current time - the length of deductive cycles does not change because of this. It is clear that in order to determine the relationship of relevance between the formulas included in the set of explicit knowledge and current modes of functioning of the agent, meta-level information is needed. The following will be considered an implicit way of determining the relationship of relevance between formulas and modes of functioning of the agent.

The relationship of relevance between knowledge (logical formulas) and solved by agents tasks (or its current operating mode) is a binary and antisymmetric. It is not transitive and not reflective, and may be defined both intensionally, for example by the algorithm, for each pair (a formula or operation mode) it gives for finite number of steps response "yes" or "no" depending on whether this couple is in the relationship of relevance and extensionally, by explicitly enumerating all pairs of this kind, together determining the relationship of relevance. The simplest and most reliable way of determining the relationship of relevance between the formulas and modes of agent's operation in terms of possible errors made at the stage of the focus, is a recursive definition for each of the formulas of language of agent of plurality of its modes of operation, for which the formula is obviously non-relevant.

III. Method of agent focusing only on the relevant information while ensuring its stability to anomalies during the reasoning in the hard real-time.

One of the most important and complex problems of intellectual system theories (including multi-agent) is to ensure the stability of intelligent agents to unforeseen situations in advance («anomalies») [Anderson et al., 2005]). Anomalies originate both due to unforeseen changes occurring in the external environment (part of which may be other agents of multi-agent systems), and because of the imperfections of existing agent's knowledge about it, and these anomalies neg-atively affect its functioning. Abutment of agents to anomalies is especially important in hard real-time systems, which is characterized by the existence of the critical time threshold (deadline) of facing the systems task solution, the excess of which is fraught with catastrophic consequences. A typical example of the anomaly for such systems is a situation where an event anticipated at the designated time, however, did not come. This event may be caused not only by the state of the external environment, but by the current state of knowledge the agent. In both cases one can speak of appearance of threat of exceeding the time allotted to the solution of the problem, i.e. the catastrophic deterioration of the functioning of both the agent and the system as a whole. It is clear that in the systems of hard real-time time resource of agent is severely limited. Next, we consider the issue of increasing the resistance to anomalies of agents with limited time resources through the use of the concept of metacognition, implemented by means of active logic.

The term "metacognition" was introduced by J. Flavell [Flavell, 1979], [Flavell, 1987] and de-fined by him as an awareness of person of their cognitive processes and related strategies, or, as he put it, as "knowledge and acknowledge with respect to enforcement-cognitive effects" In the other sources metacognition is often defined simply as a reflection of thinking (e.g. [Metcalfe et al., 1994]), bearing in mind in this "second-order knowledge." In the future, instead of the term “thinking” we will use more appropriate for the artificial intelligence systems term “reasoning”.

Studies of metacognition expanded information processing theory. The key in this new psychological paradigm was the idea of thinking as the flow of information inside and outside the system of mental structures: how information is stored and restored in the mental structures, how these structures evolve, how the storage and correction management happens, etc.

According to the model of Flavell person’s ability to control "a wide variety of informative initiatives takes place through action and interaction between the four classes of phenomena" [Flavell, 1979]:

- metacognitive knowledge,
- metacognitive feeling
- goal (or goals)
- actions (or strategies).

The model includes the knowledge of the three common factors:

- Knowledge of the functioning of "cognitive processing";

- Knowledge of the task, its requirements and how these requirements can be met as conditions change;

- Knowledge of strategies to accomplish this task (cognitive strategies to achieve goals, and metacognitive strategies to monitor the progress of cognitive strategies).

Metacognitive knowledge can influence the direction of cognitive initiatives through a deliberate and conscious search in the memory or the unconscious and automatic cognitive processes.

The difference between cognitive and metacognitive strategies should be noted. The former help the person to achieve a specific cognitive goals (for example, to understand the text), and the latter are used to control succeeding of this purpose (e.g., self-questioning for understanding of the text). Metacognitive components are usually activated when knowledge fails (in this case it may be a lack of understanding of the text at first reading). Such failure activates metacognition, allowing the person to correct the situation. Thus, metacognition is responsible for active monitoring and consistant regulation of cognitive processes.

In the context of the use of metacognitive principles for improving the resistance to anomalies of rational agent with limited time resource in the work [Anderson et al., 2006] it was proposed the concept of "metacognitive" cycle. It is defined as the cyclical performance of the following three stag-es:

- Self-observation (monitoring);

- Self-assessment (analysis of detected abnormalities);

- Self-improvement (regulation of the cognitive process).

Note that in other works devoted to metareasoning (or metacognition) ([Brown, 1987], [Cox et al., 2007], [Raja et al., 2007]), the term "metacognitive" cycle of specified type also used. Common to all these works is the approach based on stage of self-observation, which reveals the presence of anomalies, is built taking into account the binding of possible actions of agent that affect the external environment, the expected on-consequences of these actions. An indication of the presence of anomalies in this case is a mismatch between the expectations of the agent and the incoming information about the external environment. At self-observation stage, they are reduced to the verification of the presence for the agent in the discourse of formal signs and in presence of anomalies in the agent’s reasoning, solving certain problems. These formal features are the so-called direct contradictions in knowledge of agent. Formally, the presence of a pair of contraries formulas expressing the current knowledge of the agent called direct contradiction.

Because anomalies in the hard real-time systems mainly linked to the delay of occurrence of the expected responses of external environment of an agent, such situations must be detected in the monitoring process first. At the stage of self-assessment level of threat to the quality of functioning of the agent, which is fraught with anomaly detection, is set and at the stage of self-improvement, if the threat is real, a new strategy to address the problem faced by the agent is chosen. A typical output from such situations is the transition to the new strategy which requires a shorter time resources to car-ry out, but provides although acceptable, but less quality solutions facing the agent problem in comparison with the "old" strategy [Vinkov and other ., 2010].

Thus, a logical system, formalizing reasoning agent with limited resources, should give him the opportunity to evaluate the available time resource of agent at any given time so that depending on the results of the evaluation the agent could change the course of his reasoning (temporal sensitivity property of agent [Elgot-Drapkin, 1998]). In addition, the agent must be tolerant to inconsistencies in their knowledge and to be able to identify them. The prerequisite is also the ability of the agent to assess at each time the completeness of existing knowledge and to realize not only what he knows but what he does not know.

$\frac{t:\phi,\psi}{t+1:\phi\wedge\psi}$ - conjuction

$\frac{t:\phi\wedge\psi}{t+1:\phi}$ - detaching

$\frac{t:\phi}{t+1:\phi}$ - inheritance

$\frac{t:\phi,\phi\rightarrow\psi}{t+1:\psi}$ - modus ponens

Different levels of complexity of theories of active logic associated with involvement in the process of reasoning of agents with three different mechanisms: the timing, providing a temporal sensitivity of reasoning of agents, self-knowledge (agents’ ability to acknowledge both what they know at any given moment of time, and what they don’t know at any given moment of time) and detect inconsistencies in current knowledge.

Timing is achieved through a special one-place predicate now (.). In relation to him, the following applies:

$$\frac{t:now(t)}{t+1:now(t+1)}$$

Self-knowledge is achieved through the rule of inference:

$$\frac{t:\varphi,sub(\phi,\varphi),[\phi]}{t+1:now(t+1)}$$

where ϕ - any formula, not known to the agent i at step t, but it is a well-known formula of subformula ϕ known to him, i.e. the perceived by agent, sub (.,.) - double-place metapredicate expressing the relation "to be subformula», $[\phi]$ - notation, meaning that the formula ϕ absent in current knowledge the agent at step t. K (.,.) - double-place metapredicate, expressing the fact that the agent knows some formula at some point in time. Detection and elimination of contradictions is achieved through the rule of inference:

$$\frac{t{:}\varphi,\neg\varphi}{next\ t{:}contra(i,\varphi,\neg\varphi)}$$

where contra (.,.,.) – a special three-place metapredicate having the value "true" if at the moment of time t the current knowledge of the agent containing formula ϕ and $\neg\phi$.

IV. Conclusion

In this paper we propose a method of focus of the intelligent agent on relevant information in-formation while ensuring its resistance to anomalies. The method is based on metareasoning mecha-nisms, metacognition and cognitive modeling. It implemented using the active logic formalism. Promis-ing objectives of the study are to develop a method of decomposition, in which the subtasks of the same task are interacting with each other; distribution and redistribution method subtasks between agents depending on the current situation based on the concept metacognition; model of goal setting in hard real-time system.

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О ФОКУСИРОВКЕ ВНИМАНИЯ НА РЕЛЕВАНТНОЙ ИНФОРМАЦИИ ПРИ РАССУЖДЕНИЯХ АГЕНТОВ В ИНТЕЛЛЕКТУАЛЬНЫХ СИСТЕМАХ ЖЁСТКОГО РЕАЛЬНОГО ВРЕМЕНИ

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Рассматриваются вопросы фокусировки внимания только на релевантной информации при рассуждениях агентов в интеллектуальных системах жесткого реального времени. Предлагается способ определения отношения релевантности между знаниями агента и решаемыми им задачами и метод фокусировки внимания агента на релевантной информации при обеспечении его устойчивости к аномалиям на основе метарассуждений, метапознания и когнитивного моделирования.

The Algorithm to Retrieve Temporal Cases for Temporal Case-Based Reasoning

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***Abstract*—In this paper the problem of the application of temporal reasoning and case-based reasoning (CBR) in intelligent decision support systems (IDSS) is considered. The way to expand the existing case-based reasoning mechanisms to temporal case-based reasoning mechanism explained.**

***Keywords*—Intelligent decision support systems, temporal reasoning, analogous reasoning, case-based reasoning, temporal logic, temporal constraint satisfaction problem.**

I. Abstract

An important task in the development of advanced intelligent systems such as intelligent decision support systems of real-time (IDSS RT) is the problem of modelling common sense reasoning [1-2].

Along with widely used in the field of artificial intelligence (AI) techniques such as inductive reasoning, abduction, argumentation and analogy are actively developed methods of case-based reasoning (CBR-methods) [3-5]. Temporal reasoning and case-based reasoning (CBR) can be used in various applications of AI and for solving various problems, e.g., for diagnostics and forecasting or for machine learning [6-8].

Case-based reasoning, like analogous reasoning, is based on analogy, however, there are certain differences in the implementation. A precedent is defined as a case that took place earlier and is an example or justification for subsequent events of this kind. Case-based reasoning allows to make decisions in new, unknown situations, using or adapting the decision taken earlier in the already known situation, (i.e. using already acquired early decision-making experience) [4].

CBR-methods are well developed and widely used in practice.

Typically, classical CBR-methods allows to extract cases based on the values of the parameters controlled by the system at the current time, but without taking into account the dynamics of the process (i.e. the situation described as the "snapshots" of the control parameters of the observed object or system with no account of their history changes).

Given the fact that the nature of the physical processes is that for the same values of parameters of controlled process often can go with different ways, which will largely determine the future dynamics of their changes, sharply raises the question of improving the CBR-methods by giving them the possibility of taking into account the temporal and causal relationships.

Thus, the need for a new way of presenting the precedents allows to take into account parameters change history - a method based on temporal precedents, as well as adapted to take into account the time factor extraction algorithms precedents.

This work is proposed extension of CBR-methods that allows taking into account the behaviour of the controlled process or object over time.

When taking into account the time factor it is possible to consider the problem situation in the dynamics, that is, the current situation is not compared with fixed parameters snapshot from the case. We can take into account changes of this parameters over time, their behaviour.

II. Temporal case

There are several methods to build the temporal case-based reasoning mechanism on the basis of the existing snapshot-based approaches: we can replace snapshot with historical set of the snapshots or we can introduce the time explicitly.

The first method corresponding to the changes modelling. Each snapshot in the history is the system state. These states are regarded as momentary pictures of the object, which don't have any time duration. Time itself is regarded implicitly, via modelling of the system changes within time.

Method of the replacing snapshot with historical set of the snapshots is the easiest, but it often require storing a huge volume of information. Also this approach have constraints when presenting complex time dependences (events, which have duration, continuance of processes, causal relations etc.).

Some different ways to eliminate this can be found, however in the most cases they are reduced to introduction of an explicit time model. Explicit time modelling provides the possibility to make flexible formalized languages, which help to do reasoning on the basis of expressions, truth values of which are timed to the definite moment or time interval, and they can change in the course of time [9]. Time is presented explicitly, taking into consideration its properties. Time can be presented both syntactically (via explicit temporary structures) and semantically (modal logics are typical representatives of this approach). Also we gain ability to use temporal structure to speed up reasoning mechanism.

So, more promising in this light looks methods of temporal case construction based on temporal logic.

In this case, the information about time is separated from the information about parameters. This reduces the amount of stored information, and have a positive effect on the inference algorithms that should process less volume of data. In addition, we can get the advantages of possibility to determine similarity in two levels - on the level of the temporal structure and the level of a parametric snapshot comparison at the specific time moments.

In this paper, we consider the models, based on the presentation of information about time as constraints (dependences) between time primitives. In temporal logics using the concept of constraint satisfaction, information about time is presented as dependences between temporal primitives (moments, intervals or their combinations). Dependences between primitives are interpreted as constraints to real time of their appearance. Usually sets of temporal primitives and relations among them are presented as the Temporal Constraint Satisfaction Problem (TCSP), which is detailing of a more general Constraint Satisfaction Problem (CSP), what permits to use CSP methods to solve the TCSP.

Lets see how temporal case based reasoning can be build on the base of the metric temporal constraint satisfaction problem (Metric TCSP) [9].

Metric TCSP defined as $Z = (V, D, C)$, where:

- V - a finite set of temporal variables, corresponding to the time points;
- D - range of values of the temporal variables (the set of integers);
- C - a finite number of binary temporal constraints $C_{ij} = [a_1, b_1], \dots, [a_k, b_k]$, where the intervals are disjoint.

Each constraint C_ij defines for the temporal variables V_i and V_j allowable distance between them. Intervals in the constraint C_ij are interpreted as a disjunctive [3].

To define the model of temporal case the situation definition introduced as $S =< V, P, D, C >$, where

- $V = V_1, \dots V_m$ - finite set of temporal variables (interpreted as the time points);
- D - range of values of the temporal variables (the set of integers);
- C - a finite number of binary temporal constraints $C_{ij} = [a_1, b_1], \dots, [a_k, b_k]$, where the intervals are disjoint; $P = P_1, ...P_k$ – the set of the parameters of the controlled object.

Temporal case defined as the situation supplemented with a diagnosis and recommendations to the decision maker (DM) – $Tc =< V, P, D, C, Q >$, where Q - the DM recommendations.

When looking for a case applicable to the situation observed an algorithm that takes into account the temporal constraints are used.

An algorithm for constructing temporal case on the history of parameters changes contains several steps.

The first stage uses algorithm 1 to compress the history of parameters changes to the series of events $S = e_1, ...e_r$, where:

- $e_i = (t_i, P_i)$ – event description,
- $t_i \in Z$ - time of the event,
- $P_i = (p_1, ...p_k)$ – the parameters set, described object state at time t_i.

On the second stage, we extracting metric TCSP using algorithm 2.

Algorithm 1 Temporal situation construction based on the history of the parameters sets

Input: $H = H_i$ - history, where:
- $H_i = (p_1, ..p_k)$ – object parameters set on the i-th tact,
- τ – the count of the recorded tact's.

Output: $S = e_i$ – situation, where:
- $e_i = (t_i, P_i)$ – event,
- $t_i \in Z$ – time point of the observation of the e_i,
- $Pi = (p_1, ..p_k)$ – object parameters set at the t_i

Code:

$k \leftarrow 0$
$S \leftarrow S \cup \{(k, H_k)\}$
for $(i \leftarrow 1 \ to \ \tau - 1)$ **do**
  if $(H_i \neq H_k)$ **then**
    $S \leftarrow S \cup \{(i, H_k)\}$
    $k \leftarrow i$
  end if
end for
return S

This algorithm produces metric TCSP with non-disjunctive constraints from STP subclass (Simple Temporal Problems).

If we need update existing case with new information, we can use algorithm 3 to merge cases.

Note that we can use different strategies to combine constraints at the line 8 of the algorithm 3.

If we simple combine them with union operation we can increase fragmentation level (the disjunctive constraints can appear and resulted TSP will leave STP subclass). To avoid this and at the same time soft the resulted constraint we can apply the method of upper-lower tightening [12].

In this case, will be allowed any value of the time of occurrence of the event in between the lower and upper boundary (Fig. 1).

Note that the algorithm 3 assumes that the state of the controlled object is identical in the merged cases at corresponding moments of time.

In practice, however, such a condition is sufficiently rigid.

So it makes sense to implement the algorithm that averages parameters sets for the combined time point (for example such as done in the algorithm 4) or we can implement the transition from the exact value of the parameter to an acceptable range.

Algorithm 2 Temporal case construction

Input: $S = e_i$, i=0..n, where:

- $e_i = (t_i, P_i)$ – event,
- $t_i \in Z$ – time of the event observation,
- $P_i = (p_1, ..p_k)$ – object parameters set at the time t_i,
- Q – diagnosis.

Output: $U = (V, P', D, C, W)$ – temporal case, where:

- $V = V_i, i = 0..n$ – finite set of the temporal variables (time points), $V_i \in R$,
- $P' = P'_i$ – object parameters set at the time moment $V_i, P'_i = (p_1, ..p_k)$,
- D - domain of the temporal variables;
- C – set of temporal constraints $C_{ij} = [a_1, b_1], \ldots, [a_k, b_k]$,
- Q – diagnosis.

Code:

$e_i \leftarrow e_i = (t_i, P_i) \in E : \forall j \neq i t_j > t_i, where e_j = (t_j, P_j)$
$S \leftarrow S \cup \{(k, H_k)\}$
for all $(e_k \in S)$ **do**
  $e_k \leftarrow (t_k - t_i, P_k)$
  $V \leftarrow V \cup \{V_k\}$
  $P' \leftarrow P' \cup \{P_k\}$
end for
for $(i \leftarrow 0 \ to \ n+1)$ **do**
  for $(j \leftarrow 0 \ to \ n+1)$ **do**
    if $(i \neq j)$ **then**
      $C_{ij} \leftarrow \{[t_j - t_i, t_j - t_i]\}$ ▷ $(where \ t_i \ and \ t_j \ defined \ from \ the \ e_i = (t_i, P_i) \ and \ e_j = (t_j, P_j))$
    else
      $C_{ij} \leftarrow$
    end if
  end for
end for
return $U = (V, P', D, C, Q)$

Algorithm 3 Merging temporal cases

Input: U^1, U^2 - cases to merge, where:

- $U^l = (V^l, P^l, D^l, C^l, Q^l)$ – temporal case, in which $V^l = V^l_i, i = 0..n,$ – finite set of temporal variables, $V_i \in Z$, $P^l = \{P^l_i\}$ – object parameters set at the moment V^l_i, $P^l_i = (p_1, ..p_k)$, D^l – domain of the temporal variables; ^{l} – finite set of temporal constraints $C^l_{ij} = \{[a_1, b_1], \ldots, [a_k, b_k]\}$, Q – diagnosis.
- Assumed that $|V^1| = |V^2|$ and $P^1 = P^2$.

Output: $M = (V, P', D, C, Q)$ – temporal case, where:

- V=Vi, i=0..n, – finite set of temporal variables,
- $Vi \in Z$,
- $P = \{P_i\}$ – object parameters set at the moment V_i, $P'_i = (p_1, ..p_k)$,
- D - domain of the temporal variables;
- C – finite set of temporal constraints $C_{ij} = \{[a_1, b_1], \ldots, [a_k, b_k]\}$. t_i

Code:

if then$(|V^1| \neq |V^2|)$
  return ▷ Couldn't merge cases
end if
▷ Softening temporal constraints
for $(i \leftarrow 0 \ to \ n+1)$ **do**
  for $(j \leftarrow 0 \ to \ n+1)$ **do**
    if $(i \neq j)$ **then**
      $C{*}_{ij} \leftarrow C^1_{ij} \cup C^2_{ij}$
    end if
  end for
end for
return $M = (V^1, P', D, C^*, Q)$

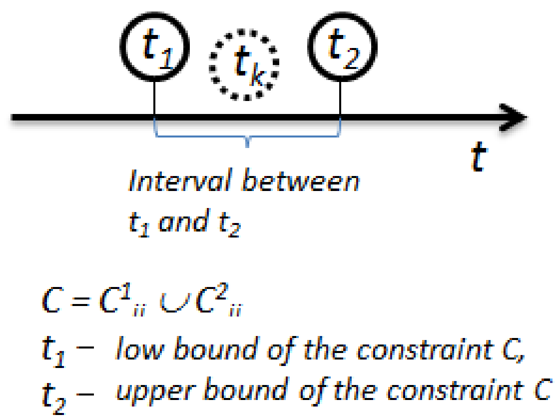

Figure 1. Illustration of the strategy to reduce the fragmentation of the metric temporal constraints on temporal case construction

III. Conclusions

The case-based temporal reasoning allows taking into account the sequence of the events and their durations.

If the metric information didn't needed on the level of the description of the temporal structure of the temporal case, we can use another base model to build it. For example we can use qualitative TCSP, based on the point algebra for example, for which exists effective reasoning algorithms [7, 11, 13].

Described models and algorithms can be used to extend the capabilities of modern CBR-systems, allowing to implement temporal case-based reasoning, taking into account the course of the controlled process, the history of its transition to the observed situation.

For example, described methods and algorithms was widely used to build intelligent features of payable parking access control system sPARK.

Modern parking solutions is the complicated complexes, which are equipped with an automatic barriers, the video cameras, fire and access alarm, etc.. The major target of the car access control system is passage control of the cars, registration of the visitors and the car owners, stealing prevention. The object of access in this system is the car. The execution units are the barriers and the gates, which system should open before the passage and close after car entrance completed. So, the system should control that the car successfully entered to the parking territory. The necessity to control the driving process leads to take into account the temporal dependencies [14]. The ability of analysis of the sequences of observed by the system actions permits to implement more reliable and intelligent

Algorithm 4 Merging temporal cases

Input: U^1, U^2 - cases to merge, where:

- $U^l = (V^l, P^l, D^l, C^l, Q^l)$ – temporal case, in which $V^l = V_i^l$, $i = 0..n$, – finite set of temporal variables, $V_i \in Z$, $P^l = \{P_i^l\}$ – object parameters set at the moment V_i^l, $P_i^l = (p_1, ..p_k)$, D^l – domain of the temporal variables; ^{l} – finite set of temporal constraints $C_{ij}^l = \{[a_1, b_1], \ldots, [a_k, b_k]\}$, Q – diagnosis.
- Assumed that $|V^1| = |V^2|$ and $P^1 = P^2$.

Output: $M = (V, P', D, C, Q)$ – temporal case, where:

- V=Vi, i=0..n, – finite set of temporal variables,
- $Vi \in Z$,
- $P = \{P_i\}$ – object parameters set at the moment V_i, $P_i' = (p_1, ..p_k)$,
- D - domain of the temporal variables;
- C – finite set of temporal constraints $C_{ij} = \{[a_1, b_1], \ldots, [a_k, b_k]\}$. t_i

Code:

if **then**$(|V^1| \neq |V^2|)$
    return ▷ Couldn't merge cases
end if
▷ Averaging parameters values
for $(i \leftarrow 0\ \ to\ \ n+1)$ **do**
    $P_i \leftarrow \frac{P_i^1 + P_i^2}{2}$
end for
▷ Softening temporal constraints
for $(i \leftarrow 0\ \ to\ \ n+1)$ **do**
    for $(j \leftarrow 0\ \ to\ \ n+1)$ **do**
        if $(i \neq j)$ **then**
            $C*_{ij} \leftarrow C_{ij}^1 \cup C_{ij}^2$
        end if
    end for
end for
return $M = (V^1, P', D, C^*, Q)$

solution.

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АЛГОРИТМ ИЗВЛЕЧЕНИЯ ТЕМПОРАЛЬНЫХ ПРЕЦЕДЕНТОВ ДЛЯ МЕХАНИЗМА РАССУЖДЕНИЙ НА ОСНОВЕ ТЕМПОРАЛЬНЫХ ПРЕЦЕДЕНТОВ

Куриленко И.Е., Гулякина Н.А.

В статье рассматривается проблема применения механизма рассуждений на основе темпоральных прецедентов в составе современных интеллектуальных систем типа интеллектуальных систем поддержки принятия решений реального времени. Рассматриваются способы перехода к темпоральным прецедентам через явное и неявное введение фактора времени. Предлагается модель представления прецедента на основе метрической точечной временной логики. Объясняется механизм извлечения темпоральных прецедентов и приводятся алгоритмы формирования прецедента и слияния (обобщения) прецедентов.

Detection of Data Anomalies at Network Traffic Analysis

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***Abstract*—The paper is devoted to the problem of possibilities to recognition for unauthorized access to information transferred over networks on the basis of time series analysis. Algorithms of anomaly search in time series collections and the results of computer modeling are produced.**

***Keywords*—time series, anomaly detection, traffic analysis, dissimilarity function**

I. Introduction

The up-to-date rapid development of information technologies and implementation them to different spheres of human activities made very urgent an information security problem since informatization of the whole society caused by the growth of computer crimes the related plunders of the confidential and other information, subject to protection, and also the material losses [1].

At present, using components of foreign production is the cornerstone of production of technical means and the software for the majority of computing systems. However, at the same time there is a threat of information leakage due to use of the functional capabilities negatively affecting on safety of processed information (further in the text —a malicious code or malware).

Such malicious functional possibilities could use for organizing hidden channels in round of well-known protection means at passing defended information on computer networks.

One of the ways of information losses under discussion with 90 years [2] is possibility of malicious codes to use parameters of transfer protocols for coding defendable hidden information The channel capacity of information losses could be rather low, for example, on 2-4 orders low than the capacity for ordinary information channels. Nevertheless, under modern velocities of information transferring (gigabytes per second) such hidden channels possesses a high capacity. Even on low-speed links of communication, the method could be efficient, if it is necessary to draw a not great volume of important information.

In case a protection system implements encoding the information transferred according to the IP protocol, a malicious code can use such parameters as a lengths of packets, temporal intervals between packets for coding transferred unauthorized information. Taking account of a high complexity of up-to-date software and closing its program codes for researching by developers, often it is impossible to produce software researching for detecting similar malicious program functions.

II. Problem investigation

Transferring encoded data on communication links is brought about by conversion of bit sequences to electromagnetic signals. The data presented by bits or bytes are transferred with a velocity defined by the number of bits in time unit. Such parameters of the physical layer of network protocols as bit rate, the encoding method, the transfer scheme and a range of a signal are determined by standards that are developed by the competent organizations. The process of physical data transfer on a certain interval can be considered as time series

In general, the time series TS is an ordered sequence of values $TS =< ts_1, ts_2, .., ts_i, .., ts_m >$ describing the flow of a long process, where the index i corresponds to a time mark. ts_i values can be sensor indications, product prices, exchange rates and so on.

The analysis of a traffic will be a basis for detection of malicious program functions in an information exchange system: if parameters of a typical information exchange on certain protocol are known, then the abnormal template of behavior in a computer network obtained by traffic analysis in the case of exchange according to this protocol could speak that at analyzed system there is a malicious program function, and anomalies in a traffic are caused by actions of such programs.

The anomaly detection problem [3] is set up as the task of searching for templates in data sets that do not satisfy some typical behaviors. The anomaly, or "outlier" is defined as an element that stands out from the data set which it belongs to and differs significantly from the other elements of the sample. Let's consider, thus, the problem of search of anomalies in sets of time series.

The problem of anomaly detection in time series sets is formulated as follows. Let $TS\_STUDY = \{ts\_study_1, ts\_study_2, .., ts\_study_m\}$ be a set of objects where each object is time series. We call it a learning set. Each of the time series in a learning set represents some "normal" behavior or a process flow. Based on the analysis of TS_Study one needs to build a model to distinguish the instances of time series from $TS\_TEST = \{ts\_test_1, ts\_test_2, .., ts\_test_n\}$ to "normal" or "abnormal".

III. Methods of anomaly searching

We propose a method for the anomaly detection in the sets of time series, This method is a modification of an "exact exception problem" [4] that is described as follows: for the given set of objects I, one needs to get an exception set I_x. To do this, there are introduced

1) the dissimilarity function $D(I_j)$, $I_j \in I$, defined on *P(I)* – the set of all subsets for I and receiving positive real values;
2) the cardinality function $C(I_j)$, $I_j \in I$,defined on *P(I)* – and receiving positive real values such that for any $I_1 \subset I$, $I_2 \subset I$ $I_1 \subset I_2 \Rightarrow C(I_1) < C(I_2)$;
3) the smoothing factor $SF(I_j) = C(I \setminus I_j) * (D(I) - D(I \setminus I_j))$, which is calculated for each $I_j \subseteq I$.

Then $I_x \subset I$ will be considered an exception set for *I* with respect to *D(I)* and *C(I)*, if its smoothing factor $SF(I_x)$ is maximal [4].

Informally, an exception-set is the smallest subset of I, that makes the largest contribution to its dissimilarity. A smoothing factor shows how much dissimilarity of a set *I* can be reduced, if from it to exclude a subset I_j.A dissimilarity function can be any function that returns a low value if elements of a set are similar to each other and a higher value if elements are dissimilar.

The algorithm *TS-ADEEP* that is based on this method was adapted for the anomaly detection problem in sets of time series. As a set *I* we use $TS\_STUDY \cup \{ts\_test_j\}$ for each $ts\_test_j \in TS\_TEST$. A dissimilarity function for time series is set up as follows:

$$D(I_j) = \frac{1}{|I_j|} * \sum_{i \in I_j} |i - \overline{I_j}|^2, \ \overline{I_j} = \sum_{i \in I_j} \frac{i}{|I_j|}$$

First, the average for the time series of I_j is calculated. The dissimilarity function is calculated as the sum of squared distances between the mean and vectors of I_j. The cardinality function is given by the formula $C(I \setminus I_j) = \frac{1}{|I_j|+1}$. The formula for calculating the smoothing factor is $SF(I_j) = C(I \setminus I_j) * (D(I) - D(I \setminus I_j))$.

If an exception set for $I = TS\_STUDY \cup \{ts\_test_j\}$ contains ts_test_j, then ts_test_j is an anomaly.

Based on this method, the algorithm *TS-ADEEP* for anomaly detection in sets of time series was introduced.

In this paper we propose the algorithm *TS-ADEEP-Multi* that is a generalization of the algorithm *TS-ADEEP* for the case of a study set contains several classes of time series. The generalization is quite obvious: splitting study set to single class subsets and consequently applying the *TS-ADEEP* algorithm, we can determine whether the considered time series is an anomaly. If time series is an anomaly for each subset or time series is not an anomaly for the only subset of the study set, the answer is quite obvious. However, there is a case where the time series is not an anomaly for several study set subsets. The algorithm *TS-ADEEP-Multi* is shown in the Table I.

A simulation of anomaly detection process was conducted on widely used datasets "cylinder-bell-funnel" [6] and "control chart" [7]. "Cylinder-bell-funnel" [6] contains three different classes – "cylinder", "bell", "funnel". "Control chart" [7] contains six different classes that describe the trends may be presented in the process: normal, cyclic, increasing trend, decreasing trend, upward shift, downward shift. The results of

Table I. THE ALGORITHM TS-ADEEP-MULTI

TS-ADEEP-Multi algorithm
input: (TS Study: learning set that contains time series of several classes; TSTEST: test set)
output: TS_ANOM_O – a set of anomaly time series of on the "optimistic" assessment; TSAnom_P - a set of anomaly time series on the "pessimistic" assessment
begin
$TS\_ANOM = \emptyset$
Let N be a number of classes containing in the learning set
$TS\_STUDY\_C =$
$\{TS\_STUDY\_C_1, TS\_STUDY\_C_2, .., TS\_STUDY\_C_N\}$ – is a partition of TS_STUDY such that
$TS\_STUDY\_C_k$ containts only examples of class $k, k = 1..N$
for j from 1 to $|TS\_TEST|$ **begin**
  choose ts_test_j from TS_TEST
  for k from 1 to N **begin**
    $I = TS\_STUDY\_C_k \cup ts\_test_j$
    Find the exception set I_x in I
    IF $ts\_test_j \in I_x$, then ts_test_j is an anomaly for class k (doesńt belong to it)
  end
  If ts_test_j is an anomaly for all of the classes $TS\_STUDY\_C_k, k = 1..N$, then
    $TS\_ANOM\_O = TS\_ANOM\_O \cup ts\_test_j$
  If ts_test_j belongs to a single class $TS\_STUDY\_C_k$, then it is not an anomaly
  If ts_test_j belongs to r classes from TS_STUDY, 1<r<k then
    $TS\_ANOM\_P = TS\_ANOM\_P \cup ts\_test_j$
end
print TS_ANOM_O, TS_ANOM_P
end

program modeling given in [8] confirmed that these algorithms can successfully find anomalies among the time series relating to these datasets.

IV. EXPERIMENTAL RESULTS

The possibility of applying algorithms for anomaly searching in collections of time series to the problem of detection of cases of atypical information exchange on a network that assumes existence of malicious codes has been researched. This problem was complicated because it is very hard to receive a representative sample which would be rather exact and at the same time exactly describing all possible variants of behavior in an information system.

Also it is necessary to note that obtaining a sample for normal behavior of an information systems is enough easily than for abnormal one because normal behavior could be modeled in laboratory conditions while abnormal behavior happens extremely rare. Moreover, the abnormal behavior is dynamic by the nature, and there can be new types of anomalies which weren't represented in the original learning sample.

It is proposed the following problem solution. There are reference models presented by time series which reflect changes of parameters of the protocol depending on types of information exchange. For comparing, the time series are used, that present real behavior of an information system in case of a data interchange. The comparison of these two models of information exchange allows to look for behavior types in the case of information exchange, different from standard, i.e. the anomalies.

As an illustration of the method, the exchange protocol by the FTP files was chosen. The method can be distributed to other standard protocols of information exchange having specifications in the form of standards or widely distributed de facto and having the description in open sources.

On the basis of analysis of a network traffic under transferring files in accordance to the FTP protocol in various conditions (including simultaneous transferring several files), the data set was obtained that represents a learning sample for creation of a model of reference data transferring.

For data acquisition, the special test bench was assembled. Data transferring on a network between two computers both according to the FTP protocol, and on a compound of protocols was carried out on this bench. For example, along with transmission of the file scanning of a network through the ICMP protocol (PING command), arbitrary exchange according to the UDP protocol – "information noise" for a reference traffic was carried out. Only length of the transferred data packet was fixed. Backward transferring accompanying exchange wasn't fixed.

Let's consider the example of the fixed data packet

```
No. Time Source Destination Protocol Info
4339 23.071158 10.10.10.50 10.10.10.100 FTP–DATA FTP
     Data: 1448 bytes
Frame 4339 (1514 bytes on wire, 1514 bytes captured)
Ethernet II, Src: 00:27:0e:2d:06:df (00:27:0e:2d:06:
     df), Dst: 00:27:0e:2d:06:17 (00:27:0e:2d:06:17)
Internet Protocol, Src: 10.10.10.50 (10.10.10.50),
     Dst: 10.10.10.100 (10.10.10.100)
Transmission Control Protocol, Src Port: 59022
     (59022), Dst Port: 9680 (9680), Seq: 288153, Ack
     : 1, Len: 1448
FTP Data
```

Here transferring was brought about from the computer with IP-address 10.10.10.50 (port 59022) to the computer with IP-address 10.10.10.100 (port 9680). The number of the packet 4339, accept time 23.071158, data are transferred in a packet (not the control footing), packet length 1448 bytes. Transferring was brought about on FTP protocol.

The following variants of data transferring were researched:

- transmission according to the FTP protocol (standard);
- simultaneous transmission according to the FTP protocols and ping (FTP-traffic was analyzed);
- simultaneous transmission according to the FTP protocols and UDP (FTP-traffic was analyzed).

The example of recorded data transferred simultaneously according to the FTP and UDP protocols is given in fig. 1. Having this information about data transferring on a network, it is necessary to define whether data transferring is "suspicious", what could testify about a possible compromise of network infrastructure, and malicious code existence.

As test data, were used specially generated time series imitating the unauthorized data transferring.

For the analysis of one of types of a traffic (the FTP protocol, the FTP and ping protocols, the FTP and UDP protocols), there was used the algorithm *TS-ADEEP* given in [4].

The obtained experimentally data were considered as a set of time series where ts_i values represent lengths of packets. These data have been previously exposed by preliminary treatment consisting of two stages: normalization and a subsequent

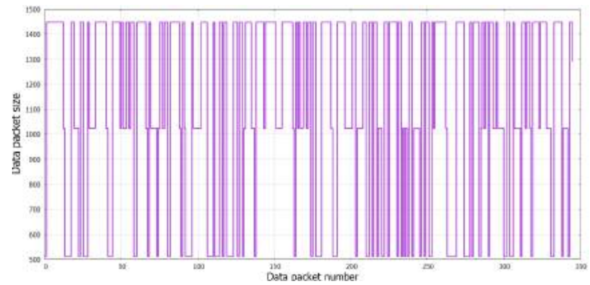

Figure 1.

discretization of the normalized time series with transition to symbolical data presentation, and moreover an alphabet size (the number of used symbols) has been varied depending on a task. The process of preliminary data conversion is based on the ideas of the *SAX* algorithm [9].

Changing parameters – an alphabet size and a time series dimensionality – it is possible to obtain an optimum representation of time series for their using by *TS-ADEEP* and *TS-ADEEP-Multi* algorithms.

Results of recognizing anomalies in the case of data transferring according to the above-named protocols are given in Table II. As it is seen from results, for the given task it was succeeded to reach the accuracy of anomaly classification of 100%.

Table II. THE ACCURACY OF ANOMALY DETECTION (%) IN DATA SETS "TRAFFIC" WITH ONE CLASS FOR THE *TS-ADEEP* ALGORITHM

		Time series size						
		210	150	100	50	30	20	10
Alphabet size	5	71.43	82.14	60.71	64.29	60.71	46.43	67.86
	10	92.86	96.43	100	96.43	82.14	85.71	64.29
	15	92.86	100	100	96.43	92.86	82.14	85.71
	20	92.86	100	100	96.43	92.86	82.14	82.14
	25	92.86	100	100	96.43	92.86	82.14	92.86
	30	92.86	100	100	96.43	92.86	92.86	82.14
	40	92.86	100	100	96.43	92.86	92.86	92.86
	50	92.86	100	100	96.43	92.86	92.86	92.86

By the simultaneous analysis of all traffic types considered in the experiment, the *TS-ADEEP-Multi* algorithm was used. Here the problem becomes complicated by that the normal behavior can correspond to one of several classes. Presented in the Table III results show, that for the case of several classes it is possible to reach the classification accuracy of anomalies up to 100% at selection of parameters of time series normalization.

Table III. THE ACCURACY OF ANOMALY DETECTION (%) IN DATA SETS "TRAFFIC" WITH SEVERAL CLASSES FOR THE *TS-ADEEP-Multi* ALGORITHM

		Time series size						
		210	150	100	50	30	20	10
Alphabet size	5	85.71	89.29	57.14	60.71	67.86	46.43	67.86
	10	96.43	96.43	100	96.43	82.14	85.71	67.86
	15	92.86	100	100	92.85	85.71	82.14	67.86
	20	96.43	100	100	96.43	96.43	96.43	75
	25	96.43	100	100	96.43	96.43	82.14	82.14
	30	96.43	100	100	96.43	96.43	96.43	92.86
	40	96.43	100	100	96.43	96.43	96.43	92.86
	50	96.43	100	100	96.43	96.43	96.43	96.43

In spite of the fact that by using *TS-ADEEP* and *TS-ADEEP-Multi* algorithms it was succeeded to reach the high classification precision by search of anomalies, these algorithms demand the large volume of calculations, therefore it is difficult to use them in the analysis of large volume of the new data. In that case, the approach, when a big calculation volume is required at the stage of constructing (learning) model, is perspective. Using of already the learned model requires a small calculation volume. Approach on the basis of the ideas of supervised learning is applied in many generalization algorithms, this approach is used also in the case of decision tree building [10].

We offer to use the approach on the basis of temporal decision trees [11]. On the basis of analysis of the learning sample containing descriptions of "normal" samples of data transfer, the temporal decision tree is built. This decision tree can classify further again entering examples. A new example is an anomaly if a temporal decision tree can't classify it.

To build a decision tree, the *Temporal ID3* algorithm was used. This algorithm was described in detail in [12]. The decision tree classifies the next example after several checks in internal nodes of a tree, therefore decision-making velocity is high. Results of anomaly detection by the *Temporal ID3* algorithm for data sets "Traffic" are given in Table IV.

Table IV. THE ACCURACY OF ANOMALY DETECTION (%) IN DATA SETS "TRAFFIC" WITH SEVERAL CLASSES FOR THE *Temporal ID3* ALGORITHM

		Time series size						
		210	150	100	50	30	20	10
Alphabet size	5	64.29	64.29	32.14	32.14	32.14	78.57	67.86
	10	78.57	75.00	64.29	67.86	60.71	67.86	57.14
	15	82.14	46.43	60.71	57.14	71.43	82.14	57.14
	20	85.71	89.29	82.14	67.86	60.71	96.43	82.14
	25	96.43	71.43	64.29	67.86	89.29	78.57	78.57
	30	96.43	82.14	60.71	96.43	71.43	85.71	67.86
	40	89.29	92.86	82.14	100.00	60.71	96.43	82.14
	50	71.43	89.29	92.86	100.00	71.43	85.71	82.14

As shown in Table IV, the temporal decision tree built by using time series for which dimensionality has been reduced to 50 and the alphabet size contains 40-50 symbols, most successfully copes with searching of anomalies.

V. CONCLUSION

Methods of anomaly detection at the solution of the problem of the network traffic analysis for the purpose of detecting malicious functional capabilities have been viewed. The algorithms implementing anomaly detection were simulated. Results of the program experiment have shown the high precision of anomaly detection what demonstrates good prospects of using the suggested methods and software.

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ОБНАРУЖЕНИЕ АНОМАЛИЙ В ДАННЫХ НА ОСНОВЕ АНАЛИЗА СЕТЕВОГО ТРАФИКА

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Статья посвящена проблеме обнаружения возможного несанкционированного доступа к информации, передаваемой по сетям, на основе анализа временных рядов. Описаны алгоритмы поиска аномалий в наборах временных рядов, также приводятся результаты компьютерного моделирования.

Intelligent Learning and Testing Predictive System with Cognitive Component

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***Abstract*—In this paper an intelligent learning and testing predictive system with cognitive components used within the framework of blended learning paradigm is proposed. Current development trends in the field of effective learning technologies implementing student-oriented approach are identified. The developed system will enable the students not only to acquire the necessary competences within the subject area, but also to identify their successful educational approaches thus achieving significant results. Storage of knowledge is carried out by means of a semantic network, which allows establishing the correspondence between the material studied and acquired knowledge.**

***Index Terms*—intelligent learning and testing predictive system, cognitive graphic tools, blended learning, mixed diagnostic tests, semantic network, 2-simplex prism, e-learning course, student-oriented approach, learning results prediction.**

I. Introduction

All human activities are focused on the cognition process and the transformation of the world. Therefore, content that we, teachers, deliver to the student must be relevant, demanded and timely to solve emerging problems and to face challenges of the modern world. High-quality e-learning courses development based on intelligent learning and testing predictive systems with effective content delivery to the learner is a promising area of the modern teacher's activity [1]. Currently, the roles teacher plays in the learning process are as follows: 1) a teacher; 2) a content developer; 3) a motivator; 4) a moderator; 5) a business coach; 6) a scientist.

Broad field of students' cognitive activities may disorient them and lower their motivation. Therefore, a tool that offers teaching methods peculiar to a particular person facilitating to achieve the desired learning outcomes is required. The outcomes are described in a syllabus of a discipline and are formulated, taking into account the individual characteristics of a particular student.

Nowadays there is a demand in intelligent learning and testing systems development. They are in demand not only for learners, but also for teachers and specialists in various problem areas [2], [1]. Modern information technologies offer new opportunities for education and training. The teacher, using the paradigm of blended education and training with intelligent learning and testing systems support, provides face-to-face activities in the classroom and also develops the high quality content for the systems under study [1].

Blended learning paradigm within the framework of a modern university education encourages the development of effective distance learning methods for a large number of students with different activities [3]. In this regard, the development and use of online tests for learning and training is an urgent task for teachers and web programmers [4]. Cognitive graphic tools allow either to observe the solution immediately or to acquire a hint to its location [5]. That will enhance students' motivation and correct, if necessary, an individual learning trajectory.

The fundamentals of intelligent learning and testing predictive system with cognitive component are presented. The research results on the course "Selected chapters of electronics" using 2-simplex prism are also given herein.

II. Basic terms and definitions

We introduce a series of concepts and definitions for further use.

Learner is a person to be trained, for example, a student at the university.

Learning object is a question presented to a learner.

Learning pattern is a decision made by a learner.

Teacher is a person who conducts or supports learning process.

Diagnostic test is a set of features which differentiate any pairs of objects belonging to different patterns.

Unconditional diagnostic test is a test in which the order of the questions is not important.

Conditional diagnostic test is a test in which each further question in a chain of questions is dependent on the results obtained on the previous stages of testing.

Mixed diagnostic test is an optimal combination of unconditional and conditional diagnostic test components [6].

III. Principles of learning, testing and results evaluation

Using a variety of electronic resources and innovative teaching methods in the classroom within the framework of syllabus the specific discipline may serve as an illustrative example of blended learning model. Students and teachers are a part of the modern information society, which is characterized by an excess of information. That causes students' intellectual overloading. In this context, a key challenge is the development of educational content; methods of interaction between the teacher and the student and tests designed to evaluate the knowledge acquired by students. That requires significant time, cost and intellectual efforts [1], [3].

The growing interest in the development and the use of intelligent learning and testing systems stimulates the need for cognitive graphic tools that allow visualizing, analyzing and validation of the key performance indicators of the learning process. The indicators are as follows: the level of acquired knowledge, skills, competences and their combination. Moreover the system under study is able to predict the further effective education trajectory for each respondent [7].

Note that the learning cycle is represented via the 5 stages [8]:

1) Background knowledge activation on the course's topic.
2) Theoretical input: basic educational material introduction.
3) Understanding control, semantization and consolidation of theoretical material.
4) Simulation and case studies.
5) Acquired knowledge and skills application.

The proposed intelligent learning and testing predictive system allows to control the learning process at each stage of the learning cycle either by a teacher, or directly by the student.

The respondents assess their results within a particular module of the course and explore the prospects for further intellectual development on the basis of assignments performance and test results at each stage of learning cycle. The learning results prediction is implemented by the system under study in a certain direction of development. The next development directions are suggested to the students: 1) research, 2) practical, 3) teaching and 4) managing activities. Thus, the the system under study contributes to the development of the skills and aptitudes which are most expressed in particular student. That is detected by the tests results analysis and represented via cognitive graphic tool 2-simplex prism [3].

2-simplex prism is a triangular prism which has identical equilateral triangles (2-simplices) in its bases.

Thus, the intelligent system, focused on the learning, testing and prediction of learning outcomes is a means of training, validation of learning outcomes and constructing of individual learning trajectory. That, in turn, is a source of students' motivation. For teachers, such a system is a modern tool of analysis and efficacy improvement of teaching and learning processes. That significantly reduces the time and cost.

An alternative to students' knowledge data storage of the course is a semantic network which is described in the paper [9].

Motivation is an important issue of mastering a given discipline. The above approach creates further value attitudes of each student, facilitating further educational activities, according to learning trajectory designed.

An analogue approach in the field of technical disciplines is the method of dynamical programming, where the object is splitted into interconnected and interdependent parts. In the case under study each part is one more step towards the learning goals. Thus, with the current performance level of the student's knowledge and the trend of development, the student can identify forward-looking learning trajectory to develop their knowledge, skills and competencies in the desired direction, and follow it, providing the necessary control at each stage of the educational process.

It should be noted that the problem of information security is relevant in particular in the field of learning technology [10]. Data safety about the learning process and outcomes of each student is essential for reliable operation of the intelligent learning and testing predictive system at each stage of education. Information attack can damage the data, mix them. That leads to a distortion of the student's learning trajectory. This may entail psychological consequences both for students and teachers.

The system under study is aimed at arousing the students' endeavor to comprehend the discipline, to reach the learning goals both by students and teachers.

The value of knowledge acquired is determined by the student's ability to apply them in practice. That is an additional stimulus to the expansion of scientific and professional horizons.

The quality of the learning process is largely depends on students' goal setting. That needs to be written in detail in the syllabus of the discipline. The syllabus should be designed both for the student and for the teacher.

The student recognizes and applies sustainable successful learning methods on the basis of the learning results analysis. The predicted level of knowledge in the future depends on the current one which serves as a sort of initial conditions for each step of learning process. Within the framework of the course "Selected Chapters of Electronics" the following knowledge components were identified: 1) knowledge of theory, 2) problem solving skills and 3) laboratory work performance. The use of a 2-simplex prism to display the results on the above components allows visualizing and evaluating the individual learning trajectory.

The facets of the 2-simplex prism correspond to the evaluation of theoretical knowledge, skills to solve problems, and laboratory work performance skills. A point in the space of these components at a particular time instant, corresponds to the current evaluation of the above components combinations. That is illustrated via 2-simplex prism. In the process of learning the position of the point can vary depending on the students' values correction. Preferably, the position of the point should be within the area of tolerance.

However, the student could initiate some preferences in the learning process. For example, with poor theory knowledge, the student may solve the problems well and is very successful in experimental studies. In this case, the learning trajectory varies with orientation on practical activities. However, the system does not allow the student to get an evaluation based on 2-simplex prism, if he does not achieve acceptable results in the theoretical component of the course. Emphasizing the problems solving component leads to a positive impact on the other components. At the same time, given the coordinates of the level of knowledge at the previous learning step and development trend, the value of further level of knowledge, including all three components at a later stage could be predicted. Increasing the value of one component inevitably affects the other one.

As a result the students acquire the motivation to do more in their studies. Thus, the individual learning trajectory is constructed. Among the students' professional preferences the next ones could be outlined: 1) researcher, 2) specialist, 3) educator. This classification of learning trajectories can effectively orient the student to further professional activity.

Note the necessary components for intelligent learning and testing system with cognitive component construction.

To assess the student a bank of mixed diagnostic tests is needed. These tests are formed in such a way that students develop essential skills and abilities they need at the moment according to the individual learning trajectory, taking into account the current level of knowledge. If unconditional diagnostic test is performed successfully, the student is allowed to perform a conditional diagnostic test components which is evaluated using a mathematical apparatus, based on a combination of threshold and fuzzy logics [11].

Conditional diagnostic test is represented via interconnected and interdependent test questions that form the individual trajectory of passing the test. During testing, the system under study may return the student to any of the previous stages when the wrong answer to the current question is given. That reveals to undertaking the necessary additional training.

IV. Fundamentals of Construction of Intelligent Learning and Testing Predictive System with Cognitive Component

A block diagram of intelligent learning and testing predictive system with cognitive component is shown in Fig. 1.

A sequence of training (testing) of respondents in the developed system is as follows:

1) Respondent learns the discipline of interest or its module. Substantially, learning course in a related discipline may be submitted by the text with additional interactive and multimedia content. For the learning course storage the semantic knowledge representation model described in the paper [9] is used. This component is provided by a learning module.
2) On the basis of learning content the unconditional diagnostic test is constructed. In this case the sequence of test questions given to a student is not important. The learner answers the questions contained in the test of the unconditional component of the test. The present stage and the next two ones are provided using testing module.
3) The transition to the conditional diagnostic test component is performed. The previous answer determines the next test question of the interconnected and interdependent set of questions. Conditional diagnostic test component comprises: 1) questions of different level of complexity, related to the knowledge acquired using unconditional diagnostic test component; 2) questions evaluating the knowledge application to a particular task, combining already acquired competences.
4) During the test the database records all the steps that the respondent performs. This level of detailization is not necessary to calculate the respondent's assessment. Although it could be essentially useful for a researcher or teacher. On the basis of this sequence of steps, and the respondent's decisions the respondent's action card (RAC) is formed.
5) After completing all the tests the RAC is projected into a set of evaluation coefficients which determine how well the respondent copes with a variety of tasks on the basis of the following capabilities: 1) knowledge of theory, 2) problem solving skills and 3) laboratory work performance. At this stage the further trajectory of learning process is constructed. Pattern recognition module is responsible for this step.
6) After completion of the learning and testing the network of proven knowledge, RAC interpretation and calculated coefficients are shown to the respondent. The coefficients are visualized using 2-simplex prism. Comparison of the RAC and the semantic network of the course allows tracing between the material learned and the knowledge acquired, thus, indicating the gaps in knowledge. Further, if the respondent have module of the course which was not comprehended, or the test was not successfully passed, he can continue learning, returning to step 1. In this case, the student himself is involved in the decision-making process. He analyzes the results and seeing his perspectives, chooses his future scenario development. This step is attributed to results interpreting module.
7) In the case of successful tests completion throughout the course of study that the subject matter is considered successfully studied and the respondent has comprehended the learning course (with possible assumptions). In this case the overall learning process result can be represented as an average assessment through all the stages of learning and testing process, performed by the respondent.

V. Cognitive Visualization of Learning Outcomes and Their Prediction

The first and most complete application of the 2-simplex prism for the discipline "Power Electronics" is described in the publication [12]. In this paper, we use a number of fragments from the publication [12] required for further discussion. Example of learning trajectories using 2-simplex prism, based

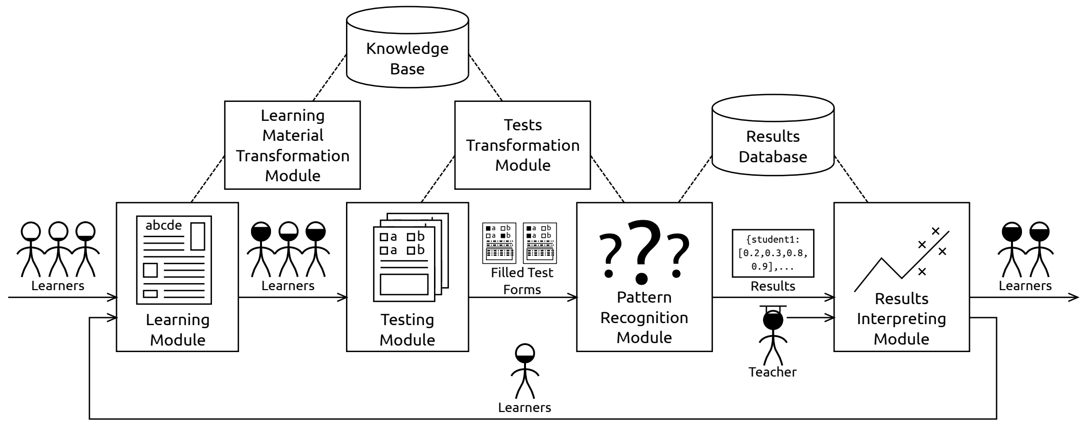


Figure 1. Block diagram of intelligent learning and testing predictive system with cognitive component

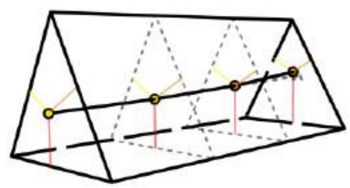


Figure 2. Using a 2-simplex prism to form a learning trajectory

on actual learning results, obtained with the use of mixed diagnostic tests is shown in Fig. 2.

The results of each of the four tests are shown in the form of points in a 2-simplices disposed on cross-sections of 2-simplex prism. Each face of the 2-simplex prism corresponds to one of the three patterns. For the majority of subjects taught in the universities, the following indicators are proposed to measure the knowledge level of the respondents: knowledge of theory (represented by red color in Fig. 2), problem solving skills (represented by yellow color), laboratory work performance (represented by green color). Each indicator is associated with corresponding pattern. The distance from the base of a 2-simplex prism to a specific 2-simplex corresponds to the time step from the start of learning to the particular testing (prediction). The height of the 2-simplex prism corresponds to total learning time plus the time interval after finishing the course. This time interval is used to represent the future results of the respondent.

A polyline within 2-simplex prism displays the evolution of the knowledge of the respondent. To assess the quality of the prediction for the last step the two lines used: solid and dashed. The solid line shows the progress of learning, revealed on the basis of the respondent's testing. The dashed line shows the prediction of the learning progress based on the previous performance of respondent. Confidence area of the prediction is presented by a triangle which consists of the dashed line segments.

Nowadays main aims are the following:cognitive graphic tools integration in the education process and estimation of an influence of learning process trajectory and its prediction visualization given for students on the speed of their learning. So, a quite simple prediction model for a learning process is used: 1) polynomial extrapolation is used; 2) learning axes are considered as absolutely orthogonal and independent and the values for each axis are predicted indepedently from other. The prediction model takes into account a history of testing results which a student has already obtained and gives a predicted result which a student should reach by the specified date. Polynomial power p is configurable and can be used for its influence estimation on a prediction quality. For a polynomial function the last $p+1$ results of already performed tests by a student for each axis are used. A system of linear equations is constructed based on the polynomial functions and is solved via Gauss method. It should be noticed that k is also configurable, so prediction can be performed for any future step, not only for the next one.

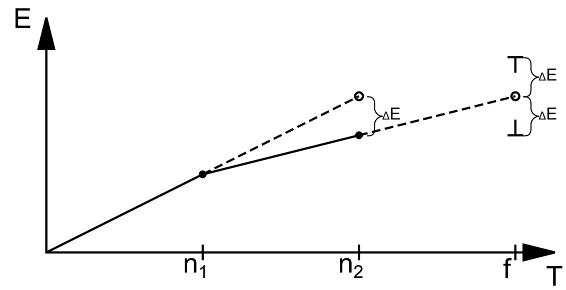


Figure 3. Example of confidence region prediction calculation.

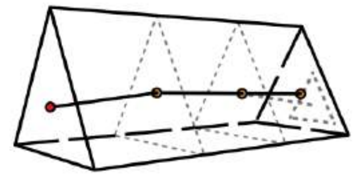
Confidence region prediction is calculated as delta between predicted and real result for the last performed test. Process of this calculation for one axis is shown in Figure 3.

Since the power of the polynomial is adjustable, it is possible to investigate the influence of this parameter on the quality of prediction. An example of the effect of the power of the polynomial on the quality of prediction is depicted in Fig. 4. By varying the power of the polynomial in the prediction process, it was found that for the majority of the respondents the best prediction is achieved by using a linear polynomial (the polynomial of the first power). This result allows to formulate the hypothesis, that on the basis of the learning progress second derivative it is impossible to reveal the progress of learning. For comprehensive confirmation of the hypothesis the study of prediction in a large number of tests is required. Other models of results prediction should be also applied to enhance the prediction quality.

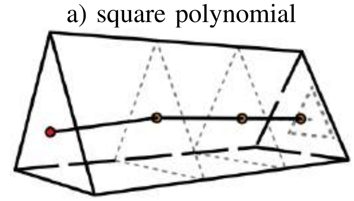
In most cases the chosen simple prediction model shows appropriate quality of prediction. That is why it will be used in the first version of the intelligent learning technology development. There are good grounds to believe that proposed approach allows to obtain the following results:

1) Illustrative representation for a student learning trajectory and trajectories comparison for different students.
2) Revealing and representation of a student learning speed.
3) Revealing of incorrect test results, e.g. revealing cheating on a test.
4) Predicting and modeling of a student learning process.
5) Increasing students' motivation to a high-perfomance learning by in-group competition increasing, which is accessible through providing both a comparison of student's results and other students results.

It should be noticed, that a major part of researches in this area are aimed at the development of vizualiation tools for teachers and administrators of universities and only minor part of them are aimed at the development for students, until they takes so much benefits for students as for teachers [13], [14]. Results of a few investigations [13], [14] shows advantages of the education model where visual representation for all students personal result is used, especially for e-learning technogies. The main reason why it works is an ability for each student to compare their results with an average and the best results among all students in their group. In paper [15] it is noticed that usage of social technologies allows to support a lot of metacognitive students actions, such as reflexion, planning, self-evaluation and increasing their motivation to learning. Special attention should be concentrated on cognitive graphic tools aimed at motivating the students competitive interests: their usage can increase the students interest to learning (the time spent on self-assessment tests) up to 20% [15].



a) square polynomial



b) linear polynomial

Figure 4. Influence of the polynomial degree on the prediction quality

VI. Specificity of Software Implementation of Cognitive Graphics Tools and Their Integration

The current software framework for a cognitive graphic tools visualization is written with a usage of JavaScript and WebGL [16]. It has a modular and extensible architecture which is presented in Figure 5. The library consists of three component groups: Input Processors, which make preprocessing data from the intelligent system outputs and serves as integration layer into the system; Scene Compositors, which are responsible for creating, configuring and placement of primitives; and Universal Primitive Library, which contains a lot of common components which are used during any scene creating. As this software version was developed based on web-technologies, it is very easy to integrate it into almost all intelligent systems especially web-based ones.

Integration with Moodle requires implementation of the following items:

1) Plugin for Moodle on PHP which append loading for our JS-library in front-end HTML-pages, extracts data from Moodle database and transfer them to front-end pages.
2) Input processor module on javascript which places HTML-element for the cognitive graphic tool and configures scene base on information acquired from the server-side PHP plugin.

It should be noticed, that all figures are rendered with a usage of visualization library which is currently at the early stage of active development. So they contain some small visualization problems, e.g. incorrect lines overlapping, and some necessary objects do not render at all, e.g. lettering for sides. Interactive demonstration for developed cognitive graphic tool, described in the present paper, is available by URL [17].

VII. Conclusion

Current state of research in e-learning area is discussed. The proposed intelligent learning and testing predictive system with cognitive component is designed to enhance the effectiveness of the learning process, to acquire the data for the analysis of the intellectual development of students in the educational process. The results obtained through the application of the system under study will effectively help to design the courses based on the blended learning paradigm. That could be performed by course content enhancement and its delivery improvement. Thus, the system could provide efficacy rise for both the students and the educators, motivating them to achieve their goals in efficient way. Having constant feedback, teachers perform real-rime monitoring of the learning process and solve the problems if necessary in a timely manner. Moreover, the individual characteristics of the students will be taken into account and learning preferences in accordance with students' values will be revealed.

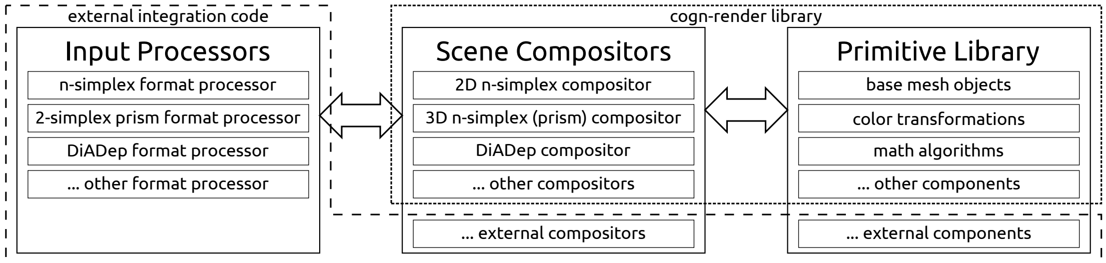


Figure 5. Architecture of library for congitive tools visualization.

The intelligent system allows identifying the student's value preferences, promoting career guidance and increasing personal effectiveness.

The system under study is offered for the courses: "Discrete Mathematics", "Information Security", "Automation and control", "Power Electronics" and others.

Acknowledgment

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ИНТЕЛЛЕКТУАЛЬНАЯ ОБУЧАЮЩЕ-ТЕСТИРУЮЩАЯ ПРОГНОЗИРУЮЩАЯ СИСТЕМА С КОГНИТИВНОЙ КОМПОНЕНТОЙ

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В статье предлагается интеллектуальная обучающе-тестирующая прогнозирующая система с когнитивными компонентами в рамках парадигмы смешанного образования и обучения. Рассматриваются современные тенденции развития в области эффективных технологий обучения, реализующих личностно-ориентированный подход. Интеллектуальная система позволит обучаемым не только приобрести необходимые компетенции в рамках проблемной области, но и определить успешные образовательные подходы для достижения высоких результатов. Хранение знаний обучаемых осуществляется с использованием семантической сети, которая позволяет установить соответствие между изученным материалом и полученными знаниями. Интеллектуальная система предлагается для организации процесса обучения в высших учебных заведениях различного профиля.

Some Aspects of Using Intelligent Technology for the Construction of Tutoring Integrated Expert Systems

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***Abstract*—We analyze the experience of development and use of tutoring integrated expert systems in MEPhI educational process. These systems were created on the basis of problem-oriented methodology and intelligent software environment of AT-TECHNOLOGY workbench. The emphasis is on the peculiarities of the implementation of certain tasks of intellectual training, related to the identification of students' knowledge and skills to solve non-formalized problems.**

Keywords*—artificial intelligence, integrated expert systems, problem-oriented methodology, AT-TECHNOLOGY workbench, intelligent software environment, automated planning, tutoring integrated expert systems, intelligent training.

I. Introduction

Interest in intelligent tutoring systems (ITS) arose at the turn of the XX and XXI centuries, and now they occupy a significant place in a wide scope of intelligent systems issues. . Educational sphere is a good "ground" for the application of artificial intelligence methods and tools, giving rise to a considerable number of approaches and system architectural solutions for intellectualization, individualization and web orientation of learning and training processes . Now, there is an «information explosion» of publications both in Russia and abroad on the subject of ITS. Without claiming to be exhaustive in our review of works in the field of ITS, we will mention only a few papers [1], [2], [3], [4], [5], reflecting the results of researches that were conducted in MEPhI and other universities. «Intelligent Systems and Technologies» laboratory at MEPhI's department of Cybernetics has accumulated a lot of experience in the development and use of tutoring integrated expert systems (IES) based on problem-oriented methodology and powerful modern tools such as AT-TECHNOLOGY [6], [7] system is accumulated in the laboratory «Intelligent Systems and Technologies» department «Cybernetics» MEPhI. Educational IES and web-IES are fully functional, new generation ITS that implement all the basic ITS model (student model, teaching model, problem domain model, ontology of courses and disciplines, etc.). As well, IES allows solving wide scope of intellectual training tasks, the main ones are [4], [6], [8]: individual planning of a course / discipline study methodologies; Mining solution of educational problems, and intelligent support of decision-making. Process of measuring knowledge level (declarative knowledge of a course/discipline) and detection of skills (procedural knowledge, which shows how this declarative knowledge could be applied in practice) is the basis for all mentioned above tasks. A number of methods for this purpose is proposed. To implement these processes there is a significant number of different methods, according to which the control tests and tasks are developed. For example, in tutoring IES network orientated model of student is formed dynamically on the analysis of answers to questions from special web-tests that are generated with the help of genetic algorithms and the method of estimation is based on calculating the final grade for the whole test. After that the current model of a student knowledge is compared with an ontology of a course/discipline. As a result, one can determine so called «problem areas» in students' knowledge. There are other approaches to identify the level of student's knowledge, as described, in particular, in [9], [5], [10], [11], however, with methodical, algorithmic and technological points of view the implementation of these processes is not particularly difficult. Speaking of ITS with possibility to automatically detect students' abilities to solve problems, there can be difficulties connected with the specifics of a particular course/discipline. For example, teaching special courses within educational programs like "Applied mathematics and Informatics" and "Software engineering" ("Introduction to intelligent systems", "Expert systems", "Intelligent Information Systems", "Intelligent interactive systems" etc.) is connected with teaching students to do such tasks as [12]: the ability to build models of the simplest situations in a problem domain based on frames and semantic networks, modeling strategies of forward/backward inference in the ES, construction of linguistic model of business sublanguage and other. Therefore, to support the construction of tutoring IES on the basis of problem- oriented methodology (AT-TECHNOLOGY workbench) was created and tested in practice in the educational process of MEPhI and other universities special funds that implement "manual" methods of solution of various UF-tasks, in particular, is presented in [13]. Anotherimportant aspect of research and development in the field of ITS is linked with the creation of tools and technologies for automated support of ITS development. Currently there is no greater diversity and innovation, the focus is on reengineering and development of the existing tools [14]. It should be noted that currently there is no standard technology of ITS development, so workbench of general purpose is often usedfor ITS . For example, [15], [16] The focus of this work is the further development of methods and tools for automated construction of tutoring IES with the use of intelligent software environment components.

II. General characteristics of the components of an intelligent software environment of the AT-TECHNOLOGY workbench

The AT-TECHNOLOGY workbench is a modern tool that supports intelligent software technology for automated construction of IES of different types and levels of difficulty. The conceptual framework for the integration of methods of knowledge engineering, ontological engineering, intelligent planning and traditional programming is the concept of "intelligent environments" first introduced in [8] and studied experimentally in the process of developing a number of applied IES, including tutoring IES [6], [8], [17], [18]. The basic role in the intellectual software environment belongs to the intelligent scheduler, which manages IES and web-IES development projects. Different versions of the scheduler are described in detail in [8], [17], [18] and other works. Therefore, this work is focused on questions related to the methods of implementation of the above-mentioned tasks of intelligent training with the help of other, equally important components of an intelligent software environment of the AT-TECHNOLOGY workbench. As shown in [8], the main components of an intelligent software environment used for building and execution of plans for the development of prototypes of applied IES include standard design procedures (SDP) and reusable components (RUC). In accordance with [8], SDP model for tutoring IES is represented as

$$SDP_T = \langle C_T, L_T, T_T \rangle \quad (1)$$

where C_T is a set of conditions, which ensure SDP invocation; L_T – an execution scenario described with internal SDP actions description language; T_T – a set of parameters initialized by the intelligent planner when SDP is included into an IES prototype development plan. Every RUC, involved in IES prototype development is defined as

$$RUC = \langle N, Arg, F, PINT, FN \rangle \quad (2)$$

N in this model is the name of the component, by which it is registered in the workbench. $Arg = \{Arg_i\}, i = 1...l$ - set of arguments containing current project database subtree serving as input parameters for the functions from the set. $F = \{F_i\}, i = 1...s$ - a variety of methods (RUC interfaces) for this component at the implementation level. $PINT$ - a set of other kinds of RUC interfaces, used by the methods of the RUC. $FN = \{FNi\}, i = 1...v$ - set of functions names performed by this RUC. The main algorithm element used during development plan generation process of the IES prototype is SDP. By SDP we mean a set of elementary instructions (steps) which are traditionally executed by a knowledge engineer at every development lifecycle stage. The intelligent planner of the AT-TECHNOLOGY workbench has knowledge about all available SDPs, and based on this knowledge it forms a set of tasks for any IES prototype development (accordingly to a current lifecycle stage). Then, basing on special requirements specified at the system requirements analysis stage, the planner decomposes the plan into smaller tasks (subtasks).

All the workbench SDPs are classified in the following manner: task type independent SDPs (for example, "knowledge acquisition from database"), task type dependent SDPs (for example forming tutoring IES components), SDPs related with RUC, i.e. procedures, that contain knowledge about RUC lifecycle from its configuring up to including it into the IES prototype model. SDPs of the last type also contain knowledge about tasks solved with this RUC and its necessary configurations. The common architecture of the AT-TECHNOLOGY workbench is built in such manner, that all functionality is distributed between the components registered in the workbench and acting under intelligent development environment. In other words, these components are reusable components of the workbench, and they are developed in accordance with some workbench rules [8].

There are two different types of RUC used in the current basic AT-TECHNOLOGY workbench version – procedural and informational components. In the first one the components provide capabilities for execution either actions with non-typical results, i.e. results that are not stored in some special storage (repository) as the results of previous developments, or actions, that require user interaction (for example, editing the ER-scheme or viewing the expert interviewing protocol). In the second one the components provide capabilities for executing actions which result in the information that has been collected earlier and is stored in the repository (knowledge, data, schemes, structures etc.) with further copying of this information into the current project and preprocessing if needed (i.e. copying of created earlier ER-diagram or typical diagram analysis). Special storages (repositories) are used for RUC of the second type. They collect different types of data which is used in further development processes.

In the basic AT-TECHNOLOGY workbench many SDPs of the first and second types are implemented and used, in particular: the SDP for combined knowledge acquisition, the SDP for database projecting, the SDP for configuring IES prototype components, the SDP for creating hyper-text tutorials etc. There are SDPs related to distributed knowledge acquisition from different knowledge sources, dynamic IES development SDP and the most complicated SDP for tutoring IES construction [8] in the experimental stage. The difficulties of the tutoring IES development technology are caused by supporting two different work modes – DesignTime, oriented to work with teachers (course/discipline ontology creating processes, different typed training impacts creating, etc.) and Runtime, for working with students (current student model building processes, including psychological model, etc.). The execution scheme of SDP «Tutoring web-IES construction» in the DesignTime mode is presented in Fig. 1, and in the RunTime mode - in Fig.2.

As shown in Fig. 2., in the RunTime mode the following AT-TECHNOLOGY workbench instruments are used: training impact building tools (hypertext schoolbook, tutoring-training tasks), basic core workbench tools for IES prototype construction, student psychological portrait builder tool, tools for course/discipline ontology building, individual learning strategy former, learning strategy realization component, different

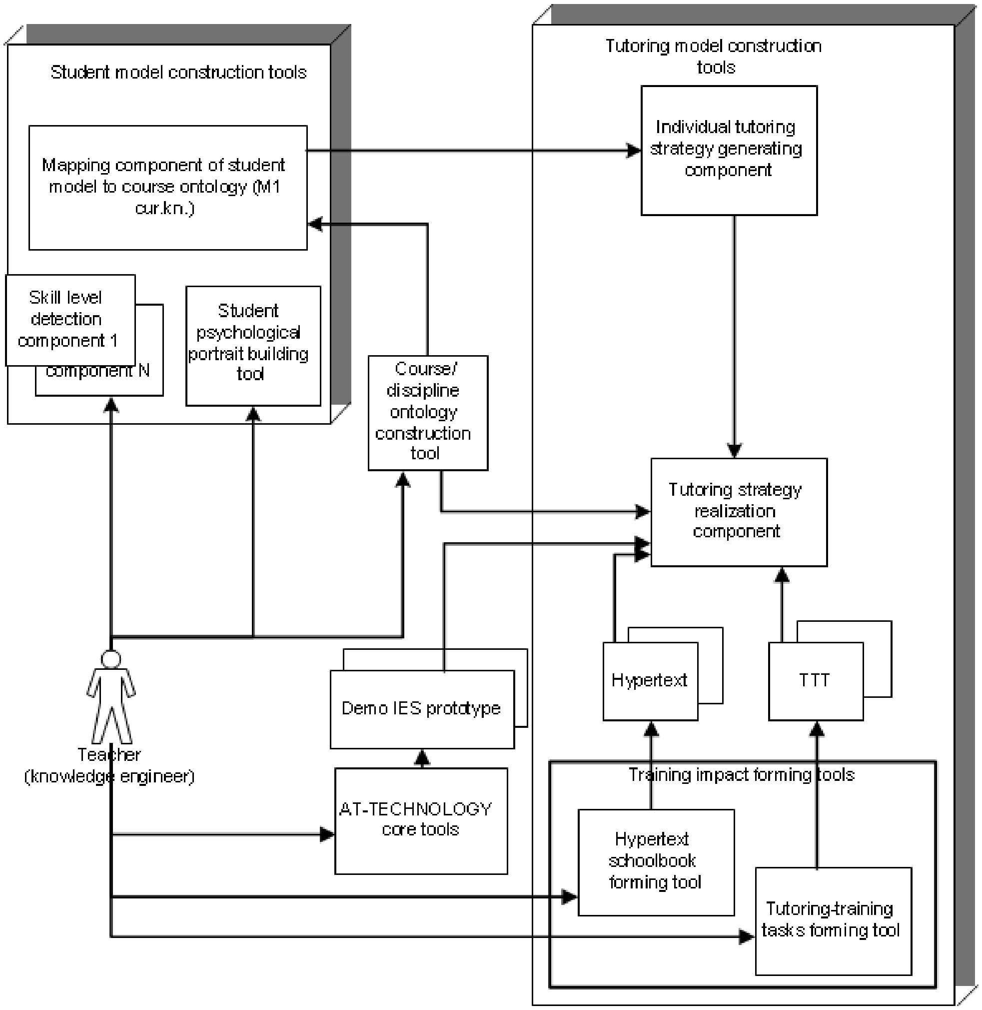

Figure 1. Execution scheme of the SDP «Tutoring web-IES construction» in DesignTime mode for a teacher (or a knowledge engineer)

skills level detection components, component for mapping a current student model to course/discipline ontology.

As shown in the scheme of Fig.2. the student model construction (M1 current knowledge, M1 current skills, psychological portrait components) is directly connect-ed to the tools for construction and realization of the tutoring model, as well as to the component for mapping a current student model to course/discipline ontology. The mapping component is also connected to the individual tutoring strategy forming component. The peculiarity of a tutoring web-IES developed with AT-TECHNOLOGY workbench is a presence of some components of skill level detection and of the component for building a student's psychological portrait (as an aggregate of personal characteristics which are collected as a results of psychological testing).

Consider this SDP in context of topicality of intelligent development technology usage for tutoring IES. The schemes of the SDP «Tutoring web-IES construction» shown in Fig.1. and Fig.2. clearly show a big amount of repeating routine operations which must be performed by a knowledge engineer during the projecting lifecycle stage (DesignTime mode) and maintenance (RunTime mode) of the tutoring web-IES for certain courses/disciplines.

The most difficult and complicated stage is the construction of the «Training with IES» training impact, which represents a comprehensive problem of the applied IES development for a certain problem domain with. This IES is developed using basic AT-TECHNOLOGY workbench tools. For example, almost all the courses of the «Intelligent systems and technologies» specialization require some knowledge of engineering methods. These methods are presented as non-formalized tasks and non-formalized methods such as «System analysis of the problem domain about applicability of the ES technology», «Choosing knowledge representation formalism», «Choosing development tools» and other tasks requiring expert knowledge [8]. The aggregate of the listed non-formalized tasks and their logical relations are the base for the problem domain construction. The problem domain is constructed with the knowledge representation language used in the AT-TECHNOLOGY workbench.

III. Features of Realization of Some Intelligent Training Tasks Based on the Use of Operational and Informational RUC

In accordance with task-oriented methodology for constructing IES [7], one of the important components of a

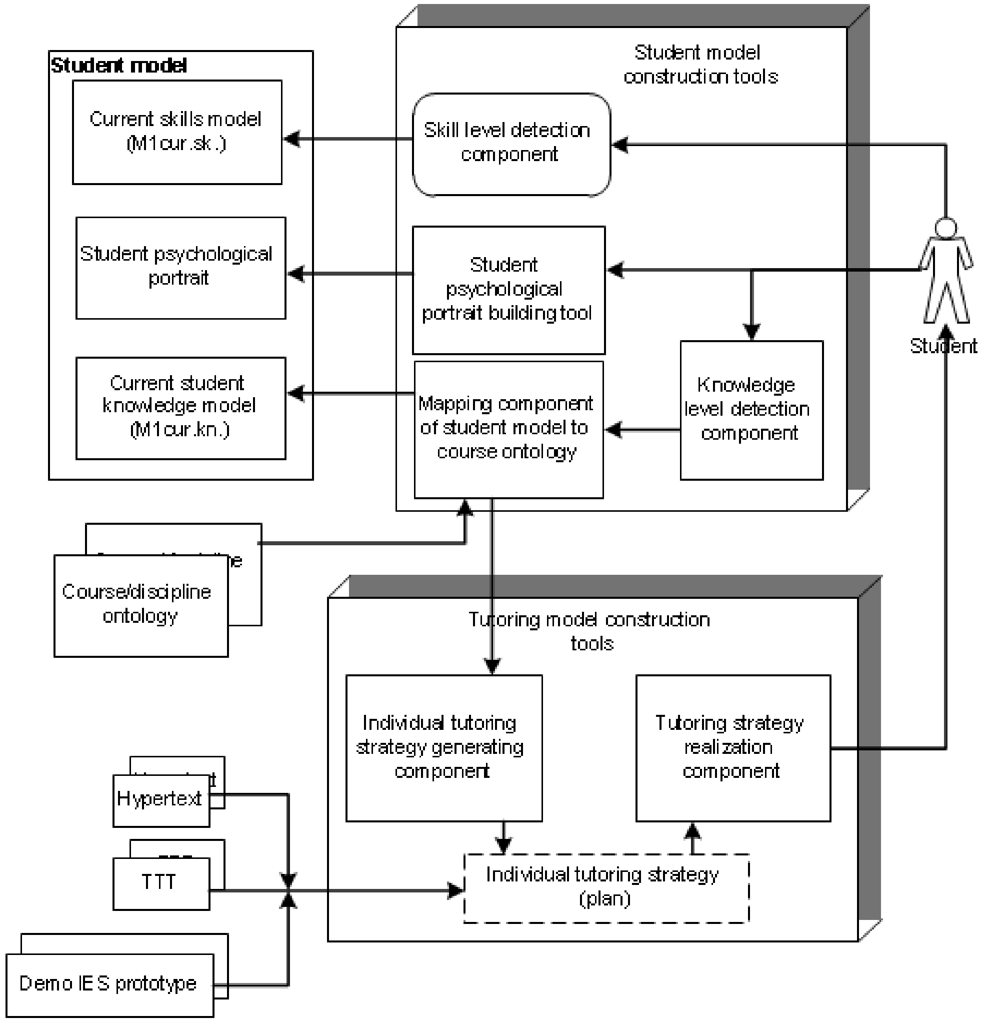

Figure 2. Execution scheme of the SDP «Tutoring web-IES construction» in the RunTime mode for students

generalized model of a typical tutoring problem is the network student model, the construction and renovation of which is carried out dynamically by implementing control measures, provided by the curriculum of each course / discipline. For these purposes, as a part of the subsystem of construction of tutoring IES/web-IES, which works in both (basic and web version) of AT-TECHNOLOGY workbench, there are special tools for building student model.

As described above, the set of SDP and RUC are components of intellectual AT-TECHNOLOGY workbench [7] providing the intellectualization of the creation and operation of a wide class of IES, including tutoring IES. Detailed description of the intellectual environment model and the means of its implementation are given in [17]. Specifications of operational and informational RUC's that copes with major issues of intellectual tutoring are presented in this work. Brief description of these RUC's is given below.

A. Individual planning of studying methods of a course

Main operational RUCs for this task are the means of building the ontology of a course/discipline [19]. Also it uses about ten informational RUC's, associated with fragments of hypertext electronic textbooks (HT-books) for specific courses / disciplines, and several informational RUC's for building a generalized ontology "Intelligent systems and technologies" and ontology "Automation of physical installations and scientific research" (Department of Automation). In general, the current RUC's for construction of a student model are the following:

1) Operational RUC "Component that identifies a student's level of knowledge" (and several informational RUC's that describes test problems for various fragments of a course/discipline ontology);
2) Four operating RUC's associated with identifying the level of skills of a student include: component of detection of student's skills to simulate the forward / backward inference, component of detection of skills to build components of a linguistic model of business prose sublanguage, component of detection of skills to simulate the simplest situation in problem domain using frames and components of detection of skills to simulate the simplest situation in problem domain using semantic networks;
3) For ontology's, "Automation of physical installations and of scientific research" is used the operational

RUC associated with the detection of learners' abilities to develop automatic control systems (ACS) over physical units ("Physical Component ACS units").

4) Two operational RUC's - "Psychological test generator" and "Component of student s personal characteristics detection". The process of generation of psychological tests is carried out using informational RUC's containing fragments copyright psychological tests aimed at identifying the set of personal characteristics of students.

It should be noted that the component displaying the current student model, compared with ontology of a course / discipline, and designed as an operational RUC. Allows to reveal "problem areas" of a student. That helps to construct the individual plan (strategy) of tutoring. Figure 2 shows the architecture of tools for building a learning model and for automatic generation of an individual learning plan, that uses operational RUC "Component of forming tutoring plans (strategies)", and a special RUC "Component of managing the application of tutoring impact ". Each training strategy includes a specific sequence of tutoring impacts such as: reading of a hypertext book; solution of several types of training problems ("Building relationships between elements of the graphical representation," "Organizing graphics", "Enter a numeric value for the interval", "graphic analysis", "The mapping and sequencing of the blocks", "Formation of the answer by selecting its components from the proposed list "," Marking the correction of the text"," Filling the gaps in the text ","Setting correspondences between blocks "," Enter the answer to the open question"); implementation of tutoring impact "Training with IES"; explanation of the obtained results; tips; localization of errors made; control of the correct solutions, etc. Any learning strategy is characterized by a specific set of procedures and application of tutoring impacts, the content of which is determined by the degree of destabilization of the problem, depending on the level of knowledge and skills of a student and his or her psychological portrait. The process of formation and implementation of all relevant tutoring impacts is supported by special operational and informational RUC's.

B. Intelligent analysis of educational problems solutions

To identify the skills and abilities of student s to solve educational non-formalized problems from six courses/disciplines represented in a generalized ontology "Intelligent Systems and Technologies" [12] a simulation of student's reasoning for solving four types of learning tasks was used: modeling strategies of forward / backward inference, simulation of simple situations of problem domain using frames and semantic networks, building the components of a linguistic model of business prose sublanguage. Let's briefly comment on operational RUC's that support the above tasks.

1) Operational RUC "Component of detection of student's skills to simulate the forward / backward inference" and several informational RUC's (fragments of knowledge bases) are designed to identify the learner's skills to simulate the forward / backward inference (courses "Introduction to Intelligent Systems", "Expert System", "Intelligent information Systems" etc.). Students go through the following steps: create DBs, consisting of production rules; input initial facts for direct inference; model a strategy of forward inference; inputs facts and goals for backward inference; model strategy of backward inference. Students' skills are evaluated with a simple solver, performing standard inference, and then this inference is compared (using special heuristics) with the students solution.

2) Operational RUC "Component of detection of skills to simulate the simplest situation in the problem domain using frames" and several informational RUCs (fragments of prototype frames, in FRL language of knowledge representation [12]) provide the functionality declared in the course "Introduction to Intelligent Systems", "Expert Systems", "Intelligent information Systems”. Students do control tasks to create prototype frames defined by a tutor [12], then by comparison with the reference frames the level of skills of a students' is detected. A complete history of student actions is saved and can be used to reproduce student's logic of reasoning.

3) Operational RUC "Component of detection of skills to simulate the simplest situation in problem domain using semantic networks" and several informational RUC's (fragments of semantic networks) provide functionality declared in the courses "Introduction to Intelligent Systems", "Expert systems" and "Intelligent Information Systems". Students do control tasks of constructing a fragment of a semantic network for a given problem domain, and then on the basis of comparison with reference fragments of the semantic network the level of their skills is defined with the help of expert techniques.

4) Operational RUC "Component of detection of skills to build components of a linguistic model of business prose sublanguage" and several informational RUC's (dictionaries, fragments of business texts, etc.) provide the functionality declared in the course "Intelligent interactive systems". Students do control tasks of creating lexical, syntactic and semantic components of a linguistic model for a business prose text sublanguage, and then the level of their skills is defined with the help of a special expert techniques. To identify the skills/abilities of learners to solve both formal and NF-problems in the ontology "Automation of physical installations and scientific research" the operating RUC "Design of automation of physical installations", which provides the following functionality in the appropriate course/discipline [20]: development of block diagrams of ACS; calculation of stability of ACS; the choice of ACS elements.

C. Intelligent Decision Support System

It is important to note that in the development of tutoring impacts such as "Training with IES" for different formalized courses/disciplines the most important task is building of problem domain models (including those based on knowledge, containing certain types of NE-factors [8]). Another important task is implementation of “consultation with IES” mode, in which there are scenarios of dialogues with the student. In this dialogues a considerable attention is given to explanations, tips and / or verification of the next stage of solving the problem, etc. Here we could apply multiple operational RUC's from the basic AT-TECHNOLOGY workbench (communication subsystem, versatile AT-solver, an explanation subsystem, etc.), as the development of tutoring impact is a task of creating a complete IES. Informational RUC's are also used (knowledge based fragments from previously created teaching operations "Training with IES", fragments of user dialogue scenarios in "Consultation with IES" mode, etc.) and operational RUC "Explanation component" provides assistance at every stage of the solution of educational problems particularly, gives hints of the next stage, gives explanations like "how" and "why" as well as makes at visualization of inference.

IV. Conclusion

Currently, we are doing a pilot software study, re-engineering and further development of all components of intellectual technologies of tutoring IES construction. In addition, we are working on implementation of Non-formalized techniques for solving tutoring tasks in other courses of various ontologie's (in particular the "Dynamic intelligent systems", etc.)

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НЕКОТОРЫЕ АСПЕКТЫ ПРИМЕНЕНИЯ ИНТЕЛЛЕКТУАЛЬНОЙ ТЕХНОЛОГИИ ДЛЯ ПОСТРОЕНИЯ ОБУЧАЮЩИХ ИНТЕГРИРОВАННЫХ ЭКСПЕРТНЫХ СИСТЕМ

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Анализируется опыт разработки и использования обучающих интегрированных экспертных систем в учебном процессе НИЯУ МИФИ. Эти системы были разработаны на основе задачно-ориентированной методологии и интеллектуальной программной среды комплекса АТ-ТЕХНОЛОГИЯ. Акцент делается на реализацию типовых задач интеллектуального обучения. Рассматриваются особенности моделирования умений обучаемых решать учебные неформализованные задачи. Приводятся примеры выявления умений обучаемых строить модели простейших проблемных областей.

Formation of the Subject Area on the Base of Wikipedia Service

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***Abstract*—The paper presents an algorithm for forming the subject domain models based on automatic data analysis of Wikipedia service. It is shown that defined terminology database, dynamically changeable with the network service development, forming a graph structure with nodes, terms, calculated by weight of various terms, concepts for two different criteria - the degree of the nodes, and PageRank. The example shows the adequacy of the proposed approaches, as well as the fact that clusters of terminological networks can be considered as the basis for the identification of individual scientific fields.**

***Keywords*—subject domain models, terminology database, Wikipedia, communication concepts, the network service probing.**

I. Introduction

Information component of contemporary society can be considered one of the most influential and important. Information for today is a product which is absorbed mostly in the Internet. Encyclopedic content resources are also among them, and some of them are claimed in educational, advisory and information purposes. For today one of the most vital tasks is the integration of open and available services and the subsequent formation of new information, visualization and the creation of supporting tools and resources.

We can define the subject domain model as the specially formed network concepts ontology. Creation of a large sector of ontology is a complex scientific and practical problem [1; 2]. The first stage of this process – formation of the terminological foundations of ontology and definition of semantic connections [3]. Subject areas models study, as well as Wikipedia (http://wikipedia.com) service are the subject of many research, confirming the relevance of the investigation [4].

Methods of co-authors networks formation, the definition of significant nodes of the network structure, research citations, as well as relevant case are among them[5].

Authors suggest the method of information networks formation - domain model based automatic monitoring and analysis of reference network information resources. The network is described as the one which meets the terms - headlines of the network encyclopedia Wikipedia.

The purpose of research - the creation of Wikipedia service scunning algorithm for the construction of subject domain models - individual concepts ontologies, which provide the search and testing on individual terms to identify gaps and ways to remove them.

The paper shows description of the theoretical principles, methodology assessment and algorithmic principles of subject areas models creation, including bibliometric field by monitoring and analyzing reference network information resources. To achieve this purpose there was developed a special algorithm of probing Wikipedia service in order to obtain a representative set of terms, concepts like basis (nodes) of the future network.

Due to the implementation of the algorithm it will be possible not only to expand the existing services, but also demonstrate a broad picture of the connection of individual concepts.

Obviously, the network concepts can be large enough if it does not limited by certain theme, corresponding subject area. This feature greatly complicates the perception of the existing network and leads to such effect as issues displacement. To overcome this effect elementary Content Filtering is applied - the only those articles from Wikipedia, which contain basic term defined by the expert is used for analysis. The compliance with these descriptors to determine the size of existing networks – subject domain models and also the dynamics of their formation. In addition, the recognition of clusters in such networks can be considered as the basis for identifying specific scientific areas[1].

II. Research Methodology

Wikipedia was taken for the review, this service is available in the global network and does not presume subscription and also available for download. For the initial access to the system there were applied special terms of target issues for which there are corresponding articles created and edited by authors-experts (Fig. 1).

In a view of these basic terms for a particular subject area there was defined representation of the information in this system. It was also determined that free link switch leads to the effect of the so-called “topic drift”.

Let’s define the “probing of information network” as a sampling of the most important content from big information networks that cannot be scanned by technical reasons.For building of terminological networks it is reasonable to use models that have been tested at peer-to-peer (P2P) networks, which based on equal participants.

In such networks, there are no dedicated servers, and each node (peer) is both: client and server.In many cases, P2P are superimposed (overlays) networks that use existing transport

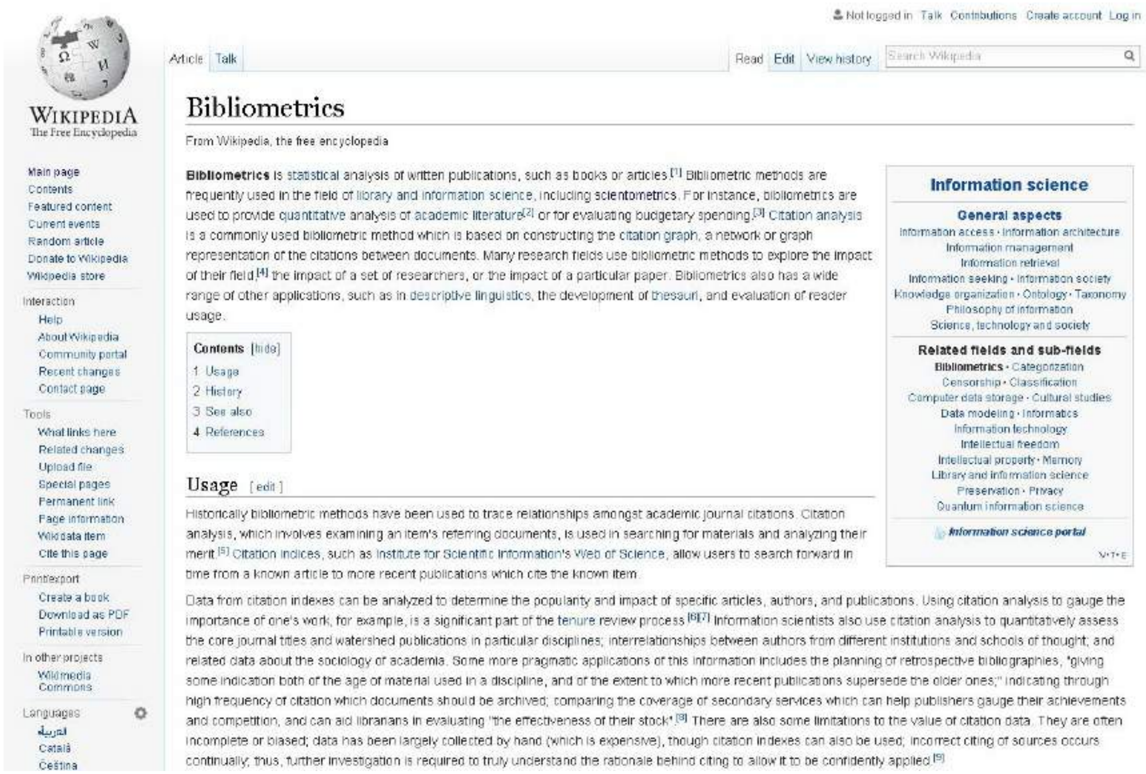

Figure 1. The Wikipedia users interface, article on Bibliometrics

protocols of the Internet.A peer network consist of nodes, each of which interacts only with a subset of other nodes in the network (due to resource constraints).

Several models are used for searching required data in such networks [7]. In the model of Breadth First Search (BFS) the query from a starting node directs to all its neighbors (nearest on certain criteria). When another node receives the request, its local index is looked for and if successful returns a result. Otherwise, the request is transmitted over the network on. In the case of a successful search, a message forms.

- Review (QueryHit) included some information of relevant search sites, and delivered over the network start node.

Another algorithm, the so-called Intelligent Search Mechanism (ISM) provides improved speed and efficiency of information retrievalby taking into account the content of nodes - neighbors to minimize the number of messages between nodes and the number of nodes, the respondents for each search query. In this case, only those components are evaluated for each request, which is the best suited to request. This model is close to the ISM is considered in this work.

The following algorithm was considered for forming models of subject areas according to the Wikipedia service, and involves avoiding of this effect. The algorithm presumes the following steps:

1) On https://www.wikipedia.org/ web page the initial word / phrase is given in the search line;
2) the Search page opens; it provides information about the concept, according to a given search. Initial word / phrase is a vertex of the graph, which will be formed on the results of the probing. All the terms-concepts corresponding the links on the chosen page, are added to the graph. From the initial node the edges-connections are formed;
3) on the current page there are chosen links from the text, without taking into account the information in sections «References», «Notes» and «External Links», as well as not taking into account the «Contents» hyperlink section;
4) all selected words / phrases - hyperlinks are the nodes of the graph;
5) the next transition is executed by the first hyperlink that was defined in the source text;
6) on the page to which the transition has been carried out according to the link, the search of the next word/phrase – the graph vertex is provided;
7) if there is such a word/phrase, the track to the 3d step of the algorithm is provided and respectively from the node-word / phrase of current search new units are being built;
8) if there is no initial word/phrase in the text – the branch is considered to be entirely formed;
9) if during transition to the next word/phrase the jump to the probing page is provided, the word is not added as the graph node, and the reverse connection with the created node is formed.
10) actions on items 3-9 repeat until there will be no initial notion, which is considered as a graph vertex. In such a case the graph is considered to be entirely formed.

According to the described algorithm the process of collecting information from Wikipedia, starting with node-concept stops when according to the algorithm the transition to a new node (with the absence of the basic units) is no longer possible, it means that "cycling" is impossible. The fragment of the program trace which defines the terminological base of the subject domain and corresponding to the above algorithm and basic term Bibliometrics, is shown on Fig. 2.

Bibliometrics

1: Bibliometrics
>!: **Information_science**
>!: **Information_access**
>!: **Information_architecture**
>!: **Information_management**
>!: **Information_retrieval**
>!: **Information_seeking**
>!: **Information_society**
>!: **Knowledge_organization**
>!: **Philosophy_of_information**
>!: **Categorization**
>!: **Information_technology**
>!: **Scientometrics**
>!: **Citation_analysis**
>!: **Citation_graph**

Step: 1; Terms: 14

2: Information_science
>|: Information_theory
>|: Data_science
>|: Library_science
>!: **Informatics**
><: Information_retrieval
><: Information_access
><: Information_architecture
><: Information_management
><: Information_retrieval

Figure 2. Fragment of the program trace

Using the Gephi software there was obtained networks visualization, the networks meet the selected subject areas (Fig. 3).

Obtained characteristics [5] of the formed network Bibliometrics: nodes – 32, connections – 303, density – 0,306.

The most valid two criteria (node degree and PageRank) terms-notions corresponding to the chosen subject area are depicted below in the Table:

The application of cluster analysis can detect most closely related groups of terms that can be used to determine the partial scientific areas by applying a special algorithm that is used in the Gephi system.

III. Conclusion

In the paper there was proposed and implemented an algorithm of subject domains models forming by automatically analysis of Wikipedia network service. Such an approach differs from the static models one by consideration of dynamic changes of the resource and considering new concepts, phenomena which appear in bibliometrics in particular. The key elements in such an approach are the names of new articles as the knowledge markers (tags), which are updated by authors – Wikipedia project participants.

Table I. Main terms

Term	Node Degree	PageRank
Information science	18	0.062
Information technology	19	0.061
Information society	19	0.061
Information management	19	0.061
Information retrieval	18	0.055
Information architecture	18	0.055
Information access	17	0.052
Bibliometrics	19	0.051
Categorization	17	0.049
Information seeking	17	0.049
Philosophy of information	17	0.049
Knowledge organization	17	0.049
Informatics	14	0.044
Citation analysis	13	0.041
Citation graph	12	0.036
Information Retrieval	12	0.036
Scientometrics	12	0.036
Information Science	12	0.035
Library science	1	0.008
Information theory	1	0.008
Data science	1	0.008
Computer industry	1	0.008
IT as a service	1	0.008
Manuel Castells	1	0.008
Industrial society	1	0.007
Content management	1	0.007
Knowledge management	1	0.007
Bibliographic coupling	1	0.007
Information systems	1	0.007
Access to Information	1	0.007
Information retrieval applications	1	0.007
Information Architecture Institute	1	0.007

It can be mentioned that the Wikipedia system, as the Google Scholar Citations system, which was reviewed earlier [6; 7] is convenient for information access, presumes the creation of users profile for information access, the access is unlimited.

It is necessary to make an accent on the fundamental difference between the proposed automatic terminology models creation from existing networks based on the direct participation of experts in process of selecting specific nodes and links. In the case described in the paper, the researcher uses only crumbs of knowledge represented as the first name, key-term concept to form a network. After that, the program uses the knowledge embedded by (editors) articles authors in Wikipedia, tags defined by internal hyperlinks. In this case, the expert environment is substantially expanded.

The model was applied for the “Bibliometrics” theme in frames of the Wikipedia service, but the suggested approach can be used for other research areas, or for other text arrays, bibliographic databases in particular. Taking into account study and the development of algorithm for the Wikipedia service, the problem of this algorithm applying for other services is set. It is necessary to provide the comparison of the reviewed area in frames of other services for further analysis.

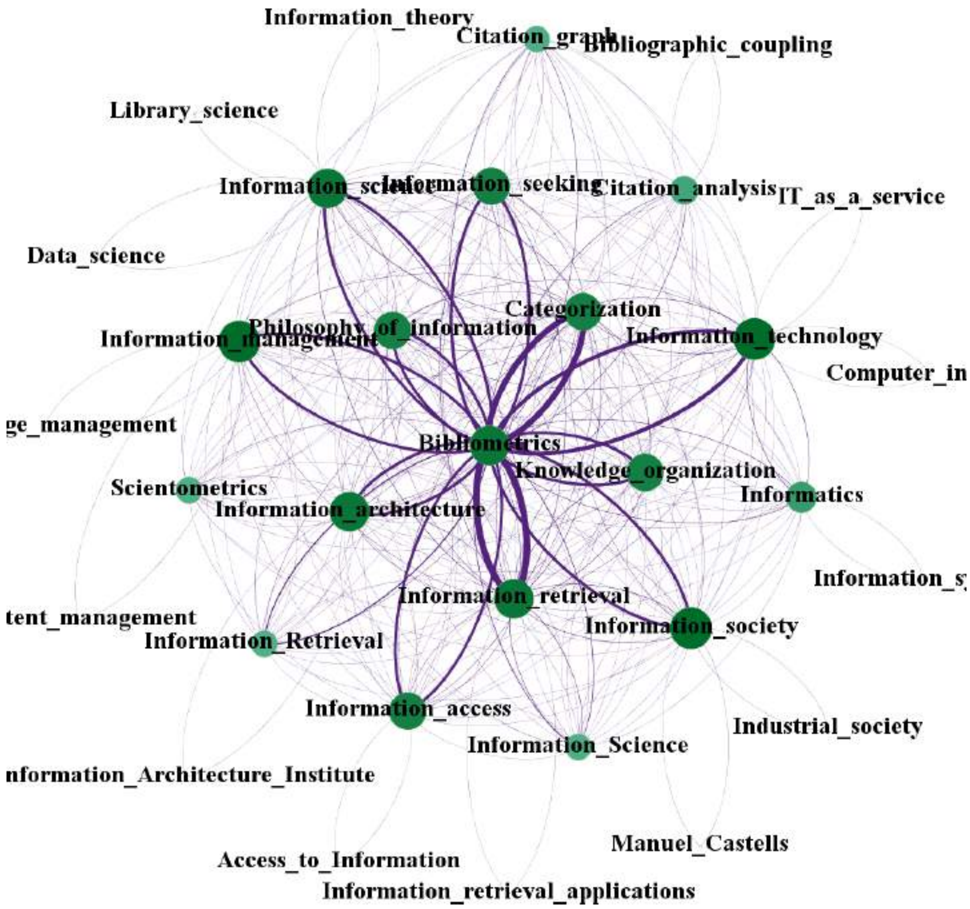

Figure 3. Fragment of the program trace

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ПОСТРОЕНИЕ ПРЕДМЕТНОЙ ОБЛАСТИ НА БАЗЕ СЕРВИСА WIKIPEDIA

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Материал статьи содержит описание алгоритма построения предметной области, который основывается на автоматическом анализе информации ресурса Wikipedia. Сервис Wikipedia был выбран для работы, как популярный энциклопедический ресурс открытого доступа. Результатом работы является построение сети понятий, взаимосвязанных между собой, при этом вершиной сети является понятие, задаваемое для исходного поиска. Сесть строится исходя из присутствия заданного слова на тех или иных веб-страницах, переход к которым осуществляется по гиперссылкам со страницы исходного понятия. Реализация алгоритма не только позволит расширить возможности существующего энциклопедического ресурса открытого доступа, но и представить расширенную иллюстрацию взаимосвязей отдельных понятий. В статье приведен пример реализации алгоритма для понятия – Bibliometrics. Также показаны преимущества системы и возможности усовершенствования предложенных приложений.

Applying of Ontological Technology of Semantic Search in E-learning

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***Abstract*—The AI in education has become the most challenging area in the last several years. Knowledge management in the lot of the modern Web-oriented applications of AI is based on ontologies. In this paper, we focus on ontological model of retrieval interaction of users and informational resources. Represent model can be used in various intelligent application.**

Keywords*—Artificial Intelligence, ontology, Semantic Web, semantic search, competence management.

I. INTRODUCTION

Artificial intelligence (AI) in computer science is an ideal "intelligent" machine wich is a flexible rational agent that perceives its environment and takes actions that maximize its chance of success at some goal. The goal of the AI field's is to deliver knowledge-based systems, which can be used in real teaching, learning and training situations. The main AI technologies include: general problem-solving, expert systems, natural language processing, vision, robotics, and games.

Researchers have been used AI field of research in education to develop a new generation of intelligent tutoring and learning systems [1, 2]. The main two components in developing an efficient and robust intelligent tutoring and learning systems in any domain are the "knowledge base" and the "inference engine". Concerning the knowledge base there are many knowledge representation and management techniques, e.g.; lists, trees, semantic networks, frames, scripts, production rules, cases, and ontologies. The key to the success of such systems is the selection of the appropriate technique that best fits the domain knowledge and the problem to be solved. That choice is depends on the experience of the knowledge engineer. Regarding the inference engine, there are many methodologies and approaches of reasoning e.g.; automated reasoning, case-based reasoning, commonsense reasoning, fuzzy reasoning, geometric reasoning, non-monotonic reasoning, model-based reasoning, probabilistic reasoning, causal reasoning, qualitative reasoning, spatial reasoning and temporal reasoning [3]. In fact these methodologies receive increasing attention within the AI in education community [4-6].

II. ONTOLOGICAL ENGINEERING IN E-LEARNING FROM THE ARTIFICIAL INTELLIGENCE PERSPECTIVE

A. Ontological Engineering in e-Learning

During the last decade, increasing attention has been focused on ontologies [7]. At present, there are applications of ontologies with commercial, industrial, medical, academicals and research focuses [8-11].

The main objective of using ontologies is to share knowledge between computers or computers and human. Computers are capable to transmit and present the information stored in files with different formats, but they are not yet compatible to interpret them. To facilitate communication and intelligent processing of information, it is necessary that all actors of the digital space (computers and humans) have the same vocabulary. Ontologies are the foundation of cooperation and the semantical understanding between computers (running a lot of nonhomogeneous software programs) and of the cooperation between computers and humans.

Most of the usages of ontologies in the field of computer science are related to knowledge based systems and intelligent systems. These types of ontologies include a small number of concepts and their main objective is to facilitate reasoning.

B. Artificial Intelligence Perspective

Ontologies' usage in educational systems may be approached from various points of view: as a common vocabulary for multi-agent system, as a chain between heterogeneous educational systems, ontologies for pedagogical resources sharing or for sharing data and ontologies used to mediate the search of the learning materials on the internet[12].

The The abstract specification of a system is composed of functional interconnected elements. These elements communicate using an interface and a common vocabulary. The online instructional process can be implemented successfully using artificial Intelligence techniques. Sophistically software programs with the following features give the intelligence of the machine: adaptability, flexibility. Learning capacity, reactive capacity, autonomy, collaboration and understanding capacity. This approach enables to solve the complexity and the incertitude of the instructional systems. An intelligent learning system based on a multi-agent approach consists in a set of intelligent agents, which have to communicate. They collaborate through messages. Software agents can understand and interpret the messages due to a common ontology or the interoperability of the private ontologies.

III. Artificial Intelligence in Education and Learning

Conferences on "Artificial Intelligence in Education "which held during the period 1993 – 2007, figure 1 shows the main areas of the AI in education [4].From this figure it can be seen that the research in the field of AI-EDU consists of seven main areas, namely: Intelligent Educational Systems (IES), Teaching Aspects, Learning Aspects, Cognitive Science, Knowledge Structure, Intelligent Tools, Shells and Interfaces. The main systems of the IES are Intelligent Tutoring Systems (ITS), Educational Robotics and Multimedia Systems.

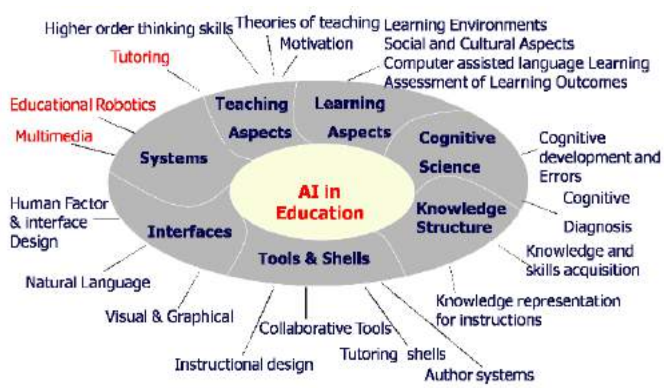

Figure 1. The main areas of artificial intelligence in education

In what follows, a brief a account of the AI-based areas of research, namely:

1) intelligent tutoring systems;
2) intelligent e-learning systems;
3) intelligent authoring shells and tools [13,14].

Intelligent Tutoring Systems (ITSs). ITS is a knowledge based software that act as an intelligent tutor used in real teaching. ITS is also used in learning, and training situations. From the technical point of view, ITS is composed of the following software components:

1) expert model;
2) student mode;
3) instructional module;
4) interface;
5) knowledge acquisition module.

ITS components are complex to build and complex to maintain. For more technical information, see [1]. The main features and characteristics of the ITS are:

- Adjust its tutorial to the student's knowledge, experience, strengths, and weaknesses.
- Generates exercises and test.
- Generates programs for illustration purposes
- Carry on a natural language dialogues and explanations.
- Organize its knowledge in a lesson-oriented manner according to student models.
- Evaluates students results for tests, and develop a student's model.
- Tireless teacher which adapts to the learners cognitive particularities and his individual progress.
- Based around a large amount of knowledge from the teaching domain.
- Learner's particularities and his progress are stored in the "student model"
- Use of pedagogical knowledge.
- Use of rhetorical knowledge (or rules) for natural language text generation
- Addition of new knowledge is simple due to the structured object-oriented knowledge representation language.
- Generate a highly structured collection of web pages.

The main benefits of ITS are:

1) enhances instructor and student productivity;
2) provides tailored instruction and remediation;
3) allowing flexibility in teaching methods.

In addition the web-based ITS provides the following benefits:

1) a unique opportunity to distribute training across multiple sites (reducing travel-related training costs;
2) provides realism and authentic learning;
3) create a new kinds of learning experiences;
4) distribute of multimedia materials;
5) disseminate work publicity [15].

IeLSs are AI-based systems that imitates the human mind. The main characteristics of these systems are the ability of inference, reasoning, perception, learning, and knowledge-based systems. To a limited degree, AI permits IeLS to accept knowledge from human input, then use that knowledge through simulated thought and reasoning processes to solve problems. Many types of IeLSs are in existence today and are applies to different domains and tasks, e.g., geology, biological sciences, medical sciences, health care, commerce, and education [2, 13].

The main stage in developing IeLS for any specific task is to build a "knowledge base" in that domain of interest. The knowledge of that domain must be collected, codified, organized and arranged in a systematic order. The process of collecting and organizing the knowledge is called knowledge engineering. It is the most difficult and time-consuming stage of any IeLS development process. Although a variety of knowledge representation techniques have been developed over the years, these techniques share two common characteristics. First, they can be programmed with certain computer languages and tools. Second, they are designed so that the facts and other knowledge contained within them can be manipulated by an “inference system”, the other major part of an IeLS. The inference system uses search and pattern matching techniques on the knowledge base to answer questions, draw conclusions, or otherwise perform an intelligent function.

Intelligent authoring shells allow a course instructor to easily enter domain and other knowledge without requiring computer programming skills. The authoring shell automatically generates an ITS/IeLS focusing on the specified knowledge. It also facilitates the entry of examples/exercises, including problem descriptions, solutions steps, and explanations. The examples may be in the form of scenarios or simulations. It allows organized entry of the course principles and the integration of multi-media courseware (developed with well-known authoring tools) which includes descriptions of the principles or motivational passages. In addition to course knowledge, the instructor specifies pedagogical knowledge (how best to teach a particular student), and student modeling knowledge (how to assess actions and determine mastery) [16].

The most common authoring shells are DIAG, RIDES-VIVIDS, XAIDA, REDEEM, EON, INTELLIGENT TUTOR, D3 TRAINER, CALAT, INTERBOOK, and PERSUADE [1]. Some tools were meant for select authors or students and others were designed for a wide set of authors. Some tools were designed to work with a limited area of domain expertise, and some were designed for a wide range of domains. Some tools had one main instructional strategy, but others had many. Each tool had their own way of representing the student's knowledge and understanding of the material being taught. Some tools generated instruction directly from domain knowledge. Some relied on pedagogical knowledge about the domain to create instruction. Some provided simulation environments for practice and exploration [17-22].

IV. ONTOLOGICAL ANALYSIS AS AN INSTRUMENT OF THE DISTRIBUTED KNOWLEDGE MANAGEMENT

Every domain has phenomena that people allocate as conceptual or physical objects, connections and situations. With the help of various language mechanisms such phenomena contacts to the certain descriptors (e.g., names, noun phrases). Professional activity is a characteristic of a domain. A domain is considered as a set of the tasks, which are solved by specialists of this domain. A domain ontology is the part of domain knowledge that restricts the meanings of domain terms, a set of agreements about the domain.

A. Formal model of ontology

The formal model of ontology O is an ordered triple

$O = \langle X, R, F \rangle$

Where X - finite set of subject domain concepts that represents ontology O; R - finite set of the relations between concepts of the given subject domain; F - finite set of interpretation functions of given on concepts and relations of ontology O. An ontology is a specification of a conceptualization.

Now a lot of the Web applications is intelligent and uses knowledge about some subject domain or produce some new knowledge. In such applications knowledge is represented in interoperable form and can be reusable. For such representation ontological approach is widely used because ontologies have a fundamental theoretical foundation (descriptive logic).

An ontology is commonly defined as an explicit and formal specification of a shared conceptualization of a domain of interest. Ontologies formalize the intentional aspects of a domain, whereas the extensional part is provided by a knowledge base that contains assertions about instances of concepts and relations as defined by the ontology.

The creation of intelligent informational systems based on ontologies, in environment of continuous organizational and technological changes requires methods and tools not only for ontology creation, but also for the whole complex of related problems - change management, estimations, personification, separation, mapping and integration etc.

In the context of knowledge sharing, I use the term ontology to mean a specification of a conceptualization. That is, an ontology is a description (like a formal specification of a program) of the concepts and relationships that can exist for an agent or a community of agents. This definition is consistent with the usage of ontology as set-of-concept-definitions, but more general.

B. Formal model of thesaurus

The thesaurus can be considered as a special case of ontology. A thesaurus is a networked collection of controlled vocabulary terms. This means that a thesaurus uses associative relationships in addition to parent-child relationships. The expressiveness of the associative relationships in a thesaurus varies and can be as simple as “related to term” as in term A is related to term B [23]. The formal model of thesaurus is a pair

$T_h = \langle T, R \rangle$

Where T – finite set of the terms; and R – finite set of the relations between these terms.

A formal definition of a thesaurus designed for indexing is: a list of every important term (single-word or multi-word) in a given domain of knowledge; and a set of related terms for each term in the list.

At the present stage of IT in the majority of cases intelligent Web applications use standards and technologies of knowledge management developed by Semantic Web project. Ontologies are an important building block of knowledge in the Semantic Web [24-26]. They provide a shared and common understanding of a domain that can be communicated across people and applications.

Ontologies of the Semantic Web consist of Semantic Web Terms (SWT) – building blocks that play the role of the natural languages words. The set of SWT associates the RDF statements with formal semantics that are defined by RDF(S) with OWL statements. The social Web provides the knowledge about persons and communities that can be represented also as an ontology.

C. Information recourses

Information recourses (IR) represented in the Internet can be classify on textual and multimedia ones, static and dynamic, structures and not structured etc., but every IR has some semantics and is concerned with some subject domain. In process of information retrieval is very important to discover IR concerned with the domain interested to user [27-29].

Structures textual information in the Internet is mainly given in HTML and XML formats. The subject domain of textual IR can be defined by two ways:

- analyzing of IR textual content and
- considering metadata of these IR.

The challenge is to create consistent terminology labels for each element in the public resources that would allow the identification of all elements that relate to the same type at a given level of granularity.

Metadata can be built in IR or be stored and updated independently of resources. With the help of RDF one can describe the structure of a IR and connect it with appropriate domain. RDF describes IR in a form of oriented marked graph - each IR can have properties that also can be IR or their collections. Most widespread set of elements for metadata specification of the Internet IR is Dublin Core Metadata Elements.

Processes of global informatization of the international community focus on the construction and use of multidisciplinary knowledge. It requires the development of knowledge engineering and knowledge management tools. A relatively new trend in this area is the ontological engineering, providing re-use and interoperability accumulated in the knowledge society.

Ontologies are used in the knowledge processing for their structuring and integration. Therefore, questions of automated creation and updating of ontologies based on heterogeneous and dynamically changing information resources Web, their integration and mapping, as well as the development of methods for inference on them are very actual now.

V. Ontological Model of Semantic Search

A. Ontology-based semantic search

In the most general understanding search is a complex problem of:

1) matching of user conception about relevant for his problem knowledge with content of available information resources; and
2) building of the specific data object (with a finite number of specific values of properties that are mined from the analysed resources) based on this matching.

The main difference of the semantic search from the traditional one is the usege of the knowledge (related to the search objects, users, information resources (IRs), domain of retrieval etc.) to improve the pertinence of retrieved information to user‘s task.

Ontologies can be useful in all these problems. But we have to keep in mind that the use of ontologies, despite such advantages as an explicit representation of semantics and a strict mathematical basis (descriptive logic), has significant shortcomings relating to the complexity of ontology processing and inference. Therefore, the appropriateness of the use of ontologies and their particular cases for knowledge representation in the semantic search is the subject of a separate study [30,31].

B. Ontological model of search

Ontological model of semantic search formally defines the main subjects of retrieval process and relations between them.

Ontological model of interaction between users and IRs describes the following classes:

- domain ontology, which describes the sphere of the user‘s information needs;
- lexical domain ontology which contains information about the lexical element of natural languages appropriated to ontology terms;
- task thesaurus – set of pairs where the first element is the domain ontology terms, and the second – the weight (positive or negative) of the term for user‘s problem;
- request – set of keywords describing one of their information needs of the user (associated with a particular task by using of the task thesaurus);
- theme – the set of requests related to the same information needs that can combine the needs of different users, based on different ontologies and thesauri, and allows you to combine semantically related queries;
- query result – a set of pairs where the first element is a reference to IR, and the second – the user evaluation of this IR;
- user – a class that has a more complicated structure and having the following attributes, which can be divided into several groups: registration information, user information imported from external sources, IPS experience of interaction with the user etc.,
- information resource;
- informational object – result knowledge with structure fixed by external ontology (for example, Web service, learning organization, human).

Knowledge about particular users, IRs and other search elements is represented by ontology individuals and their properties.

VI. Qualification Management as a Particular Case of Semantic Search Task

This model of semantic search quite easily can be adapted for various applications.

Here we consider the case of the problem of matching competencies, which is an integral part of such tasks deal with education as:

- finding of suitable contractors employer;
- comparison of specialists with different specialties (in particular, relevant to standards of different countries);

- selection of an applicant institution, offering him the necessary set of disciplines;
- valuation of the possibility of student transfer from one institution to another (what disciplines from a previously studied can be take into consideration), etc.

Model of this search domain deals with main terms of educational activities and describes the basic concepts (“discipline”, “speciality”, “competence”, “student”, “learner”, “qualification level” etc.) and the relationships between them, as well as the structure of a data object, which is the result of the search – human, educatinal organization, speciality (Fig.2).

These strict definitions based on OWL support the relevant formalization of various requests such as comparison of the values of properties from one class of different class instances.

For example, if we want to find the professor for some University hen we have to match the informational object classified as an individual of “Educational organization” that values of property “Discipline” include the values from the set defined by values of property “Discipline” of individual of class “Learner”.

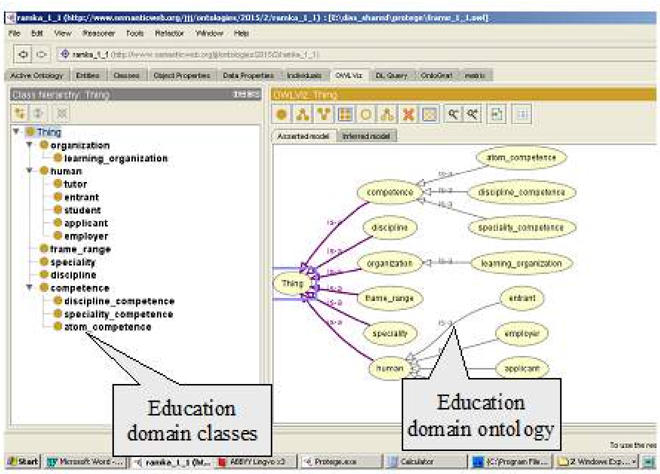

Figure 2. Education domain ontology

The main element of this model is a hierachy of competences deal with various disciplines, specialities, organizations and humans.

For comparison of specialties, skills and competences of people and organizations of different countries, it is advisable to use a set of standard atomic instances of each class.

An instance is considered to be atomic if any other instance of this class is not it‘s subset.

If two competence A and B are overlapping, then we have to build three potentially atomic competences – A_1, B_1 and C, such that

$$A \cap B = C, A_1 \cup C = A, B_1 \cup C = B$$

This process is repeated iteratively until all sets become disjoint.

Class "Atomic competence" is a subclass of class "competence", so that $\forall a \in$ "atomic competence" exists at least one element b of class "Competence", such that $a \subseteq b$, but for any element of the class "atomic competence" there is no other element c of this class "atomic competence" such that $c \subseteq a$, $a \not\subset c$. Class "Atomic competence" has a property "part of the" of class "discipline" and the property "to enter the" of class "competence".

In this case, the user describes his need in information by indicating the class of desired information object from the domain ontology A, – a human, institution, specialty etc. – and conditions imposed on it – the set of instances of the class "atomic competence" that are associated whith the selected object by relationships from the ontology that describe the links between instances (object properties).

An important advantage of the proposed search model is the fact that in this description semantics is clearly indicated the information needs. It provides the differentiated search for various relationships between the desired information object and a set of competencies.

For example, some different subsets of atomic competencies can be associated with the same instance of the class "person" by such relations as "has", "certified", "can teach", "has experience with." This differentiation allows for much more accurately satisfy user’s demand in the information by finding of the information objects that meet all requirements.

The most important task deals with competence management can be divided into two subgroups:

- building of the set of atomic competencies by the set of discipline competencies;
- updating the knowledge base by information about the domain instances.

VII. Conclusion

Artificial Intelligence is a powerful methodological and theoretical foundation for various knowledge-based applications. Integration of the AI algorithms and approaches with the up-to-date semantically enriched Web technologies provides high-efficient information processing and analysis.

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ПРИМЕНЕНИЕ ОНТОЛОГИЧЕСКИХ ТЕХНОЛОГИИ СЕМАНТИЧЕСКОГО ПОИСКА В ОБЛАСТИ ЭЛЕКТРОННОГО ОБУЧЕНИЯ

Гладун А. Я. Хала Е. А. Абдель-Бадех М. Салем

Искусственный интеллект в образовании стал самым сложным направлением, в последние несколько лет. Управление знаниями во многих современных веб-приложениях, ориентированных на ИИ базируется на онтологиях. В данной работе мы ориентируемся на онтологическую модель поискового взаимодействия пользователей и информационных ресурсов. Представленная модель может быть использована в различных интеллектуальных приложениях.

Синергетические учебные организации в сфере высшего образования

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Аннотация—Статья посвящена проблемам инженерного проектирования организаций в сфере образования. Предварительно рассмотрены основные предпосылки и идеи инжиниринга предприятий, приведена методика инжиниринга организаций и указаны допущения для стратегического инжиниринга учреждений высшего образования. Обсуждаются основные понятия синергетики и принципы синергетической методологии (в целом в науке и в частности в теории организаций). Дано определение синергетической организации и отмечены ее главные характеристики. Указано, что такой организации целесообразно сочетание стратегий организационного проектирования и самоорганизации в русле многоагентной методологии, В заключительной части работы проведен анализ видов деятельности и задач кафедры, обоснованы причины и условия перехода от обычных к виртуальным кафедрам. Одним из вариантов развития и применения синергетических стратегий в образования XXI-го века видится организация в вузах ***межкафедральных и межфакультетских структур***. В результате, предложена концепция синергетической кафедры и прослежены ее системные единицы и структуры.

Ключевые слова—искусственный интеллект; системный подход; синергетика; инжиниринг организаций; реинжиниринг; управление знаниями; стратегический инжиниринг; онтологический инжиниринг; высшее образование; синергетическая учебная организация, синергетическая кафедра.

I. Введение

В настоящее время бурно развивается новый научно-практический комплекс ***«инжиниринг предприяти»*** (Enterprise Engineering), который направлен на инженерную разработку и создание предприятий как целостных динамических систем. Он носит междисциплинарный характер и опирается на методы и подходы теории систем, синергетики, теории организаций, информатики, искусственного интеллекта, стратегического менеджмента, теории коммуникации, и других наук. Уже более двенадцати лет функционирует постоянно расширяющаяся международная сеть CIAO Network [CIAO], в которую входят университеты, исследовательские институты, предприятия и организации, заинтересованные в развитии общей теории, методов и средств *проектирования предприятий.* При этом понятие «предприятие» трактуется очень широко: от классических форм предприятий (корпораций и партнерств) до всевозможных организационных объединений, корпоративных сетей, альянсов, виртуальных организаций, цепочек поставок, и т.п. Здесь аббревиатура CIAO, образованная из слов Cooperation, Interoperability, Architecture, Ontology, характеризует тесные взаимосвязи между ними: ***кооперация*** предприятий, очевидно, подразумевает полную ***интероперабельность*** их информационных систем, а организационная архитектура предприятий понимается как стандарт разработки – нормативное ограничение на свободу проектантов предприятия, причем в основе их совместной деятельности лежат общие онтологии. По аналогии с подзаголовком знаменитой монографии М.Хаммера и Д.Чампи «Реинжиниринг корпорации:манифест революции в бизнесе» [28], Я.Дитцем и др. в 2011г. был написан «Enterprise Engineering Manifesto» [32], в котором указаны мотивы, задачи и постулаты парадигмы инжиниринга предприятий. Варианты системного подхода к инжинирингу предприятий изложены в монографиях Я.Дитца [31] и Р.Джиачетти [33].

В российском научном сообществе инициатива перехода от методологии реинжиниринга бизнеса к парадигме инжиниринга предприятий принадлежит Ю.Ф.Тельнову [24], [25], который подчеркивает, что рассмотрение предприятия только как множества бизнес-процессов может привести к нарушению его системной целостности. Поэтому актуально развитие методологии инжиниринга предприятия как интеграционного направления, что определяет синтез знаний из различных дисциплин. Здесь требуется сочетание методов математического моделирования и интеллектуальных технологий для стратегического и оперативного управления предприятиями со средствами виртуализации и интеллектуализации организационных структур. Общая теоретическая и методологическая база инжиниринга предприятий, пути его становления и развития изложены в [10], [23], [29], [37].

По Ю.Ф.Тельнову, инжиниринг предприятий можно рассмотреть как иерархическую структуру, представляющую три главных этапа разработки: ***стратегический инжиниринг***; формирование ***архитектуры пред-***

приятия с акцентом на интеллектуализацию его базовых структур; онтологический инжиниринг предприятия и управление знаниями (рисунок 1).

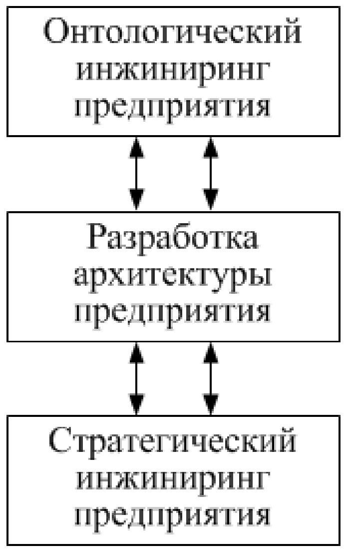

Рис. 1. Иерархическая схема инжиниринга предприятий

Стратегический инжиниринг предприятия следует начинать с изучения его среды и вариантов ее изменения (рисунок 2).

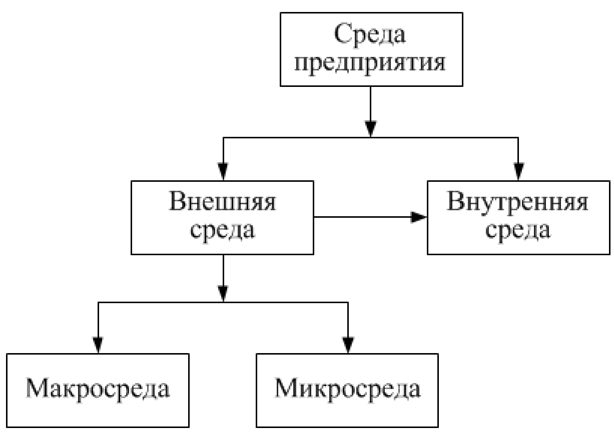

Рис. 2. Классификация сред предприятия

В основу инжиниринга организаций и учреждений высшего технического образования можно положить, по крайней мере, три допущения 1) образовательное учреждение есть сложная открытая система, функционирующая в неоднородной среде; 2) эта система, будучи динамической, выступает как совокупность процессов и структур, которые должны быть спроектированы для достижения ее целей; 3) следует привлекать инженерные подходы к решению задач построения, развития и трансформации как самого образовательного учреждения, так и его системных единиц.

В настоящей работе предлагается возможный вариант формирования *синергетических учебных организаций* в области высшего технического образования, в частности, кафедр нового поколения, образуемых в результате интеграции подходов виртуальных [18], [30], [38], интеллектуальных [19], [35], [36], обучающихся [17], [20], рефлексивных [12] организаций.

II. Синергетика и синергетические организации

A. О синергетике и синергетической методологии

Синергетика есть междисциплинарное научное направление, изучающее процессы взаимодействия, кооперации, самоорганизации и эволюции сложных систем. Сам термин «синергетика» происходит от слова «синергия», которое означает совместное действие, сотрудничество. По мнению «отца синергетики Г.Hakena [26], предложившего этот термин, его введение для обозначения теории сложных самоорганизующихся систем оправдано по двум причинам: во-первых, исследуются совместные действия многих элементов развивающейся системы; во-вторых, для отыскания общих принципов и механизмов самоорганизации требуется объединение усилий представителей различных дисциплин. В то же время он определяет синергетику как учение о взаимодействиях, приводящих к появлению новых структур [27].

Основным предметом синергетики являются процессы синтеза, формирования, развития, преобразования, которые интерпретируются как первичные аспекты сложных систем, тогда как структуры и симметрии, порожденные ими, рассматриваются как нечто вторичное. Ключевой предпосылкой любого развития выступает неустойчивость сложной системы, ее нахождение в критической области (вблизи точек бифуркации), где в условиях резкого роста неопределенности повышается возможность образования структур с новыми качествами.

Итак, в центре внимания синергетики находятся нелинейные и неравновесные системы, в которых как внешние, так и внутренние флуктуации при определенных условиях могут вызвать спонтанный морфогенез.

К числу ведущих принципов синергетической методологии относятся [19]:

1) Принцип *междисциплинарности*.
2) Принцип *синтеза взаимодействий*, тесно связанный с идеей первичности взаимодействий и вторичности структур.
3) Принцип *целостности (неаддитивности)*.
4) Принцип *дополнительности* (согласно Н.Бору, противоположности – не противоречия, они – дополнения) и *взаимной компенсации* моделей сложной системы.
5) Принцип *разнообразия путей развития* сложной системы (сочетание различных стратегий эволюции, волновой характер эволюции).
6) Принцип И.Пригожина (принцип спонтанно возникновения новых качеств в особых состояниях сложной системы) [16].
7) Принцип *соответствия* (язык описания системы должен соответствовать природе располагаемой о ней информации).

8) Принцип совместного учета факторов ***неопределенности (НЕ-факторов*** в терминологии А.С.Нариньяни [15]).

B. Синергетическая методология в теории организаций

Использование синергетического подхода в теории организаций связано с рассмотрением следующих фундаментальных проблем:

- создание и развитие синтетических концепций организаций, появляющихся на свет в процессе интеграции и гибридизации различных парадигм и теорий организации(например, функциональной и критической парадигм, теорий проектирования и самоорганизации, централизованного и децентрализации управления, и пр.);
- исследование механизмов синтеза новых организационных структур, в том числе процессов объединения, поглощения, слияния организаций;
- анализ условий и принципов перехода от классических к неклассическим организационным моделям – от механистической к биологической (органической), от монолитной к распределенной, от иерархической к гетерархической, и т.д.;
- изучение поведения организационных структур при функционировании организаций в «режимах с обострением» [Kniazeva-2005], вблизи критических точек бифуркаций, «на грани хаоса»;
- разработка общей методологии, методов и инструментария эволюционного и организаций.

C. Синергетическая организация и ее характеристики

Новое понятие «синергетическая организация» предполагает формирование различных синергий в организационных сетях. В этом плане оно является родовым, объединяющим такие важные классы как: ***виртуальные организации*** (синергия ресурсов, находящихся в различных местах); ***интеллектуальные организации*** (синергия опыта, в первую очередь, знаний; управление знаниями); ***обучающиеся организации*** (синергия стратегий и видов обучения.

Необходимыми условиями возникновения и функционирования синергетических организаций выступают процессы взаимодействия, в рамках которых реализуются различные формы и варианты интеграции, кооперации и эволюции.

Речь идет о вертикальной или горизонтальной интеграции, формировании организационных альянсов и объединений, создании совместных предприятий. В частности, сегодня активно развиваются стратегии компьютерной интеграции ресурсов в виртуальном пространстве –виртуальные ассоциации,консорциумы, холдинги, корпорации. Следует отметить, что уже при интеграции различных организаций происходит не только их объединение, но и взаимная адаптация и совместная эволюция.

При современной трактовке организации как «биосоциального организма», в качестве сильной формы интеграции можно указать гибридизацию, когда речь идет о соединении в одном организме разнородных наследственных признаков и компонентов (см.природные стратегии симгенеза, симбиогенеза, гибридогенеза в [14]). Ярким примером организационного гибрида служат финансово-промышленные группы.

Синергетической организацией (СинО)назовем открытую, интегрированную (или гибридную), развивающуюся организацию (метаорганизацию), в которой исходные организации-партнеры, работающие в сложной, динамической, плохо определенной конкурентной среде, находящиеся вблизи критических зон бифуркации и способные под воздействием незначительных факторов сильно варьировать свое состояние, кооперируют, формируя метаморфные, быстро меняющиеся организационные структуры.

В СинО происходит компенсация недостатков и усиление достоинств ряда сотрудничающих организаций. Здесь синергетические механизмы кооперативного взаимодействия приводят к синхронизации процессов у различных партнеров и формированию у них когерентного поведения. Возникающие в синергетических структурах нелинейные связи между партнерами влекут за собой супераддитивность (мультипликативность) общего эффекта при совместных действиях. В результате появляются резонансные явления, когда конкурентоспособность, эффективность и прибыль партнеров многократно возрастают. Отметим, что синергетические эффекты тесно связаны с осуществлением организационных инноваций и их последующей оценкой.

Системными характеристиками организаций и главными критериями организационного синтеза являются: среда, организационная единица взаимодействие, структура, связи, адаптация, развитие. Укажем их особенности для СинО.

1) Среда СинО: сложная, плохо определенная, динамическая.
2) Единица СинО: целостная, неоднородная, неравновесная единица.
3) Взаимодействия в СинО: сочетание стратегий кооперация и конкуренции с преобладанием первых (например, стратегия сотрудничества с координацией). Кооперация между партнерами в СинО направлена на совместное выполнение задач в условиях коллективного использования интеллектуального капитала, постоянного обмена информацией и знаниями как ключевыми ресурсами.
4) Связи в СинО: эмергентные, переменные, гибкие, нелинейные.
5) Управление СинО:комбинированное (сочетание стратегий управления и самоуправления).
6) Адаптация в СинО: необходимость взаимной адаптации партнеров и их коадаптации к среде.
7) Развитие СинО: волновая эволюция, концепция финализма, т.е. предсказание организационной эволюции «из будущего», исходя из цели

как состояния-аттрактора; симбиогенез (слияние организационных геномов разных видов).

Инжиниринг СинО предполагает сочетание стратегий организационного проектирования и самоорганизации в русле многоагентной методологии [?], [19] (на основе взаимодействия целеустремленных, активных, автономных, адаптивных агентов, имеющих собственные механизмы мотивации и формирования предпочтений).

III. Синергетические организации в образовании

A. От классической к виртуальной кафедре

В высших учебных заведениях любых видов (университет, академия, институт) базовыми единицами являются кафедры, осуществляющие подготовку студентов в рамках определенной специализации. Кафедры и их преподаватели обеспечивают жизненный цикл подготовки в вузах – от начального отбора абитуриентов до выпуска дипломированных специалистов. В узком смысле под кафедрой обычно понимается объединение преподавателей разной квалификации, но близких специальностей, одновременно выполняющих педагогическую, научную и учебно-методическую работу по одной или нескольким родственным учебным дисциплинам. Их деятельность связана с преобразованием научных достижений в передовые учебные курсы, пособия, лекции.

Согласно Положению о кафедре университета, ее основными задачами являются

- реализация учебного процесса по очной, очно-заочной(вечерней) и заочной формам обучения по закрепленным за кафедрой дисциплинам в соответствии с утвержденными учебным планом и программами дисциплин;
- создание условий для удовлетворения потребностей личности в интеллектуальном, культурном и нравственном развитии в русле образовательно-научной деятельности;
- организация и проведение фундаментальных, поисковых и прикладных исследований, научно-технических,опытно-конструкторских работ по профилю кафедры и работ по проблемам высшего образования;
- подготовка, переподготовка и повышение квалификации по основным программам профессионального обучения, а также по разным дополнительным образовательным программам.

Наряду с учебной, учебно-методической, научной деятельностью кафедра также проводит организационную и воспитательную работу, а также работу по профориентации студентов и содействию трудоустройству выпускников.

Следует отметить, что в современных учреждениях высшего образования следует формировать кафедры не по принципу специальности, т.к. специальности могут часто меняться, а по общности направлений подготовки. Более того, для реализации эффективного смешанного централизованного-децентрализованного управления университет может передавать часть своих прав и полномочий кафедрам. Именно кафедра является той базовой университетской единицей, которая наиболее заинтересована в прямых связях с заказчиками образовательных услуг и адаптации к конъюнктуре рынка. Именно кафедра наиболее активна в плане получения и выполнения инновационных заказов – как в сфере подготовки специалистов, так и области НИР и НИОКР. Именно кафедра может наиболее эффективно и целенаправленно изыскивать источники получения внебюджетных средств и обеспечить их рациональное расходование, учитывая как интересы сотрудников, так и потребности развития материальной базы и научно-педагогического потенциала.

В плане создания инновационных структур и единиц в учреждениях высшего образования, ориентированных на использование передовых информационно-коммуникационных технологий, значительный интерес вызвали концепции ***виртуального университета*** [2] и ***виртуальной кафедры*** [4], [8]. Так виртуальная кафедра, ориентированная на повышение эффективности выполнения вышеуказанных кафедральных задач с помощью интернет-технологий, есть разновидность компьютерно интегрированной, базовой образовательной единицы, состоящей из неоднородных, свободно взаимодействующих агентов. К ней относятся прямые участники образовательных процессов (преподаватели, студенты, и т.д.), а также искусственные агенты, находящиеся в различных местах. Такая кафедра образуется путем информационной интеграции и совместного использования необходимых педагогических, учебно-методических, научных, программно-технических и прочих ресурсов, собираемых с различных кафедр, факультетов, университетов, научных учреждений, предприятий, бизнес-структур,. Затем формируется имитационная модель работы кафедры в виде искусственной организации, функционирующей в виртуальном пространстве.

Создание виртуальных кафедр способствует интеграции различных форм обучения и обеспечивает естественное развитие идей открытого и дистанционного образования. Оно также может быть направлено на оказание научно-методической поддержки неопытным, молодым преподавателям со стороны ведущих профессоров в разработке новых учебных курсов, учебных планов и программ (см. проект «Виртуальная кафедра» в Новосибирском государственном университете).

Многоагентные технологии инжиниринга виртуальной кафедры описаны в работах [4], [8], [19], а проблемы управления знаниями на виртуальной кафедре затронуты в публикациях [6], [7].

B. Сетевые межкафедральные структуры

Согласно статье 27, п.1 Федерального закона «Об образовании в РФ» образовательные организации самостоятельны в формировании своей структуры. Это показывает актуальность разработки концепции инжиниринга учреждений высшего технического образования с широким применением передовых информационных и коммуникационных технологий. Одним из перспективных вариантов развития и применения синергетических стратегий в образования XXI-го века видится организация *межкафедральных и межфакультетских структур* как системных единиц высших учебных заведений.

Сеть есть одна из важнейших форм *коллективного интеллекта* [13], тесно связанная с процессами самоорганизации, спонтанного возникновения новых структур при достижении особых состояний узлов (свойство эмергентности). По виду элементов все сети подразделяются на *однородные* и *неоднородные*, а по типу связей – на сети с фиксированными и переменными связями. Сети по своей природе подвижны, адаптивны и многофункциональны. Они образуются, развиваются и преобразуются в зависимости от преследуемых целей.

В современных условиях потребность в построении сетевых межкафедральных структур определяется следующими главными причинами:

- наличие у кафедр общих (совместимых) целей, интересов и ценностей, в частности, межкафедральных дисциплин, определяющих необходимость в частой трансдисциплинарной коммуникации [1] и совместной деятельности;
- увеличение потребности в дополнительных педагогических ресурсах, связанное с широко используемой во многих вузах стратегией *даунсайзинга* (сокращения числа профессоров и преподавателей при постоянном увеличении педагогической нагрузки);
- непрерывное развитие новых образовательных стратегий и технологий, все возрастающая роль стратегий открытого и дополнительного образования, а также технологий электронного обучения.

C. Синергетическая кафедра

Целью совместного российско-белорусского проекта, выполняемого в 2016-2017г.г. по линии РФФИ-БРФФИ, является разработка концепции синергетической кафедры на основе интеграции подходов виртуальных, интеллектуальных, обучающихся, рефлексивных организаций, анализ путей инжиниринга синергетической кафедры, разработка вариантов организационной структуры синергетической кафедры и построение ее многоагентной модели.

Синергетическая кафедра есть новая сетевая образовательная единица, обеспечивающая рост эффективности выполнения основных задач и функций кафедры благодаря кооперативным взаимодействиям между кафедрами-партнерами, разворачивающимися на базе передовых информационно-коммуникационных технологий. и приводящим к синергетическим эффектам (в частности, к усилению достоинств и ослаблению недостатков самих партнеров). Этот термин рассматривается нами как родовое понятие, охватывающее понятия виртуальной кафедры, интеллектуальной и самообучающейся кафедры (см.[Тарасов и др., 2006б]. В самом деле, создание виртуальной кафедры предполагает синергию удаленных друг от друга образовательных ресурсов, создание электронных учебников и виртуальных тренажеров. Дальнейший переход к *интеллектуальной кафедре* означает синергию знаний, разработку корпоративных баз знаний и систем управления знаниями, распространение интеллектуальных обучающих систем и учебных сред для поддержки процессов обучения, объяснения и понимания. На самообучающейся кафедре реализуется синергия индивидуального и коллективного обучения, а также синергия опыта благодаря формированию организационных умений при взаимодействии организационных знаний и организационных навыков, реализации всеобщего обучения и самообучения на индивидуальном, групповом и организационном уровнях.

К числу основных признаков синергетической кафедры (СинК), относятся:

- полиструктурность, сочетание различных сетевых структур;
- способность организационной структуры к автономному функционированию в быстро меняющейся среде благодаря корпоративному опыту, оперативному восприятию изменений и использованию прогностических стратегий («опережающее обучение» в смысле А.Д.Урсула);
- приоритет стратегий интенсивного развития человеческих ресурсов, стимулирование познавательной мотивации и создание в организации условий, благоприятствующих самообучению, групповому обучению и развитию творческого потенциала сотрудников (студентов и преподавателей);
- формирование, накопление, развитие, обобщение и продуктивное использование своего и чужого опыта; наличие специальных средств,обеспечивающих междисциплинарную информационную прозрачность» и циркуляцию знаний между партнерскими кафедрами как внутри факультета или университета, так и на межуниверситетском уровне;
- вхождение в различные организационные объединения и альянсы, умение извлекать из этого практическую выгоду.
- получение обратной связи от заказчиков и поставщиков образовательных услуг);
- проведен процедур «эталонного тестирования» или «сопоставления СинК с образцом» (Benchmarking), т.е. сравнительная оценка образовательных продуктов и услуг, методов и средств обучения по отношению к ведущим образовательным учреждениям; построение на

этой основе «образа будущего состояния» синергетической кафедры»

Остановимся подробнее на архитектурных особенностях СинК. В структурном плане синергетическая кафедра может представлять собой полный или растуший граф, «колесо» или «звезду. В зависимости от характера взаимосвязей между узлами сети и уровня их кооперации и координации выделяются две базовые структуры СинК: *распределенная кафедра* (рисунок 3) и *расширенная кафедра* (рисунок 4).

Распределенная кафедра представляет собой открытую, достаточно однородную сеть учебно-научно-производственных единиц, подразделений, и структур, расположенных в различных местах (и, возможно, даже в различных областях региона), в которой главную роль играет децентрализованное управление, опирающееся на постоянные и интенсивные горизонтальные связи.

Фрактализация подобной кафедры связана с сохранением ее базовой структуры при изменении масштаба. Типовая структура распределенной фрактальной кафедры приведена на рисунке 3.

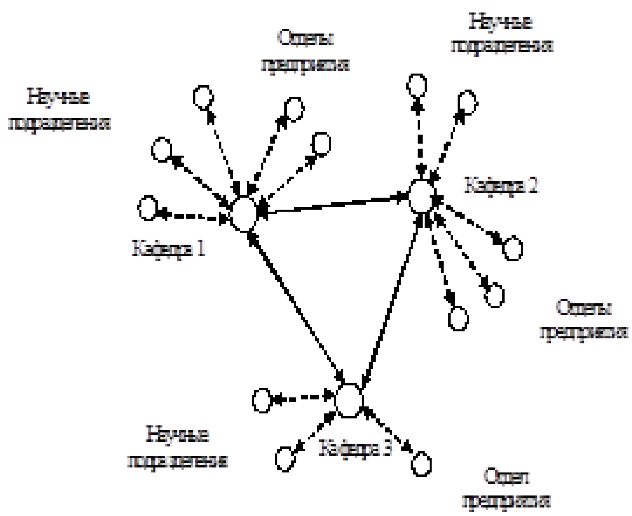

Рис. 3. Пример сетевой структуры синергетической кафедры как распределенной фрактальной кафедры

Напротив, *расширенная кафедра* имеет открытую, неоднородную и переменную сетевую структуру, где в центральном узле сосредоточены важнейшие, стратегические ресурсы и знания, составляющие основу организации и управления обучением, а некоторые учебные процессы или их отдельные компоненты, например, лабораторные работы, выводятся наружу и доверяются периферическим узлам – внешним, например, промышленным или бизнес-партнерам (рисунок 4). В рамках подобной структуры могут быть реализованы стратегии аутсорсинга в сфере образования.

В общем случае, речь идет о создании гибкой эволюционной организации с переменной, настраиваемой на среду сетевой структурой. Такая сеть должна иметь возможность самореорганизации в интересах оперативной адаптации к быстро меняющейся среде.

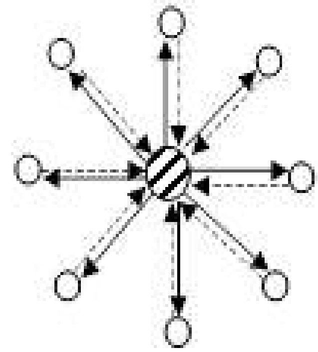

Рис. 4. Пример сетевой структуры синергетической кафедры как расширенной организации: модель взаимодействия центрального узла с периферическими

Наконец, технологической основой создания и функционировании СинК выступает *портал знаний*, предназначенный для создания единого информационного пространства у ее участников [3]. Его практическое использование преподавателями и студентами СинК позволит повысить эффективность их педагогической и учебной деятельности, в первую очередь, благодаря ускорению доступа к требуемой информации и организации более интенсивного информационного взаимодействия. Вопросы динамики изменения образовательного пространства СинК в контексте синергетических идей рассмотрены в статье [11].

IV. Заключение

В статье определено понятие синергетической организации и, в частности, синергетической кафедры, Изложены элементы стратегического инжиниринга СинК. В следующих наших работах предполагается описать архитектуру СинК и провести ее онтологический инжиниринг.

Поддержка

Исследование проводится в рамках совместного проекта РФФИ-БРФФИ №16-57-00208 Бел_а «Разработка интеллектуальных обучающих систем и синергетических учебных организаций на основе открытых семантических технологий, онтологического инжиниринга и моделей понимания».

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SYNERGISTIC ORGANIZATIONS IN THE FIELD OF HIGHER EDUCATION

Tarassov V.B., Golenkov V.V.

The paper is devoted to the problems of educational organizations engineering. First of all, some notions and ideas of enterprise engineering (EE) are considered. A three-leveled scheme for EE is sketched, and basic assumptions for performing strategic engineering of modern higher education organizations are formulated. The main emphasis is made on developing engineering techniques for such organizations on the crossroad of design, self-organization and evolution approaches. So the basic concepts of synergetics and main principles of synergistic methodology are discussed. Both definition of synergistic organizations and its basic characteristics are presented. Then, main activities and tasks of university department are analyzed, the need in transition from classical departments to virtual departments having some features of synergistics organizations is justified. A perspective approach of developing and implementing synergistic strategies in higher

education of XXIst century consists in organizing horizontal inter-departmental structures. Finally, the concept of synergistic department in university is introduced, and its systemic units and structures are envisaged.

Keywords: Artificial Intelligence, Enterprise Engineering, Re-Engineering, Systemic Approach, Synergetics, Knowledge Management, Strategic Engineering, Ontological Engineering, Higher Education, Synergetic Organization, Synergetic Department.

Introduction

The paper faces the problem of applying modern enterprise engineering approaches in the field of higher education. Here enterprise engineering is represented by a three-leveled hierarchical structure: strategic engineering, development of enterprise architecture with the emphasis on horizontal structures, and ontological engineering as a tool for enterprise knowledge management.

University department is taken as a basic engineering object; its strategic engineering phase is considered. At this level the university environment and ways of its changes are of primary concern.

Three assumptions are formulated to deal with higher education organizations: 1) educational organization is an open complex system that operates in a heterogeneous environment; 2) this system as dynamic object is represented by families of processes and structures to be designed for its goal achievement; 3) it is worth applying some engineering approaches to solve the problems of building, developing and transforming both educational organization itself and its systemic units.

A possible variant of forming new synergistic organizations in the field of higher education is suggested. It supposes the integration of virtual organization, intelligent organization, learning organization approaches. In particular, the concept of synergistic university department is introduced; some underlying structures are discussed.

Main part

The synergistic approach to advanced educational organizations engineering is developed. Synergetics focuses on the synthesis, formation, transformation, co-operation, evolution processes that are interpreted as primary aspects of complex systems, whereas appropriate structures and symmetries are viewed as their secondary aspects. Here non-equilibrium and non-linear systems are of special concern, where both external and internal fluctuations under some circumstances can bring about spontaneous morpho-genesis.

The following basic principles of synergistic methodology are discussed:

1) Transdisciplinarity Principle.
2) Principle of Designing Interactions.
3) Holism Principle (Non-Additivity).
4) Bohr Principle of Complementarity (the opposites are not contradictions, they complement each other); 5. Principle of Evolution Diversity (existence of various evolution paths, wave character of evolution). 6. Prigogine Self-Organization Principle(spontaneous order is a process where some form of overall order arises from local interactions in initially disordered system).
5) Correspondence Principle (a modeling language for complex system must correspond to the nature of available information on this system).
6) Principle of joint Consideration of various Uncertainty Factors (the table of Non-Factors in Narinyani's terms).

These principles are used for eliciting synergetic educational organizations and specifying theirs intrinsic characteristics. A short review of virtual departments in the context of educational resources synergy is given. The reasons for introducing horizontal inter-departmental structures are discussed.

The concept of engineering synergetic department in university is proposed, its co-operative nature is explained. Some examples of networked structures for virtual department units are considered. The need in creating the united information knowledge space trough corporate knowledge portal to support synergistic department operation is shown.

Conclusion

The concepts of higher education synergistic organizations and specifically synergistic department were introduced and clarified. Some fundamentals of their strategic engineering were presented. Our next studies will be focused on selecting architectures for synergistic departments and constructing ontological systems for them

Проектирование и реализация программного агента облачной среды электронного книжного магазина для поддержки виртуальной кафедры

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***Аннотация*—Поддержка виртуальной кафедры связана с учетом индивидуальных информационных запросов ее сотрудников, что означает их периодическое обращение к услугам книжного интернет-магазина. В данной работе рассмотрена облачная система книжного интернет-магазина, где для хранения данных используется NoSQL база данных ElasticSearch, которая одновременно является поисковым движком. Представлена общая архитектура электронного магазина с многоагентной подсистемой. Приведена блок-схема алгоритма работы программного агента. Рассмотрены вопросы создания онтологии программного агента, а также работы агента с онтологией и исследования ее параметров.**

Ключевые слова*— искусственный интеллект; интеллектуальная система; виртуальная кафедра; управление знаниями; программный агент; электронный магазин; облачная среда; база знаний; онтология.

I. Ease of Use

Одной из перспективных стратегий развития высшего образования в эпоху передовых инфрмационно-коммуникационных технологий является создание виртуальных кафедр [Голенков и др., 2001], [Емельянов и др.,2000]. Под виртуальной кафедрой понимается сетевая, компьютерно интегрированная организация в сфере высшего образования, объединяющая учебно-педагогические ресурсы, находящиеся в различных местах.

Формирование виртуальной кафедры означает:

- подбор кафедр – партнеров, имеющих общие (совместимые) цели, потребность в опыте и ресурсах друг друга, что определяет необходимые условия формирования виртуальной кафедры и правила вхождения в нее;
- компьютерную интеграцию и использование лучших педагогических, учебно-методических и организационно-технических ресурсов ряда кафедр, а также научных и производственных структур на основе новейших сетевых технологий;
- совместное производство и использование географически распределенных педагогического опыта (знаний) и образовательных технологий, а также их быстрое приумножение
- формирование автономных виртуальных учебных групп с гибким, оперативным распределением и перераспределением функций и ролей партнеров, взаимодействующих на расстоянии.
- реализацию междисциплинарной стратегии обучения, а также стратегии «обучения через работу».

Такая кафедра, объединяющая цели, традиции, ресурсы (в первую очередь, педагогические и технологические) и опыт нескольких кафедр (и даже вузов), будет наиболее конкурентоспособной на рынке образовательных услуг и может обеспечить подготовку специалистов мирового уровня.

Одной из ключевых задач поддержки виртуальной кафедры является управление знаниями [Гаврилова, 2004]. [Кудрявцев, 2010], [Управление знаниями, 2006], в особенности, индивидуализация информационного обеспечения ее сотрудников. Речь идет об организации быстрого и эффективного выполнения информационных запросов пользователей к электронным книжным магазинам. Автором развивается агентно-ориентированный подход [Тарасов,2002], [Курейчик и др., 2004], [Сотников и др., 2014] к реализации взаимодействия пользователя с электронным книжным магазином в облачной среде.

II. Архитектура электронного книжного магазина с многоагентным модулем

Рассмотрим классическую облачную систему книжного интернет-магазина, которая представляет собой набор взаимосвязанных программных механизмов (рисунок 1). Здесь основным бизнес-процессом является поиск необходимой книги, через пользовательский интерфейс системы. Для хранения данных используется NoSQL база данных ElasticSearch, которая одновременно является поисковым движком. Файловая система выступает в роли хранилища файлов. В то же время, в системе имеется многоагентный модуль, позволяющий использовать возможности программных агентов. Хранение агентов в отдельном модуле необходимо для того, чтобы гибкая логика агентов не перемешивалась с жесткой логикой приложения – это гарантирует стабильную работу системы. Программные агенты имеют доступ к некоторым интерфейсам системы для обеспечения выполнения требуемых задач.

В настоящей работе будет детально рассмотрен один коммуникационный агент, занимающийся общением с пользователями на тему поиска научных книг.

На более низком уровне система представляет собой набор виртуальных машин, в которых находятся компоненты системы: JS-приложение для отображения интерфейса; JVM и Java servlet container для rest-сервисов и многоагентного модуля; база данных с возможностями полнотекстового поиска ElasticSearch; средства кэширования в памяти HazelCast (рисунок 2). Такая архитектура позволяет создать отказоустойчивую систему, способную выдерживать высокие нагрузки. Поскольку используется принцип инверсии зависимостей [Мартин, 2010], каждый из компонентов можно при необходимости заменить.

III. Алгоритм работы программного агента

Разработка и реализация программного агента, обрабатывающего человеческий язык, является достаточно известной задачей (см., например, работу [Гаранина и др., 2015]). Программный агент, опираясь на собственную модель знаний, «понимает» вопрос человека, транслирует его в запрос полнотекстового движка и с помощью пользовательского интерфейса выводит результаты на экран.

Для того чтобы искусственный агент понимал конкретный язык человека, необходимо, чтобы знания о языковых конструкциях хранились в его базе знаний. Помимо этого, агент должен «понимать», что человек может задать вопрос, совершенно не относящийся к научным книгам, т.е. в базе знаний следует предусмотреть механизм классификация запросов. Также должны поддерживаться варианты пополнения или расширения базы знаний. Это обусловливает необходимость использования онтологии, как структуры для хранения знаний [Guarino, 1998], [Гаврилова, 2003].

Если запрос подходит под классификацию, то необходимо извлечь контекстную информацию и транслировать ее в запрос поисковой машины, а затем выдать результаты. Вместе с этим, надо дать понять пользователю, что ответ готов, и он может ознакомиться с результатами (ответные фразы тоже занимают важное место в онтологии агента). Блок-схема алгоритма работы коммуникационного агента изображена на рисунке 3.

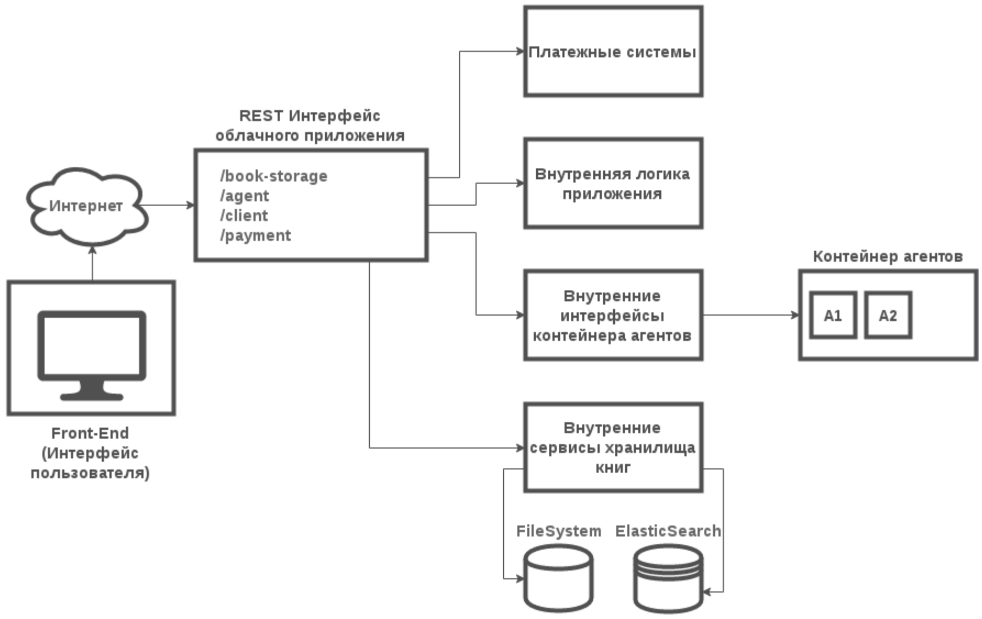

Рисунок 1 – Логическая схема приложения. Уровень программных компонентов

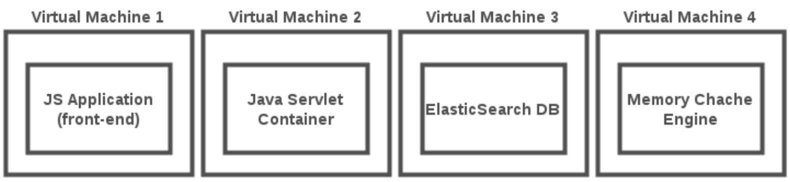

Рисунок 2 – Логическая схема приложения. Уровень инфраструктуры

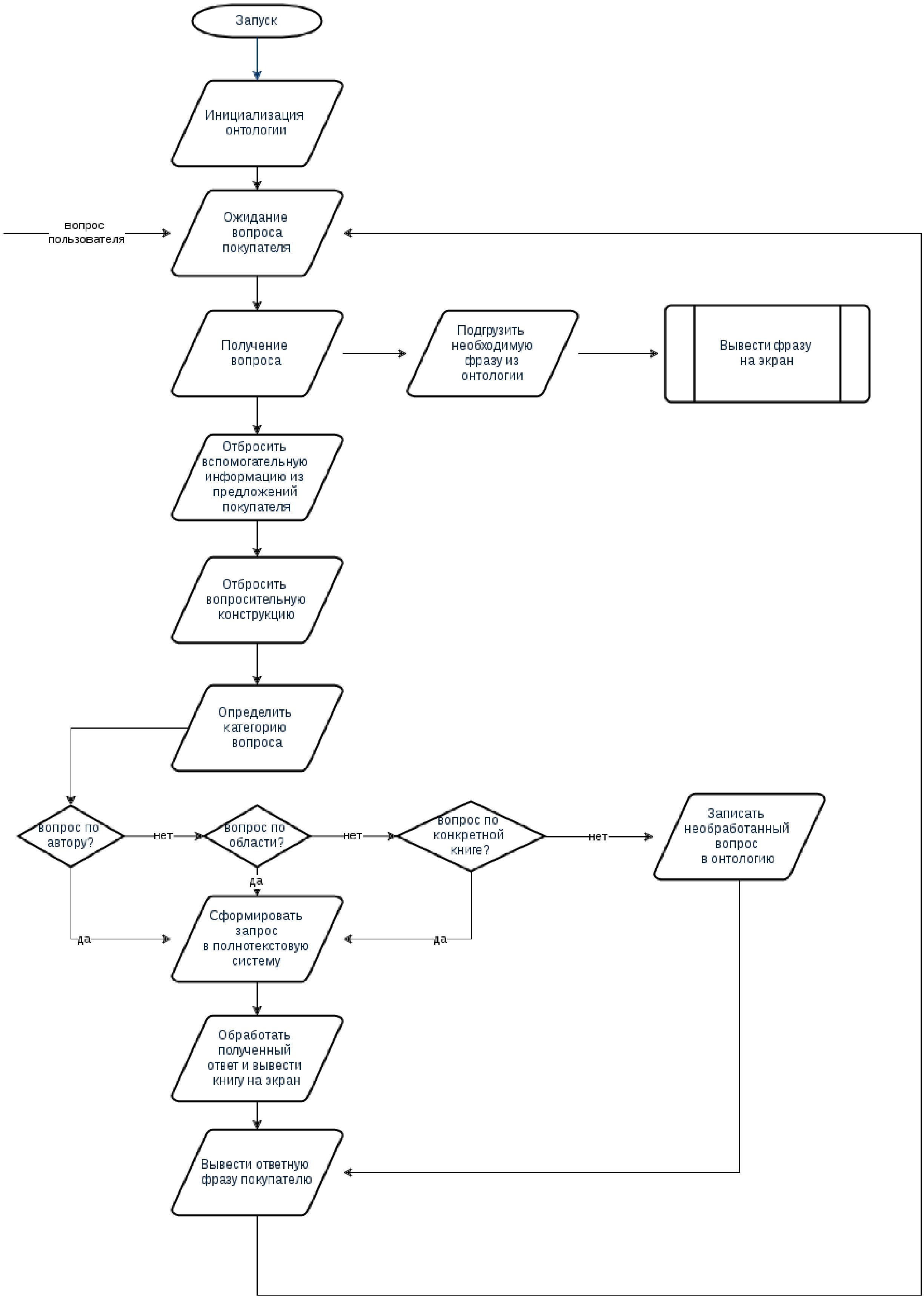

Рисунок 3 – Алгоритм работы коммуникационного агента. Общение с покупателем

IV. Проектирование онтологии программного агента

В спецификациях Международной федерации физических агентов (FIPA Specifications, Part 12. Ontology Service) онтология рассматривается как множество символов вместе с соответствующей интерпретацией, которая должна разделяться сообществом агентов. В ее основе лежит словарь символов, описывающих как объекты предметной области, так и отношения между ними. Интерпретация задает связь между символами в онтологии и объектами предметной области.

Онтология представляет собой граф знаний, в узлах которого находятся понятия, а дуги выражают отношения между ними. Она используется для нечеткой оценки запроса пользователя, а также для трансляции вопроса в полнотекстовый запрос.

В базе знаний агента должны храниться следующие знания:

- знания о языке и конструкциях предложений;
- знания, относящиеся к классификации запросов;
- знания о поисковых машинах;
- знания, связанные с общением, т.е. стандартные фразы ответа пользователю и представления результатов.

Поскольку программный агент имеет систему приобретения знаний, его база знаний будет пополняться со временем. Вопросы, которые агент не смог классифицировать, должны быть обработаны теми, кто обслуживает систему. После этого онтологию агента следует расширить.

V. Трансляция запросов в специальный синтаксис поисковой машины

Часть знаний из онтологии агента, позволяет транслировать запрос о книгах в запрос полнотекстового движка. Покажем это на примере: Исходный вопрос пользователя (за исходный язык был взят английский, поскольку он наиболее просто поддается формализации):

– Hello! Do you have Arkady Borisov "Introduction to Ontology Engineering"?

В онтологии хранятся знания о структуре предложений, в зависимости от языка. Исходя из имеющейся информации, агент может отбросить все, кроме дополнения. Взяв, дополнение, может построить поисковый запрос в таком виде:

```
 "match" : {
   "author" : "Arkady Borisov",
   "type" : "methodical manual"
{
 }
```

По этому запросу можно извлечь все документы из полнотекстовой базы данных. Сравнение названий предоставим полнотекстовой машине, чтобы не нагружать агента лишней работой.

VI. Работа программного агента с онтологией

Онтология в чем-то похожа на графовую базу данных, однако в общем случае представляет собой устойчивую модель знаний (понятий и отношений), заложенную человеком. Онтология O1 и множество человеческих вопросов Q могут быть отображены

во множество запросов QqE полнотекстового движка ElasticSearch. Аналогичную ситуацию имеем для других полнотекстовых движков Solr (онтология O2) или Lucene (онтология O3).

$$f\,(O1, Q) \rightarrow QqE; \quad (1)$$

$$f\,(O2, Q) \rightarrow QqS; \quad (2)$$

$$f\,(O3, Q) \rightarrow QqL; \quad (3)$$

Общая онтология позволит осуществлять работу с любой полнотекстовой машиной, что обеспечивает взаимозаменяемость и независимость компонентов системы.

$$O1 \cup O2 \cup O3 = Oc. \quad (4)$$

VII. Исследование параметров полученной онтологии

Проведем исследование полученной онтологии. Модель знаний агента основана на классификаторе человеческих вопросов, множестве ответных реакций, а также лингвистических знаниях. Граф созданной онтологии приведен ниже на рисунке 4.

Каждая из областей знаний агента делится на различные подмножества, которые в свою очередь могут также рекурсивно дробиться. В процессе совершенствования системы, граф онтологии может быть перестроен под уточненные требования к системе, в него могут быть добавлены новые узлы, а также исключены старые. При обучении агента могут быть выведены новые необходимые понятия. Агент будет самостоятельно или с помощью учителя пополнять существующие знания, в частности, добавлять лингвистические конструкции или ответные фразы.

Числовые параметры онтологии: число классов – 16; число свойств – 20; число индивидов – 6.

С развитием системы параметры могут заметно измениться и через определенное время выйдут на оптимальный уровень. Аналогично, можно создать онтологии с позиции представления знаний о языке и модели разговора. Также возможно создание онтологии с позиции поисковых систем. Ниже на рисунках 5 и 6 приведены модель онтологии с позиции знаний о языках. Небольшое количество экземпляров классов (индивидов) говорит о том, что система находится в стадии запуска.

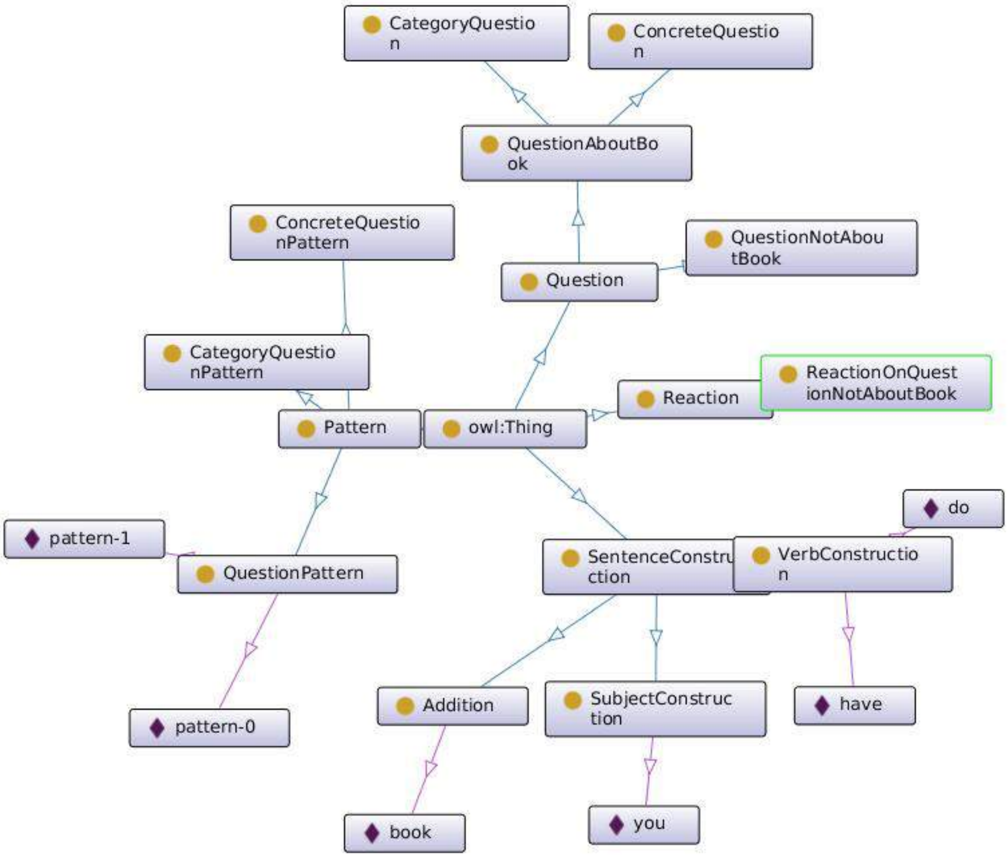

Рисунок 4 – Граф, представляющий модель исходной онтологии

Даже в небольшой рабочей системе количество объектов может составлять десятки или сотни миллионов. Несколько онтологий можно объединить в одну. Для успешной операции соединения идентификаторы IRI (Internationalized Resource Identifier) эквивалентных сущностей должны быть равны. В противном случае могут появиться избыточные одинаковые узлы, которые приведут к неправильной работе системы. В процессе разработки и использования формат онтологии будет совершенствоваться, поскольку крайне трудно оптимально спроектировать систему под все требования с первого раза.

VIII. Заключение

Разработанный нами прототип электронного книжного магазина позволит усовершенствовать существующие средства интернет-торговли при помощи добавления интеллектуальных модулей контейнером агентов. Таким образом, будет обеспечено не только сохранение текущей инфраструктуры системы, но и подключение агентов с их онтологиями к интерфейсам приложения. Данная структура может быть полезной не только для информационной поддержки сотрудников виртуальной кафедры, но и для любой другой системы, в которой осуществляется поиск по каким-либо объектам. При этом пользователь системы не видит разницы между программным агентом и человеком-консультантом, которому будет передано управление, если агент не сможет понять требования пользователя.

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DESIGN AND IMPLEMENTATION OF SOFTWARE AGENT IN CLOUD OF ELECTRONIC BOOK STORE FOR VIRTUAL DEPARTMENT SUPPORT

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The support of virtual universitary department supposes taking into account individual information needs of its collaborators that requires a periodic use of electronic book store. An agent-based cloud system of electronic book store is considered in this paper, where NoSQL database and search engine ElasticSearch is applied. A general architecture of electronic book store with multi-agent subsystem is presented. The algorithm of software agent (infobot) operation is given. In order to understand human quests such an agent has to be equipped with an appropriate ontology. The problems of constructing ontologies for software agents are discussed. Both principles of ontology use by the agent and basic ontology parameters are considered.

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Interpretation of School Geometry Text Using Applied Ontology

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***Abstract*—The paper proposed approach to mathematical text interpretation using applied ontology. An experiment on partially automated creating of ontological conception of geometry texts for school was described (Including axioms, theorems and tasks).**

***Keywords*—geometry; ontology; natural language.**

I. Introducing

The Problem of text interpretation in natural language (NL) using AI methods has a wide range of solutions from machine-generated translation to knowledge extraction using data mining (after natural language text processing). The Approach to a problem of mathematical texts interpretation using applied ontology is analyzed in this paper. The task is to obtain ontological representation of school geometry texts. Such representation must identify couplings between axioms and theorems, and realize ontology-based structure by geometry task NL-text for solver module.

Knowledge extraction from texts and moving from task NL-description to semantic representation have been described in number of papers [1, 2, 3], but above described task is different by its essential novelty. In this paper a full mathematical text translation is supposed to include the final representation in integral system that is able to solve geometric tasks automatically using its natural language description and display obtained solution in graphical representation. The graphic contains also NL- comments about solution steps and its description.

Thus stated task solution combines NLP achievements, ontology-oriented solution and computer-generated graphics, resulting in a fresh look on to the use of ontologies in partitioning NL-texts. In the applied aspect the solution opens prospects of its use to gain qualitatively new education level. The above mentioned information is the basis of the task solving relevance.

II. Overview

A. Ontology

General characterization of ontology arrangement software is given in [7]. The original ontology implemented using DBMS Progress software is used. The ontology is based on semantic web and uses a hypergraph framework to organize knowledge.

B. Subject Area

School geometry was selected as a subject area, but ontology representation illustrates the possibility of using Hilbert's and Tarski's axioms elements [4, 5].

C. Operation Logic

General logic of text interpretation implies linguistic processing of main array of text to create an ontological representation. Later the representation could be edited and checked visually or using solver. This process is described in more details in section III.

III. Experiment

Text for the experiment was taken from middle-school geometry textbook. Text fragments were extracted using Microsoft Word macros. Then these fragments were linguistically processed. As a result, an ontological structure was obtained which created semantic network of axioms, theorems and tasks.

A. Linguistic Processing

Text processing consisted of two steps: 1) revision and correcting; 2) linguistic translation. Within the first step text fragments were selected for the second step, where these fragments were translated to ontology using linguistic features. Especially most important fragments were marked with tags "theorem", "proving" and "the theorem is proved".

Morphologic and syntax steps of linguistic processing are based on knowledge about language and subject area. Semantic analysis is based on paraphrase conception [6], adapted for paper objects in view.

The full automation of Linguistic processing for real textbook is rather complicating. At this point of research the processing was executed in semi-automated mode, while the programming features were used as tools. It assisted the researcher in marking important text fragments and editing the automatically obtained ontological structures.

B. Ontological Representation

A graphic representation of a specialized syntactic structure of one of the first theorems is shown on fig. 1. The vertices' connections generally conform to the NL-interrogatives ("who?", "what?", "where?" and etc.) reflecting the plurality and logic. Russian words on fig. 1 mean: "если" – "if",

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“равны” – “equal”, “то” – “then”, “и” – “and”, “соответственно” – “conforming to” and etc. These words are concepts and relations of ontological representation, so there is no need to translate them all on English.

In terms of the subject area, the ontological structure is similar to the table representation on fig.2 (figure shows only small part of the table). Names, types and relations are self-explanatory, l_part and r_part are the left and the right parts of a theorem (an axiom or a rule). Also like on fig.1 words on fig. 2 are no need in translation on English for the same reason.

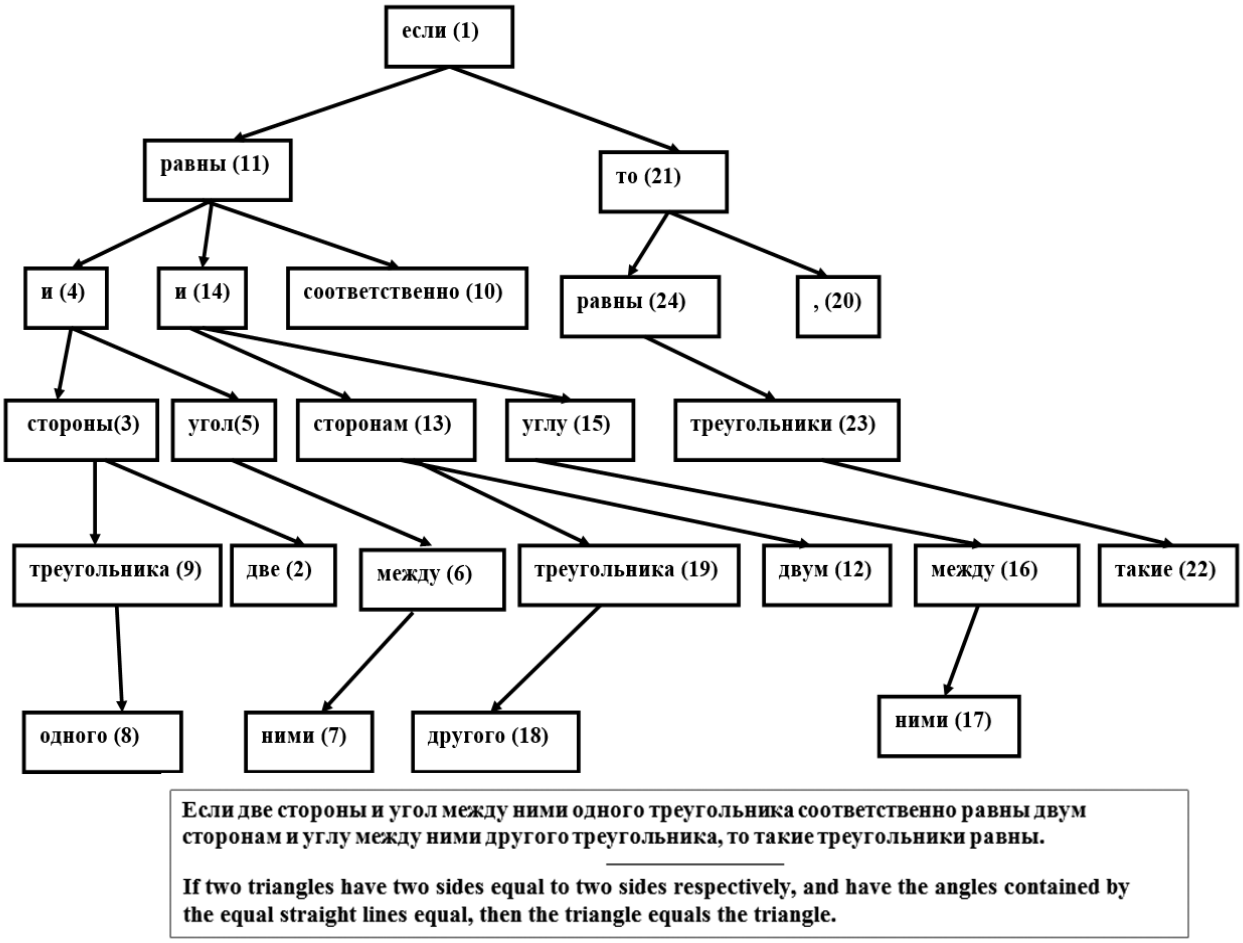

Fig. 1. The theorem text syntactic representation.

Object types and relation names act as links to the according geometry concepts (a point, a straight line, to belong, between, to equal). It allows to use the ontology heuristics, which descriptions contain the according concepts.

C. Examples

The ontological representation shall be shaped as a result of interpretation reflecting connections between of axioms and theorems, as well as the ontological structures reflecting tasks from the text. Examples of number of syntactic and ontological structures obtained in experiment are shown on HTML-page [7].

IV. ENTIRE SYSTEM

Let us briefly run through the general pattern of the system based on the ontological representation descried above.

A. General pattern

General pattern of the system is shown on fig. 3. The system includes linguistic translator, ontology, solver and graphic module. Syntactic structures of theorems similar to that shown on Fig.1 are compared with left sides of paraphrasing rules.

In case of successful comparison in the ontological representation the structures corresponding to the right part are formed. This process includes a lot of detail is not a part of the topic of this work. These details are related to the rule choosing (productiveness and cycling protection), to the anaphoric and elliptic constructions solving and etc.

B. Solver

A solver receives the ontological structure of task and forms a chain of basic operations using knowledge of the subject area. Further this chain is converted to text and sent to the graphics module to be executed.

Редактирование Сервис Выход

Код	Область	№ акс	Тип объекта-1	Имя объекта-1	Отношение	Тип объекта-2	Имя объекта-2	Левая/правая
1		1	точка	T-A	различны	точка	T-B	l-part
2	Геометрия	1	точка	T-A	на	прямая	Pr-1	r-part
3	Геометрия	1	точка	T-B	на	прямая	Pr-1	r-part
4	Геометрия	2	точка	T-A	различны	точка	T-B	l-part
5	Геометрия	2	точка	T-A	на	прямая	Pr-1	l-part
6	Геометрия	2	точка	T-B	на	прямая	Pr-1	l-part
7	Геометрия	2	точка	T-A	на	прямая	Pr-2	l-part
8	Геометрия	2	точка	T-B	на	прямая	Pr-2	l-part
9	Геометрия	2	прямая	Pr-1	совпадают	прямая	Pr-2	r-part
10	Геометрия	3	точка	T-A	различны	точка	T-B	l-part
11	Геометрия	3	точка	T-A	различны	точка	T-C	l-part
12	Геометрия	3	точка	T-C	различны	точка	T-B	l-part
13	Геометрия	3	точка	T-A	на	прямая	Pr-1	l-part
14	Геометрия	3	точка	T-B	на	прямая	Pr-1	l-part
15	Геометрия	3	точка	T-C	вне	прямая	Pr-1	r-part

Fig. 2. Screenshot of table of axioms, theorems and rules.

The ontological structure of solution is an acyclic graph. The theorem structure is also acyclic including direct and inverse theorems (e.g. Pythagoras theorem and its inverse theorem). Theorem organization suggests the possibility of certain restrictions on their use. This is important for solving the tasks in conditions of restrictions on an algorithmic basis.

C. *Interface and graphics*

A graphic module displays the result and comments, describing the actions. In current version graphic is realized using Microsoft Word macros that is determined by the applied aspects. Macros generated drawing allows observing solution steps (forward and backward) and keeping communication with ontology.

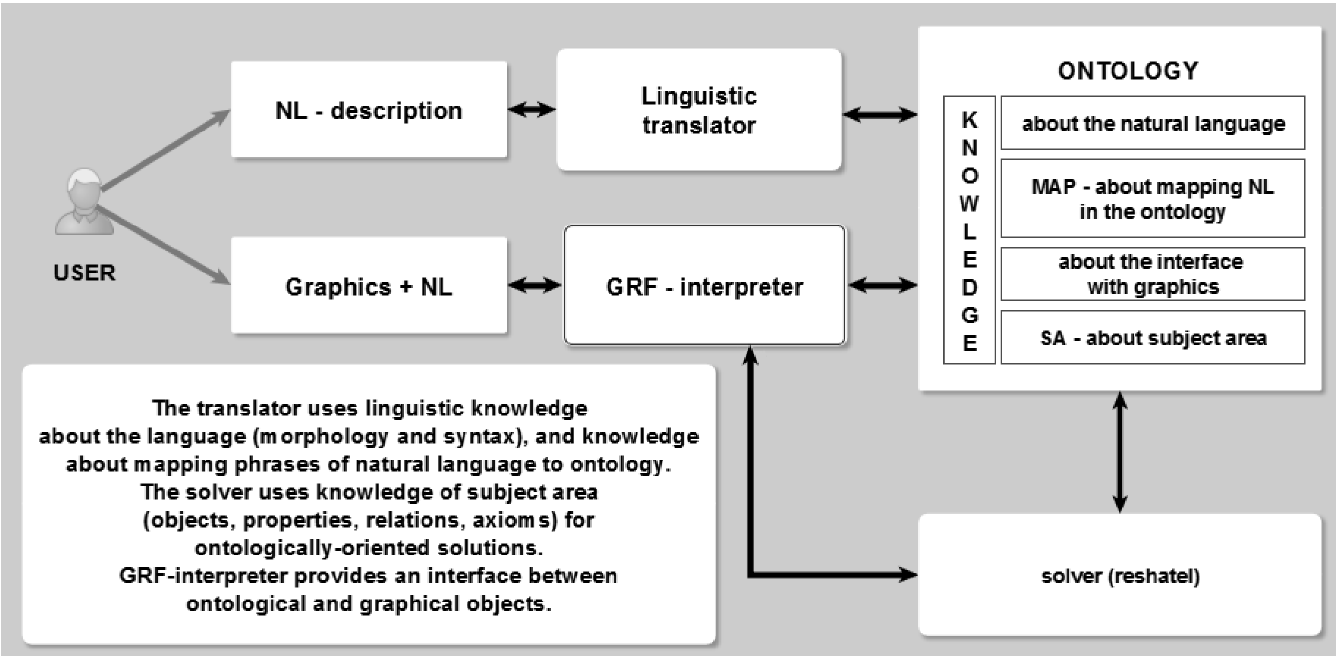

Fig. 3. System general pattern.

Only syntactic structures are contained in left side of paraphrasing rules. In the right side could be contained both syntactic groups and subject area oriented structures. In the latter case so called canonical NL-description of ontological structure is included in left side. This description is most clearly fixed NL-content in subject area terms.

For example phrases “point passes through line”, “point in the line”, “line passes through point” and etc. should be reduced to canonic description “**point contained in line**”.

For chronologically corrected theorem ontology forming was important to have regarded that the basic geometry axioms are listed in the end of the textbook. This is useful for pedagogical purposes, but it makes difficult the formation of the text ontological structure. It is the reason for partially automated representation creating, it means need for researcher intervention into the process.

V. Conclusion

The experiments have generally confirmed the prospects of the proposed approach. Its development intends increasing the level of automation in the ontology formation, improving solver capabilities and testing on a huge set of tasks.

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ИНТЕРПРЕТАЦИЯ ТЕКСТОВ ШКОЛЬНОЙ ГЕОМЕТРИИ С ИСПОЛЬЗОВАНИЕМ ПРИКЛАДНОЙ ОНТОЛОГИИ

Курбатов С.С., Воробьев А.Б.

В работе предложен подход к интерпретации математических текстов с помощью прикладной онтологии. Описан эксперимент по полуавтоматической генерации онтологического представления текстов школьной геометрии. Разработана структура представления в онтологии аксиом, теорем и задач. Представлена схема целостной системы, включающей лингвистическую обработку текста, онтологический решатель и средства визуализации.

Ontology-Based Design of Intelligent Systems for Educational Purposes

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***Abstract*—Application of the ontological approach to the design of intelligent systems for educational purposes is considered in the paper.**

Keywords—information; knowledge; informatization of education; academic discipline.

I. Introduction

The key problem of higher education is a mismatch between the capabilities of the traditional approaches to teaching and the actual volume of knowledge and skills, which a modern school graduate must have.

Further development of education is impossible without improving the methods and means of informatization. As before, there are problems of a reasoned attitude towards learning, the formation of self-learning skills, coordination of educational materials. One of the solutions of these problems is the use of methods and means of artificial intelligence for the development of computer systems for educational purposes. Intellectualization of computer systems for educational purposes is carried out in the following areas:

- logical-semantic structuring of the educational material with an explicit semantic interdisciplinary connections and links between modules disciplines within each subject;
- development of computer systems for educational purposes, which know good enough and can do everything what they were taught, ie, which can answer all questions and solve all the problems on the relevant training materials;
- not only significant expansion of consulting capabilities of computer systems for educational purposes according to training material, and also possibility (1) to request the analysis of the correctness and completeness of the proposed student response to specified question, (2) to request the analysis of correctness and elegance of the specified task solution, proposed by student, (3) to request justification of correctness of this fragment of educational material specified by student, (4) to request the similarities and differences specified objects or fragments of educational material, (5) to request analogs or antipodes of the object, or a fragment of material (6) to request information about the logical-semantic structure of educational material;
- adaptive management of individual activities of the student based on continuously refines formal model of the student it takes the form of recommendations addressed to the student, indicating either a fragment of educational material that is useful to study (perhaps repeatedly), or a question that it is expedient to respond and report the response to system or problem, that it is advisable to solve and to report the response to system;
- constant refinement of the formal student model to improve the efficiency of the adaptive control of his training. This update is based on (1) the analysis of control the student - analysis ignored recommendations of the system, (2) the analysis of the student's answers to the questions, which are recommended to him by the system or chosen by his initiative, (3) the analysis of problem-solving options that are recommended to the user system, or selected on their own initiative;
- Automatization of project management, which are carried out by teams of students and aimed at development of skills of *collective* problem solving within the relevant subject or group of subjects or specialty in general.

Ontological approach to the design of intelligent systems for educational purposes, proposed in this paper, is based on the following principles:

- Training material, studied by using educational purpose intelligent system, is formalized as a section of knowledge base of the system. Logical-semantic structuring of the formal educational material presented in a hierarchical system of *subject domains* corresponding to *ontologies*. It can be one subject domain with a corresponding ontology for the *module of the subject*. But for *academic subject*, for the *group of academic subjects* and even more so for the *speciality* in general is always a system consisting of a sufficiently of a great number of subject domains and ontologies. It is very important to clearly specify the connections between these domains and ontologies in this hierarchy of subject domain and ontologies, in particular, *interdisciplinary connections*, which allow the student to form a *complete picture of the world* in which everything is interconnected. During structuring of *formal educational material* is very important to decompose it into *subject domains* and *ontologies* to not go beyond the borders of each subject domain and its corresponding ontology for possibility to solve a lot of problems.

- The internal representation of the knowledge base of intelligent system for educational purposes is carried out in the language of *SC-code*, which is the universal language of semantic knowledge representation, the base semantics of which is defined by *Ontology of entities*, which is a top-level ontology. This SC-code provides representation of any *ontologies*, any *subject domains* and connections between them. The concepts, which provide such representation, are given by (specified by) using *Ontology of ontologies* and *Ontology of subject domains*.
- Beside *subject domains* and *ontologies*, providing formalization of educational material in the knowledge base of intelligent systems for educational purpose include a variety of other subject domains, and ontologies, for example, (1) *Subject domain* and *ontology of student*, within *formal models of student* forms, (2) *General subject domain* and *ontology of actions and tasks for user training*, which is a formal model of the general methods of adaptive learning management, (3) family of particular subject domains and ontologies of actions and tasks to teach the user knowledge and skills of solving problems within relevant subject domains and ontologies, which are formal models of particular methods of adaptive learning management within relevant subject domains and ontologies.
- Unification of all the ontologies that can be used in intelligent systems for educational purposes (first of all - it is *Ontology of subject domains* and *Ontology of ontologies*). It provides (1) compatibility of knowledge bases of intelligent systems for educational purposes, in particular, the compatibility of formal ontological models of studying materials of different subjects and (2) component (modular) design of knowledge bases, because specified ontologies become reusable components of knowledge bases.

II. Classification of Intelligent Systems for Educational Purposes

Let's classify intelligent systems for educational purposes on the following grounds. Firstly, the volume of acquired knowledge and skills of a student, secondly, by the form of training. According to the first aspect of intelligent systems for educational purpose can be:

- module of subject;
- academic subject;
- a group of academic subjects;
- all academic subjects in the specialty.

It requires the greatest possible independence of each level of these systems for the hierarchy of intelligent systems for educational purposes to be effective. To do this, you should develop an ontology corresponding to the training material, which primarily depends on the teacher, his knowledge and interest in the final result.

According to the second aspect four levels of learning activities can be distinguished:

- individual self-study;
- management of individual training;
- management of collective learning;
- management of the training activities of the organization.

III. Semantic Electronic Textbooks

Semantic electronic textbook (SET) is an interactive intelligent tutorial that contains detailed guidelines for educational material for it's studies and intended for motivated, independent and active user who wants to master the relevant knowledge and skills.

Semantic electronic textbook - an electronic textbook which is based on a semantically structured educational and methodological materials. Through semantic structuring of educational and methodological materials SET gains entirely new possibilities compared to traditional electronic textbooks [3], [4].

Semantic electronic textbook can:

- Understand the wording of the addressed problems to it, to look for ways to solve them, and solve problems;
- Analyze freely constructed response and semantics of user errors;
- Identify semantic errors in own information resources (for example, correctness of definitions and statements, correctness of the concepts, correctness of proofs of theorems);
- To provide users with the freedom to use any aliases registered in the system.

Semantic electronic textbook provides automationzation of all forms of studies: lectures, tutorials, practical classes, laboratory work, tests and examinations.

Semantic electronic textbook in general consists of the following components:

- Formal model of semantically structured information resources;
- Formal model of processing of semantically structured information resources and its implementation;
- Semantic model of user interface;
- Semantic knowledge base;
- Consultant (semantic navigation and intelligent problem solver);

- Tutor (tutor for specific tasks and virtual learning laboratory - tutor for laboratory work).

Besides possibility to read texts and illustrative materials of textbook there is opportunity to navigate in the semantic space of educational material.

There is an opportunity for user to ask any questions and the task of the study subject domain. This is achieved by the inclusion problems solver to SET, ability to solve problems by formulations, including which are entered by the user. In this case the specified problems solver can find a way of solving the problem, even if the appropriate way (eg, algorithm) it is unknown.

There is an opportunity for user to train under the supervision of the system (to acquire practical skills) in dealing with a wide variety of tasks in the studied subject domain. The system performs a semantic analysis of the correctness of the solution of problems both in easy constructible results and solutions protocols; locates user's errors in solving problems, determine their reason and issues appropriate recommendations to the user.

IV. Intelligent Training Systems

Due to the increasing complexity and the information richness of learning software it is necessary to implement management of the process of learning and interaction with user. Since the training system becomes more complex, feature-rich and designed for different categories of users, it's necessary to adapt to the individual needs of each user. The ability of the training system to adapt to the user is an indicator of its performance and, as a result, of intelligence.

Intelligent training systems (ITS) [3], [6], [7] is a complex hierarchical system consisting of a plurality of interacting subsystems, each of which solves a specific class of problems. As a basic component of the intelligent tutoring systems using semantic electronic textbook. The main functions of intelligent tutoring systems are:

- Monitor the activities of students and the constant refinement of the knowledge base about students (students analysis subsystem of actions);
- Selection of the recommended sequence of study teaching material (learning management subsystem);
- Selection of the recommended sequence specified by the student questions, problems and laboratory tasks (learning management subsystem);
- Testing of knowledge of students (subsystem of knowledge testing);
- Tracking interruptions in the learning process of each student and ensuring the possibility of a return to the interrupted state (subsystem trainee action analysis, learning management subsystem);
- Managing the transition between modes of learning (learning management subsystem).

Feature of the implementation of the learning process in ITS is that beside representation and processing of knowledge of subject domain system should contain information about their users, to be able to handle it, and thus adapt to the individual needs of each user. In addition, one of the most important issues in the design of the training system is to control the feedback (usually untrained in the field of computer technology). Interaction with the user, unlike the interaction of the subsystems in the computer system is a more complex process, since it is present in an element of unpredictability. The user exerts its influence on the work of ITS, i.e functioning of the system in terms of interaction with them becomes manageable both system and user. In this regard, there is a problem processing the external user actions, as well as the description and implementation of the system of control mechanisms in general. Systems of this class are classified as complicated and their design requires appropriate technology and design techniques. Instrumental ITS design tools are discussed in [3], [4].

To adapt to the individual characteristics of user intelligent system can accumulate knowledge about hi or she, that reflects how the system imagine user. Description is situational structure containing information about how the system imagine user (may take into account the likelihood that the system may be wrong).

For the structuring and systematizing description the user enters *Subject domain of users of ostis-systems*. The maximum class of objects related to the field of research is enters *Subject domain of users of ostis-systems* is the concept of *user of ostis-system*. Set of *user of ostis-system* includes *signs* of all those interacting with *ostis-system* with a purpose and solve certain problems. In terms of knowledge processing *user ostis-system* acts as an external agent, which forms message by performing basic actions provided by user interface in *sc-memory*.

Variety of *users of ostis-system* is divided into a set of *non-registered users of ostis-system* and a set of *registered users of ostis-system*.

Executable specification of currently executed actions and interaction history stores in *sc-memory* for each *user of ostis-system*. Links of relation *current activities** connect sc-node, denoting the user, and a set of specifications of these actions. For *registered users of ostis-system* after the completion of the steps by past entities and their specifications are transferred to the *history of interaction**. Sequence of actions a result, execution time and execution time, etc. can be included into specification Within the domain user specification includes:

- *description of the state of user of ostis-system characteristics*;
- *the role within the system*;
- *relationships with other users*.

Description of state characteristics can be displayed based on the *history of interaction** or included in knowledge base explicit. In the first case sc-agents make a logical inference, based on which the assumption of the system about description of the different characteristics of the user build. In the second case, the *user's knowledge**, *user's interests**, a *description of previous experience** include into knowledge base.

Links of relation *user's knowledge** connect *sc-node* denoting the user, sign of *subject domain*, and sign of a generalized *structure*, which is a subset of the *sc-elements* (concepts) *of* *subject domain* and reflects the state of knowledge of the user within a given *subject domain*. The level of assimilation of the concepts defined by role relations: *formed image of the concept'*, *concept was understood'*, *concept was assimilated'*.

Links of relation *user's interests** connect *sc-node* indicating the user, sign of *subject domain*, and a sign of the set of *sc-elements*, which are a subset of the objects of *subject domain* and representing interests within the *subject domain*.

As part of the subject domain the classes of users specifications are selected, reflecting:

- *characteristics of the target state of user of ostis-system*,
- *the current state of the characteristics of user of ostis-system*.

Performed roles within the system determines the set of feasible objectives and types of actions performed. Roles are defined by binary oriented relations: *developer of ostis-system** and *end user of ostis-system**. Among *developers of ostis-system** is distinguished *administrator**, *manager**, *expert**. Among the *end users of ostis-system** sub roles selection depends on the type of ostis-system. For example, intelligent tutoring systems are distinguished *expert**, *teacher**, *student**.

V. Complex of Intelligent Systems for Automation of Training of Engineers

The most important contingent of university graduates are engineers of various profiles. Training of Engineers has its own specifics. The basic method of preparation of young professionals is to create conditions that allow (1) to accumulate real design experience in the development of technical systems of the relevant class and (2) to link closely knowledge and skills acquired in the study of all subjects with the specified project activities. At the same time the young specialist will acquire high level of mathematical, system, technology, and corporate-team culture. In addition, he must learn not only how to develop technical systems of the relevant class, but also how to improve the technology of development of such systems.

The high technology development of intelligent systems has special *requirements* for young professionals in the field of intelligent systems engineering. Effective training of such specialists is only possible based on the *project method* of training. Comprehensive support for the project method of teaching of engineers of intelligent systems are supposed to implement in the form of built-in intelligence system that (1) is built on the same technology, on which intelligent systems designed; (2) directly included in the designed intelligent system (a subsystem). Built-in intelligent system of design method of teaching intelligent systems engineers is an intelligent system of management of intelligent system design with additional function of management of qualification development of intelligent systems developers.

As an example, consider organization of the preparation of intelligent systems engineering at the Department of Intelligent Information Technologies of Belarusian State University of Informatics and Radioelectronics. The range of intelligent systems, providing training automatization includes:

- semantic electronic textbooks and smart learning systems for all academic subjects of the specialty «Artificial Intelligence»;
- integrated semantic electronic textbooks and an integrated intelligent tutoring system in «Artificial Intelligence»;
- Intelligent metasystem IMS (Intelligent MetaSystem), which is ostis-system of a design automatization of ostis-systems and contains all the information about the current state OSTIS technology, provides comprehensive information service development;
- Intelligent system of support tool for design ostis-systems and control their design, built-in developed ostis-systems;
- ostis-systems, developed by a team consisted of students of different courses, master students and post-graduate students;
- Corporate intelligence system of the department, which provides automation and management for the different activities of department staff. First of all, an organization of continuous improvement of the whole complex of intelligent systems to provide automation of activities of the department;
- intellectual support system of preparation and holding of OSTIS conference as one of the most important activities of the department.

There are a variety of educational management techniques in intelligent tutoring systems. In general, training management methods can be divided into two classes: methods without forming a strategy and training methods with the formation of learning strategies.

In the first case of the training activity is controlled by user commands. In this case, subject of the training management is the user. The system can implicitly interfere in this process, giving certain recommendations.

In a second case, form of learning strategies as a plan of implementation of educational activities. Strategy of training can be divided into stationary training strategy, formed on a predetermined path, and non- stationary learning strategies. Depending on the method used and the situation on the control object to the plan of educational activity can get those or other actions.

Consider the formal typology of classes of actions aimed at solving the problem of educational management.

educational action
*<= decomposition**
{
- *action. select properties of learning activities required to achieve the goal*
- *action. process the situation*
- *action. form a plan of training activities*
- *action. select methods for checking relevance with the plan (select the relevance criteria)*
- *action. select methods of correlating product activities and the goal*

}

act. process the situation
*<= decomposition**
{
- *action. Compare the current and target situation*
- *action. find context of the situation*
- *action. structurize description of situations*
- *action. classify the situation (to summarize the situation)*
- *action. transform the situation*
- *action. develop a hypothesis about the relationships in situations*

}

The result of the action of this class is a more detailed of the proposed executed *action. learn course material*, i.e, implementation plan forms. Formation of the plan depends on the context of the conditions under which the activity should be carried out.

VI. Conclusion

Development of a multi-level educational management model allows phased design of relevant intelligent system of management and reuse of its components.

Design of this model is based on the proposed system of subject domains and allows ontologies allows different approaches to the design of learning management systems.

Ontological design makes it possible to implement the agreement between the subject domains of each individual subject, and thus allows to build a system of interdisciplinary connections and provides the integrity of the knowledge of the speciality.

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ОНТОЛОГИЧЕСКОЕ ПРОЕКТИРОВАНИЕ ИНТЕЛЛЕКТУАЛЬНЫХ СИСТЕМ УЧЕБНОГО НАЗНАЧЕНИЯ

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Ключевой проблемой высшего образования является несоответствие между возможностями традиционных подходов к обучению и тем объёмом фактических знаний и навыков, которыми должен обладать современный выпускник учебного заведения.

Дальнейшее развитие образования невозможно без совершенствования методов и средств его информатизации. Как и раньше существуют проблемы развития мотивированного отношения к обучению, формирования навыков самообучения, согласования учебных материалов. Одним из направлений решения этих проблем является применение методов и средств искусственного интеллекта для разработки компьютерных систем учебного назначения. Интеллектуализация компьютерных систем учебного назначения осуществляется в следующих направлениях:

- логико-семантическая структуризация учебного материала с явным указанием семантических междисциплинарных связей, а также связей между модулями учебных дисциплин в рамках каждой дисциплины;

- разработка таких компьютерных систем учебного назначения, которые достаточно глубоко знают и умеют все то, чему они учат, т.е. которые могут ответить на все вопросы и решить все задачи по соответствующему учебному материалу;
- не только существенное расширение консультационных возможностей компьютерных систем учебного назначения в соответствии с учебным материалом, но и возможность (1) запрашивать анализ корректности и полноты предложенного обучаемым ответа на конкретный указываемый вопрос, (2) запрашивать анализ корректности и элегантности предложенного обучаемыми варианта решения указываемой задачи, (3) запрашивать обоснование корректности указанного обучаемым фрагмента учебного материала, (4) запрашивать сходство и отличия указываемых объектов или фрагментов учебного материала, (5) запрашивать аналоги или противоположности указываемого объекта или фрагмента материала, (6) запрашивать информацию о логико-семантической структуре учебного материала;
- адаптивное управление индивидуальной деятельностью обучаемого на основе постоянно уточняемой формальной модели обучаемого, осуществляемое в форме адресованных обучаемому рекомендаций, указывающих либо фрагмент учебного материала, который целесообразно изучить (возможно повторно), либо вопрос, на который целесообразно ответить и сообщить ответ системе, либо задачу, которую целесообразно решить и сообщить вариант ответа системе;
- постоянное уточнение формальной модели обучаемого для повышения эффективности адаптивного управления его обучение. Такое уточнение осуществляется на основе (1) анализа управляемости обучаемого – анализа игнорируемых рекомендаций системы, (2) анализа ответов обучаемого на вопросы, которые рекомендованы ему системой, либо выбраны по его инициативе, (3) анализа вариантов решения задач, которые рекомендованы пользователю системой, либо выбраны по собственной инициативе;
- автоматизация управления проектами, которые выполняются коллективами обучаемых и которые направлены на формирование навыков коллективного решения задач в рамках соответствующей учебной дисциплины, или группы учебных дисциплин или специальности в целом.

Предлагаемый в данной работе онтологический подход к проектированию интеллектуальных систем учебного назначения основан на следующих принципах:

- Учебный материал, изучаемый с помощью интеллектуальной системы учебного назначения, представляется в формализованном виде в качестве раздела базы знаний этой системы. Логико-семантическая структуризация формализованного учебного материала представляется в виде иерархической системы предметных областей соответствующих им онтологий. Для модуля учебной дисциплины это может быть одна предметная область и соответствующая ей онтология. Но для учебной дисциплины, для группы учебных дисциплин и тем более для всей специальности в целом это всегда система, состоящая из достаточно большого количества предметных областей и онтологий.
- Внутреннее представление базы знаний интеллектуальной системы учебного назначения осуществляется на языке SC-код, который является универсальным языком смыслового представления знаний, базовая семантика которого задается Онтологией сущностей, являющейся онтологией самого верхнего уровня. При этом SC-код обеспечивает представление любых онтологий, любых предметных областей и связей между ними.
- Кроме предметных областей и онтологий, обеспечивающих формализацию учебного материала, в базе знаний интеллектуальных систем учебного назначения входит целый ряд других предметных областей и онтологий.
- Унификация всех онтологий, которые могут быть использованы в нескольких интеллектуальных системах учебного назначения (прежде всего – это Онтология предметных областей и Онтология онтологий). Это обеспечивает (1) совместимость баз знаний интеллектуальных систем учебного назначения, в частности, совместимость формальных онтологических моделей учебных материалов различных дисциплин и (2) компонентный характер (модульность) проектирования баз знаний, поскольку указанные обще употребляемые онтологии становятся многократно используемыми компонентами баз знаний.

Ontology-Based Design of Intelligent Systems in the Field of History

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Abstract — **The article considers the usage of ontological approach to design of intelligent systems in the field of history.**

Keywords -- subject area, ontology-based design, history, artefact

I. Introduction

A. Purpose and Relevance

The work is devoted to the ontology-based approach to constructing intelligent systems in the field of history, the specific nature of this kind of systems and the features of their design.

The need to formalize, systemize and process knowledge is equally critical in historical studies as in any other science. At the same time, humanities are the field where formalizing knowledge is somewhat difficult, reasoning is less transparent, and knowledge is based not on concepts, but on ideas, which, in their turn, require clarification and specification [1].

The relevance of the intelligent systems' design in the field of history is related to the growing interest of the society and the academic community to retrospective methods that are making history a tool for research, as well as to history as a way to preserve and transmit culture in its broadest sense.

B. The issues to be addressed in order to achieve the goal

- compatibility of historical systems of various purposes needs to be ensured for the most complete and effective representation and usage of historical knowledge;
- in order to ensure wide dissemination and use of intelligent systems in the field of history we need to move beyond narrow specializations and to develop multifunctional and multi-purpose systems.
- the large volume of dynamically changing knowledge requires such a technology for designing the systems of similar purpose that would allow to create flexible, easily modifiable and reconfigurable intellectual systems;
- since formalization of historical knowledge needs contribution from experts in specific areas of historical knowledge, there is a need to support such teamwork in development of knowledge bases that eventually turns experts into knowledge engineers.

C. Proposed Approach

The proposed approach to building intelligent systems in the field of history is based on the following provisions:

- OSTIS Technology is set as a basis for building intelligent systems which ensures compatibility of design solutions. OSTIS is a technology for component-based design of intelligent systems, which allows to develop intelligent systems quickly and efficiently [2]
- the ontology-based approach to design of intelligent systems that can solve the problem of compatibility of various intelligent systems and their components ensures flexibility of the systems under development and enables teamwork in their design.

II. The system of ontologies as the basis for building intelligent systems in the field of history.

The hierarchical system of subject domains and their corresponding ontologies permits to specify all concepts used within a particular paradigm, allocating them to subject domains and specifying them within relevant ontologies.

The following types of ontologies can be identified:

- *structural ontology*
- *set-theoretical ontology*
- *terminological ontology*
- *logical ontology*

Each ontology is a model (specification) of a certain subject domain, or, more specifically, it is a specification of a paradigm of concepts that are used in a subject domain [3].

Explicit definition of ontologies in knowledge bases of intelligent systems is necessary in order to:

- record the current coordinated version of interpretation (clarification) of all concepts used;
- ensure the efficient and continuous process of development and harmonization of concepts used [4].

A number of subject domains common for all historical systems can be distinguished within historical knowledge [5]. Such subject domains can include:

- *Subject domain of artefacts* describing all historically significant artificial man-made material entities, produced as a result of purposeful action.
- *Subject domain of individuals and social communities*, which researches humans and all communities of people emerged as a result of human activity.
- *Subject domain of historical actions, events and situations.*

- *Subject domain of ideas,* describing all the ideas arising as a result of purposeful activity.

Subject domain of artefacts is partial in relation to the *Subject domain of temporary entities*, specification of which is presented in IMS Metasystem [6]. Let us take a look at the main classes of the research concepts in the *Subject domain of artefacts* [7].

documentary artefact
= material information carriers in the form of texts, graphic images, audio, video, and images, with historical and cultural value.
*<= partitioning**:
- *written document*
  *<= partitioning**:
  - *handwritten document*
  - *printed document*
    *<= partitioning**:
    - *cartographic document*
    - *official document*
    - *narrative document*
      *<= partitioning**:
      - *personal document*
      - *fiction document*
      - *historical document*
      - *scientific document*
- *film- and photo- document*
- *phonodocument*

construction
= immobile man-made artefcat with historical and cultural importance
<= partitioning *:
- *building*
  *<= partitioning**:
  - *residential building*
  - *public building*
    <= partitioning *:
    - *civic building*
    - *administrative building*
    - *religious building*
  - *production building*
    <= partitioning *:
    - *industrial building*
    - *agricultural building*
- *structure*
  *<= partitioning**:
  - *hydraulic structure*
  - *utility network*
  - *fortification structure*

*=> inclusion**:
- *construction complex*
- *architectural complex*

household item
= article of daily use
= household product
*<= partitioning**:
- *tableware*
- *clothing*
- *furniture*
- *weapons*
- *jewelry*
- *tools of trade*
- *means of transportation*

visual art item
= artifact created as a result of creative actions of humans
*<= partitioning**:
- *painting item*
- *sculpture*
- *decorative-applied item*

The following subject domains are partial for the *subject domain of artifacts*:
- *Subject domain of archaeological artifacts*
- *Subject domain of ethnographic artifacts*

Let us consider the main classes of research objects for the *Subject domain of individuals and social communities* [8], [9].

person
= individual

social community
= group of people with similar functions, goals, social statuses, social roles, and cultural requirments.
<= partitioning:*
- *ethnic community*
  *<= partitioning**:
  - *race*
  - *tribe*
  - *ethnos*
  - *nationality*
  - *nation*
- *socio-territorial community*
  *<= partitioning**:
  - *city*
  - *village*
  - *quarter*
  - *region*
- *social stratum*
  *<= partitioning**:
  - *caste*
  - *estate*
  - *etacratic group*
  - *socio-professional stratum*
  - *class*
- *primary group*
  *<= partitioning**:
  - *family*
  - *friend*

- *classmate*
- *colleague*
- *social organization*
  <= *partitioning* *:
  - *formal organization*
  - *informal organization*
  <= *partitioning* *:
  - *labor organization*
    <= *partitioning*:*
    - *manufacturing organization*
    - *scientific organization*
    - *educational organization*
    - *medical organization*
    - *cultural and educational organization*
    - *administrative organization*
    <= *partitioning*:*
    - *governmental organization*
    - *cooperative organization*
    - *joint stock organization*
    - *organization owned by labor collective*
    - *private organization*
    - *joint organization with foreign capital*
    - *foreign organization*
  - *public organization*
    <= *partitioning*:*
    - *environmental organization*
    - *sports organization*
    - *political organization*
    - *leisure organization*
    - *charitable organization*
    - *cultural organization*
    - *religious organization*

=> *inclusion*:*
- *crowd*
- *quasigroup*
- *audience*

Subject domain of historically important actions, events, and situations is a partial subject domain to the *Subject domain of actions.* Let's take a look at some of the classes of research objects:

historically significant action
=> *inclusion*:*
- *goal-oriented rational action*
- *action of value*
- *affective action*
- *traditional action*

=> *inclusion*:*
- *labor action*
- *intellectual action*
- *religious action*
- *creative action*
- *communication*
- *play*

Let us consider *structural ontology* on the example of the *Subject domain of constructions.*

Subject domain of constructions
=> *ontology**
Structural ontology of the Subject domain of constructions
= [*
Subject domain of constructions
<= *partial subject domain**:
Subject domain of historical artifacts
=> *partial subject domain**:
- *Subject domain of buildings*
- *Subject domain of structures*

∋ *maximal class of research objects'*:
construction
∋ *nonmaximal class of research objects'* :
- *building*
- *structure*
- *construction complex*
- *architectural complex*
- *ruin*
- *authentic construction*
- *restored construction*
- *lost construction*

∋ *concept researched in other subject domain':*
- *architectural style*
- *construction element*

∋ *researched relation'*:
- *architect**
- *material of structure**
- *owner**

*]

Let us consider the *set-theoretical ontology* of the *Subject domain of constructions*.

Subject domain of constructions
=> *ontology**:
Set-theoretical ontology of the Subject domain of constructions
=[*
construction
∈ *historical artifact*
<= *partitioning**:
- *building*
  <= *partitioning**:
  - *residential building*
  - *public building*
    <= *partitioning**:
    - *civic building*
    - *administrative building*
    - *religious building*
  - *production building*
    <= *partitioning**:

• *industrial building*
• *agricultural building*
• *structure*
<= *partitioning**:
• *hydraulic structure*
• *utility network*
• *fortification structure*
=> *inclusion**:
• *construction complex*
• *architectural complex*

material of construction*
∈ *binary relation*
=> *definitional domain*:*
construction ∪ construction material
=> *first domain* *:
construction
=> *second domain* *:
construction material

architect*
∈ *binary relation*
=> *definitional domain**:
construction ∪ individual
=> *first domain**:
construction
=> *second domain**:
individual

location*:
∈ *binary relation*
=> *definitional domain**:
construction ∪ geographic coordinates
=> *first domain* *:
construction
=> *second domain* *:
geographic coordinates
***]**

Each *logical ontology* contains the entire set of axioms, definitions, and statements over the concepts of a subject domain, helping to build a logical ontology-based set of logical reasoning about this subject domain. Let us take a look at a fragment of *logical ontology* of the *Subject domain of family relationship*. This subject domain is a *partial subject domain* of the *Subject domain of individuals and social communities.*

The subject domain of family relationship
=> *ontology*:*
Logical ontology of the subject domain of family relationship
=[*
parent*
=>*explanation**:
[A ***parent**** is a *binary relation* that connects two *persons*, one of whom is a parent of another one]
∈ *Russian language*

mother*
=>*explanation**:
[A ***mother**** is a *binary relation* that occurs at the place of a *parent**, if the second domain is an *person* that belongs to a class of *woman*.]
∈ *Russian language*
∈ *key sc-element':*
...
∈*statement*
=> *sc-text translation**:
[Every *person* can have only one *person*, which is *mother** for that *person*]
∈ *Russian language*

sibling*
=>*explanation**:
[A ***sibling**** is a *binary relation* that connects two persons whose both *parents** are identical]
∈ *Russian language*
<= *used constants*:*
{
• *parent**
• *person*
}

female cousin*
=>*explanation**:
[A ***female cousin**** is a binary relation that connects two *persons*, the second of which belongs to a class of *woman* and whose parents are connected with a *sibling** relation]
∈ *Russian language*
<= *used constants*:*
{
• *parent**
• *individual*
• *female*
• *sibling**
}
*]

Let's look at how formal definitions, corresponding to given explanations, appear in SCg language [6]:

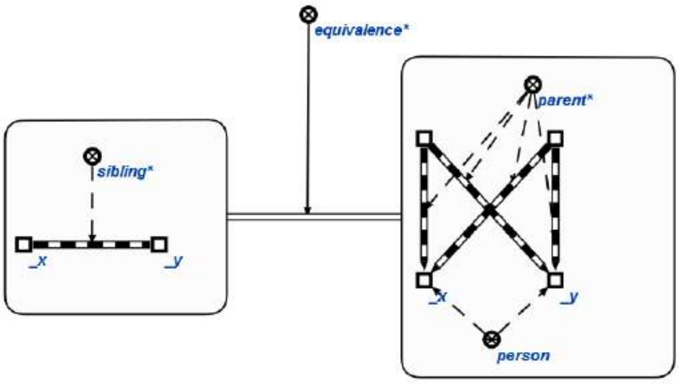

Figure 1. Definition of ***sibling**** relation

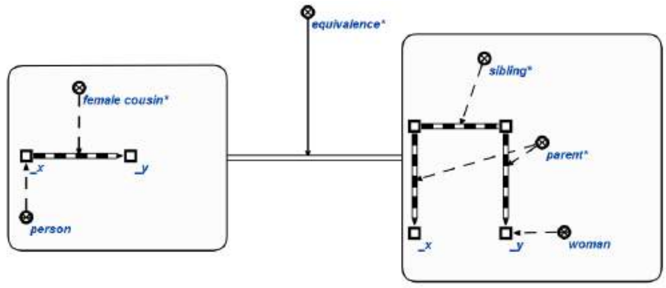

Figure 2. Definition of ***female cousin**** relation

The above mentioned ontology fragment shows that it can be a good basis for performing a number of tasks in historic systems. In particular, for finding an individual's relatives of different degrees of kinship, even if these links are not evidently present in the subject domain. Or, for finding possible family relationship between any two individuals in the knowledge base.

Distinguishing subject domains and their data ontologies allows to distinguish independent areas within the system, which can be developed without the need to harmonize actions in the subject domain with the developments in other subject domains. At the same time, it clearly prescribes the development stages that would require such harmonization.

III. Types of Intelligent Systems in the Field of History

A large number of various historical systems is present at the moment. Historical systems can be classified as following, by the **subject of research**:

- systems describing a specific area of historical knowledge: history of mathematics, history of literature, archeology and history of archeology [10], [11];
- systems describing a specific period of time: history of the Middle Ages, the Modern history [12];
- systems describing the history of a certain territory: history of Europe, history of the city of Minsk [13].

And, accordingly, any possible intersection of these three sets.

By purpose all historical systems can be divided into:

- reference systems, which provide structured information in the required subject domain [14]
- training systems, which have a knowledge monitoring complex along with the structured material [15].
- systems supporting scientific research in the field of history, or tools for historians.
- guiding systems supporting ciy or museum tours [16] [17] [18].

All these systems have two major drawbacks:

- it is impossible to use knowledge from the knowledge base of one history system for solution of any kind of problems in another one;
- the knowledge bases of these systems are ultimately incompatible due to the absence of common ontology.

However, as the systems operate with the same type of knowledge, it might provide the basis for the development of common ontologies of such systems. The ontological approach in the design of systems in the field of history, will provide an opportunity to integrate various systems, as well as to borrow the necessary components that are present in one of the systems, but not in the other ones.

IV. Conclusion

General ontology of historical knowledge as a reusable component will accelerate the development of intelligent systems in the field of history and provide opportunities for using solutions from one system within the framework of another one in order to address the necessary applied problems.

Ontology-based approach to design of intelligent systems in the field of history will provide for the flexibility of the systems being developed and for the possibility of organizing project activities in a way that these activities are maximally independent in detail elaboration of various subject domains, while preserving the integrity of the systems under development.

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ОНТОЛОГИЧЕСКОЕ ПРОЕКТИРОВАНИЕ ИНТЕЛЛЕКТУАЛЬНЫХ СИСТЕМ В ОБЛАСТИ ИСТОРИИ

Губаревич А.В., Моросин О.Л., Ландэ Д.В.

Работа рассматривает онтологический подход к построению интеллектуальных систем в области истории, специфику данного рода системы и особенности их построения.

Вопрос о необходимости формализации, систематизации и обработки знаний стоит в исторической науке не менее остро, чем в любой другой. При этом гуманитарное знание является областью трудно формализуемого знания, где рассуждения менее прозрачны, а знание опирается не на понятия, а на идеи, которые в свою очередь требуют уточнения и определения.

Актуальность разработки интеллектуальных систем в области истории обусловлена все возрастающим интересом общества и науки к ретроспективным методам изучения, где история становится инструментом исследования, а также к истории как способу сохранения и трансляции культуры в самом широком ее понимании.

Онтологический подход к проектированию баз знаний, в том числе в области истории, подразумевает выделение предметных областей и онтологий данных предметных областей, разработка в рамках которых может вестись без необходимоси согласования действий в данной предметной области с разработками в других предметных областях.

На данный момент существует большое количество различных исторических систем. Исторические системы по **предмету исследования** можно классифицировать следующим образом:

- системы, описывающие определенную область исторического знания: история математики, история литературы, археология и история археологии;
- системы, описывающие определенный период: история средних веков, история нового времени;
- системы, описывающие историю определенной территории: история Европы, история города Минска.

И соответственно, любые возможные пересечения этих трех множеств.

По назначению все исторические системы можно разделить на:

- справочные, которые предоставляют структурированную информацию в требуемой предметной области;
- системы учебного назначения, где кроме структурированного материала есть отдельный комплекс, отвечающий за контроль знаний.
- системы поддержки научных исследований в области истории, которые являются инструментом работы историка.
- системы-гиды – системы поддерживающие экскурсионное сопровождение по городам, музеям.

У всех перечисленных систем есть два основных недостатка:

- невозможность использования знаний из базы знаний одной системы по истории для решения каких-бы то ни было проблем в другой;
- принципиальная несовместимость баз знаний этих систем в виду отсутствия общей онтологии.

Тот факт, что все эти системы оперируют одним и тем же типом знания, дает основания для разработки общих онтологий подобных систем. При онтологическом подходе в проектировании систем в области истории появится возможность интеграции различных систем, а также возможность заимствования необходимых компонентов, которые представлены в одной их систем, и отсутствуют в другой.

Общая онтология исторического знания в качестве многократно используемого компонента позволит ускорить процесс разработки интеллектуальных систем в области истории и обеспечит возможность использования решений из одной системы в рамках другой системы для решения необходимых прикладных задач.

Онтологический подход к проектированию интеллектуальных систем в области истории позволит обеспечить гибкость разрабатываемых систем и возможность организации проектной деятельности таким образом, чтобы эта деятельность была максимально независима при детализации различных предметных областей, и одновременно при этом сохранялась целостность разрабатываемых систем.

Интеллектуальные системы поддержки принятия решений в медицине: ретроспективный обзор состояния исследований и разработок и перспективы

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***Аннотация*—Целью работы является ретроспективный обзор состояния исследований и разработок в области интеллектуальных систем поддержки принятия решений (СППР) в медицине. Отмечается, что история современных СППР уходит корнями в создание экспертных систем в 70-х годах XX века. В первых разделах работы представлены задачи «классических» экспертных систем и соответствующие решения. Оставшаяся часть посвящена обсуждению состояния исследований и разработок в области СППР в медицине и здравоохранении в целом, а также их применениям. Различные типы приложений анализируются. В работе приведено более 50 примеров интеллектуальных СППР в медицине.**

***Ключевые слова*—интеллектуальная система поддержки принятия решений, СППР, экспертная система, здравоохранение, медицина, мониторинг здоровья пациентов.**

I. Введение

Целью работы является обзор основных направлений в области разработки и применения интеллектуальных систем поддержки принятия решений в медицине. Отмечается, что история современных СППР уходит корнями в создание экспертных систем в 70-х годах XX века. В первых разделах работы представлены задачи «классических» экспертных систем и соответствующие решения. Оставшаяся часть посвящена обсуждению вопросов развития и интеграции таких систем в рамках мониторинга здоровья. Различные типы приложений анализируются. В работе приведено более 50 примеров интеллектуальных СППР в медицине. Даются оценки развития рынка интеллектуальных систем поддержки принятия решений в медицине и отмечаются основные тренды в развитии данного класса интеллектуальных систем.

II. Общие замечания

Согласно общепринятому определению, экспертная система (ЭС) – это компьютерная система, способная частично заменить специалиста-эксперта в разрешении проблемной ситуации (в решении задач, традиционно считающихся трудными для людей-экспертов и не имеющих строгих математических моделей их решения). Современные экспертные системы начали разрабатываться исследователями искусственного интеллекта в 1970-х годах, а в 1980-х получили коммерческое подкрепление. Экспертные медицинские системы предназначены для обеспечения оперативной и систематической помощи медицинскому персоналу в разрешении проблемных ситуаций и принятии решений по вопросам диагностики и лечения пациентов.

Считается, что «классическая» экспертная система решает задачи, обладающие следующими характеристиками:

- задачи не всегда могут быть представлены в числовой форме;
- исходные данные и знания о предметной области неоднозначны, неточны, противоречивы;
- цели нельзя выразить с помощью четко определенной целевой функции;
- не существует однозначного алгоритмического решения задачи (возможность предоставления решений и ответов при наличии исходных данных, сформулированных с той или иной степенью допущения).

Это, в частности, предопределило широкое применение ЭС в медицине (т.к. перечисленные выше свойства являются типичными для медицинских задач).

Важным характеристическим признаком ЭС является наличие подсистемы объяснения (предполагает способность описания и обоснования цепочек предложенных рассуждений и заключений). ЭС должна предусматривать наличие механизма формирования разграниченных выводов; не только генерацию диагноза, рекомендаций или советов, касающихся отдельных случаев, но и возможность формулирования предположений о том, что произошло с исследуемым объектом; возможность постепенного расширения и модернизации функционала.

Следует отметить, что идея 80-х, состоящая в том, что систему практического уровня значимости можно наполнить сведениями, полученными от людей-экспертов, к настоящему моменту фактически ушла в прошлое. На смену ей пришла парадигма обработки больших данных для приобретения знаний. Границы понятия ЭС размываются, и в настоящий момент целесообразно говорить о таких ИТ-решениях, как интеллектуальные медицинские системы, системы поддержки принятия решений, СППР в медицине / сфере здоровья (уже в настоящий момент и в перспективе – также сервисы поддержки принятия решений, в т.ч. для b2c сегмента), в международной практике - clinical decision support system, medical decision support systems, а также управление знаниями в медицинской сфере (clinical knowledge management technologies).

Полный обзор СППР и ЭС в медицине, конечно же, не представляется возможным. Так, уже в 1987 году в мире было представлено около 1000 ЭС, а сегодня уже никто подсчетами не занимается. Но, как показывает анализ, число экспертных систем растет по экспоненте, при этом совершенствуются методы и алгоритмы вывода решений, увеличивается количество фактов и правил в базах знаний.

III. Функции ЭС и СППР в медицине. Типы ЭС и СППР

СППР в медицине предназначены для решения следующих задач: подача тревожных сигналов и напоминаний, ассистирование в процессе диагностики, поиск подходящих случаев (прецедентов), контроль и планирование терапии, распознавание и интерпретация образов. Важная функция СППР - распространение «лучших практик», в т.ч. международных. Чаще всего СППР используются именно для помощи при постановке диагноза, назначении и, при необходимости, корректировке назначенного лечения. Однако область их применения охватывает все уровни заботы о здоровье:

- Профилактика (в процессах иммунизации, скрининга, при разработке системы профилактических мероприятий – как для отдельного пациента, так и для группы, и т.п.);
- Диагностика (дифференциальная диагностика);
- Лечение (назначение, в т.ч. подбор лекарственных препаратов с учетом совместимости, противопоказаний, индивидуальных особенностей пациента и т.п., мониторинг и контроль, например, в интересах выявления рисков, опасных событий, угроз с немедленным уведомлением лечащего врача и иных ответственных лиц);
- Отслеживание состояния после завершения основного лечения (мониторинг на разных стадиях и для разных категорий пациентов, в т.ч. мониторинг пациентов с ХНИЗ).

В международной (в ряде случаев – и в российской) практике СППР часто встраиваются в более общие медицинские информационные системы (МИС) клиник, ЛПУ.

В особый класс можно выделить системы интерпретации медицинских изображений, в частности, МРТ и КТ (правда, по оценкам некоторых экспертов, такие системы работают пока нестабильно и в 2/3 случаев оказываются недоступны для использования в реальной практике – результаты исследования, представленные в 2015 году в Journal of the American Medical Association[1]). При этом аналитики включают развитие СППР в области медицинской визуализации в число важнейших технологических трендов на ближайшие годы (еще одним важным трендом является развитие систем в области кардиологии).

Если говорить более детально, СППР в клинической медицине могут выполнять следующие функции[2]:

- дифференциальная диагностика и выбор лечения в широком круге нозологических форм (здесь важно подчеркнуть именно большое число дифференцируемых заболеваний, в том числе редких);
- подготовка решений вне зависимости от выраженности клинических проявлений болезни, что предполагает диагностику при ранних формах заболеваний и стертой клинической картине;
- учет фоновых состояний (сопутствующих заболеваний) пациента, что особенно важно при подборе лечения;
- анализ динамики патологического процесса с прогнозом потенциально возможных неблагоприятных ситуаций (при учете проводимой терапии, включая и побочные эффекты медикаментов);
- оценка состояния в режиме «реального» времени, что может быть достигнуто при актуализации за счет информации, поступающей с приборных комплексов и персональных систем.

СППР в сфере здоровья часто основаны на анализе прецедентов и принципах доказательной медицины (case- или evidence-based подходы), при этом используются сведения как из практики, так и из результатов научных исследований. В некоторых системах предусмотрен функционал накопления базы негативных кейсов (неправильно поставленные диагнозы, ошибочно назначенная терапия и др.), которая затем используется не только в практической деятельности медицинских

[1] http://spectrum.ieee.org/tech-talk/biomedical/diagnostics/fail-computerized-clinical-decision-support-systems

[2] Кобринский Б. А. Особенности медицинских интеллектуальных систем. // Информационно-измерительные и управляющие системы. - 2013. -№ 5. С. 58-64.

специалистов при работе с пациентами, но и для оценки состояния здравоохранения в стране.

Другими типами СППР являются:

- СППР для автоматизации административно-хозяйственных процессов (во многом подобны ERP, также должны быть нацелены на задачи стандартизации системы здравоохранения, трансляции лучших отечественных медицинских практик на всех ее уровнях и пр.):
    - СППР для управления расходами ЛПУ и пациента: поиск оптимальных сценариев диагностики (в т.ч. для того, чтобы избежать ненужных и/или дублирующих друг друга обследований), оптимизация числа койко-дней для стационаров, закупка лекарственных препаратов и т.п.;
    - СППР для управления здравоохранением на уровне региона, страны.

Также СППР играют роль образовательных платформ и средств повышения квалификации врачей, в т.ч. в составе телемедицинских систем дистанционного обучения. Кроме того, они обеспечивают поддержку проведения медицинских исследований (что также является значимым трендом последних лет, обеспечивается за счет накопления и интерпретации больших объемов разнородной медицинской информации – первичной и вторичной).

Как указывалось выше, одной из главных задач СППР в медицине по-прежнему, со времени первых систем, остается дифференциальная диагностика (как следствие – снижение числа врачебных ошибок и повышение уровня безопасности пациента). Решение этой задачи крайне актуально и в РФ, и в мире. Согласно данным, приводимым компанией Socmedica, в США 440 000 пациентов в год умирают от врачебных ошибок (затраты на врачебные ошибки – $7,3 млрд. в год), в РФ 50 000 пациентов в год умирают от врачебных ошибок, 170 000 становятся инвалидами.

IV. Краткая история СППР в медицине и области их применения

Исследования в области использования искусственного интеллекта в медицине начались в конце 60-х-начале 70-х гг. XX века. Первые примеры включают в себя такие системы, как AAPHelp (Университет Лидса, задача – поиск причины резких болей и принятие решения о необходимости хирургического вмешательства), INTERNIST (Питтсбургский университет, задача – помощь при постановке диагноза по наблюдаемым симптомам, в т.ч. при наличии возможных «конкурирующих» диагнозов, база медицинских знаний INTERNIST использовалась позднее при коммерческих внедрениях систем CADUCEUS и Quick Medical Reference), CASNET/Glaucoma (Ратгерский университет, задача – поддержка принятия решений при диагностировании глаукомы), ONCOCIN (Стэнфорд, задача – поддержка принятия решений при лечении пациентов, получающих химиотерапию) и ряд других. Однако наиболее известным решением, которое считается прообразом последующих экспертных систем в медицине («первое убедительное доказательств полезности применения систем, основанных на правилах, в клинической практике»[3]), стала система MYCIN[4]. Эта система, разработанная в Стэнфорде, была предназначена для оказания помощи специалистам при постановке диагноза и назначении лечения для инфекционных заболеваний (вначале – крови, потом для более широкого спектра заболеваний). MYCIN был основан на системе эвристик, правил вида «если-то» и использовании машины вывода. Платформа (программная оболочка) MYCIN использовалась позднее как основа для разработки других экспертных систем, в т.ч. коммерциализованных и внедренных в клиническую практику.

Коммерциализация экспертных систем в медицине в международной практике началась в 80-е гг. Успешными примерами являются DXplain (Laboratory of Computer Science, Massachusetts General Hospital, Harvard Medical School; база знаний включает более 2000 заболеваний и 5000 симптомов, система развивается и используется до сих пор) и Quick Medical Reference (Питтсбургский университет и First Databank, Калифорния; система использовала знания из медицинской литературы о 700 заболеваниях и более чем 5000 симптомов и лабораторных показателей и могла использоваться и как справочник, и как «эксперт-консультант», формирующий суждения о диагнозе).

Другими примерами известных «классических систем» являются Germwatcher (была разработана в помощь больничному эпидемиологу; содержит большой объем данных по различным микробиологическим культурам. Включает базу знаний, основанную на правилах, которая используется для генерации гипотез о возможных инфекциях); PEIRS (интерпретирует и комментирует отчеты по химическим патологиям. В систему встроен модуль машинного обучения, который позволяет патологу создавать новые правила); Puff (предназначена для интерпретации результатов функционального пульмонологического теста; использует прецедентную информацию – десятки тысяч случаев); HELP (полная госпитальная информационная система, основанная на технологиях искусственного интеллекта); SETH (система, предназначенная для анализа токсичности лекарственных средств. Система основана на моделировании экспертных рассуждений, для каждого токсикологического класса учитывающих клинические симптомы и применяемые дозы. Система выполняет мониторинг лечебного процесса, направленный на контроль взаимодействия лекарств); системы в области клинической микробиологии (Vitek2 Compact, BD Phoenix, MicroScan и др.); ATTENDING (пример «критикующей системы» экспертного типа, обеспечивает поиск ошибок в предлагаемом решении и выдвижение альтернативного варианта. Система

[3] Tu S.W., Musen M.A. A flexible approach to guideline modeling. //Proc AMIA Symp. 1999, P. 420–424.
[4] Shortliffe E.H. Computer-Based Medical Consultations: MYCIN. New York: American Elsevier. 1976. 286p.

критикует план предоперационной подготовки и выбор способа анестезии, тем самым обращая внимание на недостатки, требующие исправления, и на опасности, которых можно избежать) и PHEO-ATTENDING (осуществляет оценку действий при назначении дополнительного обследования больному с феохромоцитомой, используя позиции двух конкурирующих медицинских школ).

С начала истории развития и до настоящего времени среди СППР можно выделить узкопрофильные и более универсальные системы. Так, например, «классическим» направлением является поддержка принятия решений в области диагностики и лечения онкологических заболеваний (от систем типа ONCOCIN, LISA – лечение острой лейкемии у детей – и Kasimir до IBM Watson).

V. Отечественные системы 80-90 гг. XX века

В 70-90 гг. прошлого века в нашей стране также был разработан ряд ЭС / СППР в медицине, характеризуемых довольно высоким, по тому времени, уровнем и практической значимостью. Полезный обзор таких систем, прежде всего, с акцентом на педиатрию, приведен на сайте[5].

Примером такой системы является созданная в Московском НИИ педиатрии и детской хирургии автоматизированная система для синдромной диагностики неотложных состояний у детей «ДИН». Эта ЭС содержит информацию о 42 синдромах, которые представляют собой список диагностических предположений-гипотез. Так как выбор лечения во многом определяется прогнозом возможных осложнений, в системе описаны взаимосвязи синдромов, определяемые причинно-следственными, временными и ассоциативными отношениями. Причинно-следственные связи предполагают информацию о синдромах, которые могут быть причиной данного синдрома или, наоборот, являться его следствием. В последнем случае речь идет о прогнозировании возможных осложнений, обусловленных наблюдающимся у ребенка в данный момент синдромом. Временные связи позволяют восстанавливать информацию о предшествующих синдромах, которые могли послужить причиной того состояния, которое имеется в данный момент, что особенно важно для тех случаев, когда ребенок поступает в отделение реанимации без анамнеза.

Другой пример - программный комплекс «Айболит» для диагностики, классификации и коррекции терапии острых расстройств кровообращения у детей, созданный в Центре сердечно-сосудистой хирургии имени А.Н. Бакулева, применявшийся при оперативных вмешательствах и выборе послеоперационного лечения в условиях реанимационного отделения.

Информационная и экспертно-диагностическая система «ДИНАР» для реанимационно-консультативного центра (РКЦ), разработанная Санкт-Петербургской педиатрической медицинской академией и Свердловской ОДКБ при участии сотрудников Института биофизики УроРАН, позволяла обеспечить дистанционное наблюдение за больными с угрожаемыми состояниями, определение ведущего патологического синдрома и степени тяжести, помощь при выборе лечения, принятие тактического решения с учетом распределения централизованных ресурсов медицинского обеспечения.

СППР получили определенное распространение в хирургии, в частности, в экстренной абдоминальной. Так, А.А. Егоровым и В.С. Микшиной была разработана СППР для определения возможных исходов и способов завершения операции по поводу перитонита (за рубежом также активно развивалось и развивается направление, связанное с хирургией, например, в 2007 г. была разработана СППР для классификации тяжести острого панкреатита и прогнозирования летального исхода, которая базировалась на 10 клинических параметрах, определенных при госпитализации и через 48 часов после поступления в стационар).

Московский НИИ педиатрии и детской хирургии был одним из «центров компетенций» в соответствующей области и разработчиком целого ряда экспертных медицинских систем (пример см. выше). При этом отдельно следует отметить диагностические системы в клинической генетике. В Московском НИИ педиатрии и детской хирургии была создана широко известная система по наследственным болезням у детей «ДИАГЕН», ориентированная на выделение узкого дифференциально-диагностического ряда из 1200 моногенных и хромосомных заболеваний детского возраста на долабораторном этапе обследования детей, т. е. до проведения специальных дорогостоящих исследований, позволяющих окончательно уточнить диагноз. Она включала, среди прочего, фотоархив, содержащий более 1000 изображений характерных фенотипических проявлений данных болезней и синдромов. В системе была предусмотрена и работа в условиях неопределенных и неточных исходных данных. В Центральном институте травматологии и ортопедии (ЦИТО) им. Н.Н. Приорова, при использовании разработок Центра искусственного интеллекта ИПС РАН, была создана система автоматизированной диагностики остеохондродисплазий у детей, включающая методику определения оптимальной тактики лечения больных с этими заболеваниями. В Медико-генетическом научном центре РАМН были разработаны система по хромосомной патологии SYNGEN, включающая более 1900 синдромов врожденных пороков развития (ВПР) и система CHRODYS (600 ВПР, включая видеотеку на некоторую часть из них), позволявшая осуществлять анализ фено-кариотипических корреляций при хромосомном дисбалансе.

К сожалению, эти передовые для своего времени системы уже существенно устарели – как в отношении применяемых ИТ-инструментов, алгоритмов, методов и средств, так и в отношении используемых медицинских знаний – и не получили дальнейшего развития. Между тем, например, аналогичная австралийская компьютерная система диагностики наследственных синдромов

[5] http://www.rmj.ru/articles/pediatriya/Avtomatizirovannye_diagnosticheskie_i_informacionno-analiticheskie_sistemy_v_pediatrii/

POSSUM[6], появившаяся примерно в тот же период, активно развивается и используется до сих пор (более того, по сути, представляет собой уже целую платформу с большим количеством дополнительных функционалов, платформа интегрирована с PubMed и т.п.).

Можно говорить об отечественной школе ЭС в медицине, традиции которой была, во многом, утрачены.

VI. Современное состояние ЭС и СППР в медицине за рубежом

Примерами современных систем, успешно развиваемых с 2000-х (и в настоящее время), являются следующие:

- IndiGO (Archimedes) – система обеспечивает обработку данных клинической, физиологической природы и сведений об управлении процессом лечения и формирует индивидуализированные протоколы диагностики и лечения с учетом факторов риска, истории болезни, сведений о полученном лечении, биомаркерах и т.п. по конкретному пациенту. На основе информации, считываемой с электронной карты, система IndiGO, в частности, прогнозирует риск таких событий, как сердечный приступ, диабетический криз и т.д. Основой разработки системы стал грант объемом $15.6 млн., полученный в 2007 году от Robert Wood Johnson Foundation;
- Auminence (Autonomy, исходно была основана в Кэмбридже, Великобритания, теперь является дочерним предприятием Hewlett-Packard) – система дифференциальной диагностики, анализирует сведения о симптомах и др. информацию, выявляет значимые паттерны и формирует диагностический план (checklist);
- DiagnosisOne (платформа smartPath) – система использует данные об оказанных медицинских услугах и ряд других сведений для поиска упущений и формирования планов лечения, ориентирована на повышение эффективности практической деятельности медицинского специалиста;
- СППР Isabel Healthcare – система поддержки принятия диагностических решений на основе сведений о симптомах, использует веб-интерфейс, поддерживающий процесс анализа симптомов в процессе дифференциальной диагностики. Также обеспечивает «информационно-аналитическую поддержку point of care», позволяя объединять знания, накопленные, например, конкретным учреждением с научными знаниями от ведущих медицинских издательств. Кроме того, она позиционируется и как образовательная платформа;
- Problem-Knowledge Couplers (Sharecare) – информационно-аналитическая система в сфере здоровья с широким функционалом (который не всегда можно считать функционалом класса СППР). Интересной особенностью является то, что система позиционируется также в сегменте wellness; кроме того, производитель заявляет, что она ориентирована на донесение знаний до пациентов, конечного потребителя (слоган системы - KNOW YOUR HEALTH). В частности, система может помочь пользователю найти необходимого медицинского специалиста;
- VisualDx – система поддержки диагностических решений с использованием принципов дифференциальной диагностики, также активно используется в образовании (как указано на сайте производителя, используется более чем половиной ведущих медицинских университетов мира, применяется в 1500 клиник и институтов). Обладает рядом уникальных особенностей, в частности, крупнейшей в мире библиотекой медицинских изображений;
- СППР Siemens – системы Protis (интерпретация результатов обследований на основе сведений о большом числе пациентов), PRISCA (анализ факторов риска);
- Nuance – системы поддержки принятия решений для радиологии;
- СППР крупнейших издательств и медиаконгломератов:
  - Elsevier Clinical Decision Support (дочерняя компания Elsevier Group; известные бренд-имена системы: Mosby's, Gold Standard, Pinpoint, First Consult.) – система основана на использовании огромных массивов научной и клинической информации (медицинские журналы, книги, онлайн ресурсы типа MD Consult), принадлежащих Elsevier. По сути, это линейка продуктов, предназначенных для информационно-аналитической поддержки медицинских специалистов (в т.ч. при назначении лекарственных препаратов, формировании протоколов, основанных на анализе корпуса кейсов и принципах доказательной медицины) и научных исследований, а также для использования в образовании и для управления эффективностью ЛПУ;
  - Micromedex[7] (Thomson Reuters) – издательство Thomson Reuters является одним из ключевых провайдеров контента для СППР в медицине и автором собственной разработки Micromedex. Линейка продуктов включает системы Micromedex 360 Care Insights (персонализированная – относительно пациента – поддержка принятия решений, в т.ч. выявление пациентов, входящих в группы риска), Micromedex® Clinical Knowledge Suite (СППР, используемая для назначения

[6] http://www.possum.net.au/

[7] http://micromedex.com/

лечения, выявления токсичности препаратов, управления процессом лечения и др.), Micromedex® Patient Connect Suite (вовлечение пациента в процесс лечения и заботы о здоровье). У систем имеются мобильные версии (например, для оперативной проверки совместимости лекарственных препаратов) для iPhone, Android, BlackBerry. Внедрена в 5500 ЛПУ в 83 странах мира. СППР в медицине развивают и другие издательства и медиаконгломераты (например, Wolters Kluwer Health: БЗ UpToDate и ProVation Order Sets; Hearst: Zynx Health. Интересной спецификой линейки Zynx Health является наличие систем Secure ConText Messaging™ и Mobile Care Navigation Network, обеспечивающих, среди прочего, эффективную коммуникацию врача и пациента, в т.ч. в сложных, «перегруженных» средах).

Говоря о современных СППР в медицине, конечно же, нельзя не упомянуть систему IBM Watson. Аппаратная архитектура Watson такова, что позволяет осуществлять параллельные и распределенные вычисления, т.е. сразу работать с множеством задач в параллельном режиме. Кроме того, выполнять работы сразу на нескольких устройствах, подключенных к головному суперкомпьютеру. После обучения Watson начал использоваться для диагностирования и назначения курсов лечения онкологических больных в нескольких лучших клиниках США. К концу первого года испытаний результаты Watson стали устойчиво превосходить показатели эффективности обычных врачей среднего и хорошего уровня.

В последние годы СППР в медицине активно развиваются в странах Юго-восточной Азии, Ближнего Востока.

Также в направлении СППР развиваются исходно более простые программы, такие как симптом-чекеры и другие программы для конечного (в т.ч. непрофессионального) пользователя. Примеры: WebMD Symptom Checker, DrNow, iPharmacy, EasyDiagnosis и др.

Большинство ведущих СППР систем имеют в настоящее время онлайн- и мобильные версии.

VII. Рынок СППР в медицине

В число ключевых игроков в области СППР в медицине входят следующие производители: Accenture, iMDsoft, Quintiles, Clinicmaster, Surgical Information Systems LLC, Allegro CTMS, Clinical Computing, Thermo scientific, ITH icoserve, Promantra, Inc., Haitai Medical Information Systems Co., Clinical Computer Systems, Inc., Healthcare Management Systems SCC Soft Computer и 3M Health Information Systems (по оценкам Grand View Research, Inc., 2015 г.).

По данным Transparency Market Research, такими игроками являются Medical Information Technology, Inc. (Meditech), Epic Systems Corporation, McKesson Corporation, Zynx Health, Siemens Healthcare, Cerner Corporation, Wolters Kluwer N.V., Philips Healthcare (также по оценкам на 2015 г.).

Исследование Markets And Markets называет ведущими игроками рынка СППР в медицине Agfa Healthcare (Бельгия), athenahealth, Inc. (США), Allscripts Healthcare Solutions, Inc. (США), Carestream Health, Inc. (США), Cerner Corporation (США), Epic (США), GE Healthcare (Великобритания), McKesson Corporation (США), MEDITECH (США), NextGen Healthcare Information System LLC (США), Novarad Corporation (США), Philips Healthcare (Нидерланды), Siemens Healthcare (Германия), Wolters Kluwer (США), и Zynx Health (США), по данным на 2013. По числу инсталляций лидировала компания MEDITECH.

По оценкам Markets and Markets, объем рынка медицинских СППР продолжит рост в ближайшие годы (Рис. 1, по данным Socmedica):

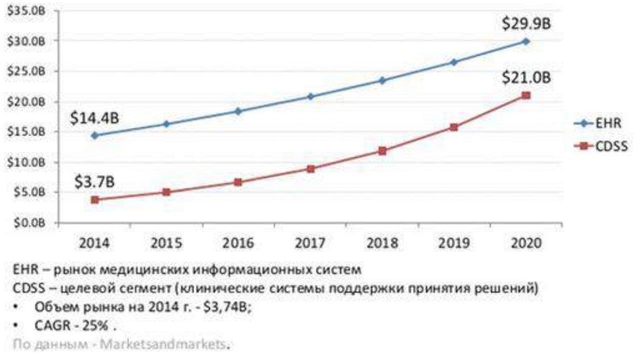

Рисунок 1 - Рост рынка СППР в медицине

Корпорация CDW назвала рост интереса ЛПУ к аналитическим инструментам в числе важнейших трендов и спрогнозировала кратный рост этого направления в ближайшие годы.

Целесообразно также сопоставить такого рода оценки с оценками рынков mHealth и телемедицины (mHealth, по данным PwC, - $23 млрд. к 2017 году; телемедицина, по оценкам Machina Research, - €70 млрд. к 2020 году). Как представляется, в среднесрочной и долгосрочной перспективе развитие рынков mHealth и телемедицины будет тесно связано с системами и *сервисами* поддержки принятия решений, что, в свою очередь, приведет к существенному росту рынка соответствующих решений.

Объем российского рынка МИС (пока, в основном, продукты-субституты для СППР, по оценкам Socmedica) составляет 11,5 млрд. руб. в год, темпы роста рынка составляют 9% в год.

Рынок покрывает все сегменты:

- b2b (ЛПУ, страховые компании, производители МИС);
- b2c (пациенты и врачи);
- b2g (органы, ответственные за развитие здравоохранения).

Развитие СППР в медицине поддерживается другими технологическими трендами, такими как работа с большими данными, медицинская визуализация (что, в частности, позволяет пространственно смоделировать типовое развитие патологического процесса при конкретном заболевании).

В США одним из стимулов для внедрения СППР на практике стало подписание в 2009 году акта HITECH (Health Information Technology for Economic and Clinical Health Act), в некотором роде, обязывающего медицинские учреждения более широко внедрять информационные технологии (в частности, предполагается система штрафов за отсутствие автоматизации и неэффективное / неправомерное использование электронных медицинских карт, ЭМК, с 2016-2017 гг.). В 2011 г. и последующие годы появился целый ряд аналитических исследований, констатирующих, что именно применение технологий интеллектуального анализа информации и СППР в медицине позволят использовать потенциал ЭМК в полной мере. В 2014 США (U.S Department of Health and Human Services) анонсировали, что в ближайшее время $840 млн. будут направлены на реализацию инициатив, связанных с повышением эффективности работы медицинских специалистов, в т.ч. за счет решения «классических» задач СППР, например, минимизации объемов «ненужных» обследований.

В большинстве случаев, СППР в медицине на текущем уровне развития не могут и не должны заменить медицинского специалиста. Исследование, проведенное в 2010 году Agency for Healthcare Research and Quality (AHRQ), США, показывает, что неправильное использование СППР может принести больше вреда, чем отсутствие таких систем (что никак не отменяет все положительные последствия их корректного использования).

При этом развивающимся трендом можно считать выход СППР на сегмент b2c. В данной области имеется еще целый ряд нерешенных проблем (как медицинского, так и технологического характера). Однако развитие в этом направлении, видимо, неизбежно, многие специалисты уже отмечают грамотность пациентов, в т.ч. старшего возраста, способных адекватно интерпретировать найденную в интернете информацию (см., например, мнение российского врача[8]). СППР для персонального использования, как представляется, могут развиться на основе консультационных сервисов, систем типа личного календаря здоровья, симптом-чекеров и т.п., а также за счет более активного внедрения персональных устройств, осуществляющих сбор информации в режиме 24*7, что требует сложной и оперативной интерпретации.

VIII. Современные российские СППР

Дискуссия, которая ведется в РФ по проблематике экспертных систем в медицине, достаточно обширна. Темы, связанные с экспертными системами в сфере здоровья, системами поддержки принятия решений в медицине, активно обсуждаются на мероприятиях и в профильных журналах и в области здравоохранения (например, в журнале «Врач и информационные технологии», на конференции «Информационные технологии в медицине» и др.), и в области информационных технологий, искусственного интеллекта. Но, к сожалению, главная проблема в настоящий момент – малое число разработок, реализация которых находится на уровне практической значимости и которые доходят до внедрения. Лишь малое число систем соответствует МИС 5 поколения (согласно исследованиям аналитического агенства Gartner).

Значимым примером, знаменующим, среди прочего, выход экспертных систем и СППР в область персонализированной медицины, является система OncoFinder (Онкофайндер) – программа анализа внутриклеточных сигнальных путей и подбора наилучших терапевтических препаратов при различных типах рака. Исходя из индивидуальных особенностей пациента, система подбирает ему наиболее адекватный тип терапии таргетными препаратами. Разработана Первым Онкологическим Научно-Консультационным Центром (ПОНКЦ). Партнеры: Федеральный научно-клинический центр детской гематологии, онкологии и иммунологии имени Дмитрия Рогачева (ФНКЦ ДГОИ), ФМБЦ им. А.И.Бурназяна ФМБА России, Институт Биоорганической Химии РАН, Университет Летбридж, Канада, Калифорнийский Технологический Институт, США. В 2015 году был подписан меморандум о взаимопонимании IBM с фондом «Сколково» и с Первым Онкологическим Научно-Консультационным Центром (ПОНКЦ), предусматривающий объединение возможностей IBM Watson Health и решения OncoFinder, разработанного специалистами ПОНКЦ.

Другой интересный пример – сервис ONDOC — система персонального здравоохранения (сайт и мобильное приложение для контроля здоровья; лучший мед. портал 2015 года). Позиционируется как система персонального здравоохранения, включающая в себя сервисы для надежного хранения персональной медицинской информации, ее комплексного анализа и выявления лучшего способа укрепить и сохранить здоровье. Задачи разработчиков: создать среду, в которой люди смогут заботиться о своём здоровье; предоставить пользователям доступ к лучшим медицинским практикам; повысить качество и облегчить взаимодействие пациента с клиниками и врачами через глубокую интеграцию и партнерство. Важной особенностью является работа с сегментом b2c (пользователи имеют персональную электронную медкарту, ищут врачей и проходят лечение в партнерских клиниках, они получают рекомендации врача прямо в свой профиль ONDOC; пользователи получают напоминания о приеме лекарств и т.п. – при этом не все функции системы можно в данный момент считать функциями СППР, но представляется, что система будет развиваться именно в этом направлении).

Целый ряд разработок в сфере СППР ведется компанией ЗАО «Соцмедика» (Socmedica, резидент инновационного центра «Сколково», специализирующейся

[8] http://www.mgnot.ru/index.php?mod1=art&gde=ID&f=12501&m=1

на создании экспертных систем в области медицины). На основе Объединенной Базы Медицинских Знаний (UMKB) и технологий моделирования медицинских знаний компания разрабатывает системы следующих типов:

- экспертные системы по прогнозированию рисков развития заболеваний, осложнений и эффективности лечения;
- экспертные системы по ранней диагностике заболеваний;
- экспертные системы по планированию лечения;
- экспертные системы по мониторингу состояния здоровья пациента;
- автоматизированные системы анализа и статистической обработки клинического материала.

Общая архитектура систем Socmedica представлена на Рис. 2.

Рисунок 2 - Общая архитектура систем Socmedica

Системы Socmedica используют онтологии и лингвистический процессор (компании ABBYY), что сближает их с решением Watson.

Кроме того, ряд отечественных компаний ведет разработку симптом-чекеров (см. выше про связь с СППР): Medme, Mail.ru и др.

Как представляется, в направлении СППР развиваются также продвинутые консультационные сервисы и специализированные соцсети (например, проект «Доктор на работе»).

Примеры отдельных внедрений включают также следующие (данные, в ряде случаев, носят отрывочный характер, информацию о реальном внедрении, а также о соответствии систем характеристикам ЭС/СППР не всегда удается подтвердить):

- Экспертная система алгоритмической диагностики и лечения всех уровней поражения периферической нервной системы (Компания 3D ЛИГА совместно с Российским геронтологическим научно-клиническим центром; в соответствии с жалобами пациента система последовательно рекомендует врачу проведение порядок и особенности тестов, в результате достигается выбор оптимальной программы, индивидуализация и автоматизация; обладает элементами телемедицины, обеспечивая режим удаленных консультаций и консилиума);
- Система поддержки принятия решений по перинатальному мониторингу (Краевое Государственное бюджетное учреждение здравоохранения «Красноярский краевой медицинский информационно-аналитический центр »; была разработана система поддержки принятия решений «Перинатальный мониторинг» для трехуровневой системы оказания медицинской помощи женщинам в период беременности и родов на основе анализа факторов риска в части патологий плода и патологий матери);
- Экспертные системы компании «АБ Систем»: Электронное Управление Приемом Медикаментов, Система Практического Управления (информационная система, служащая для автоматизированного составления планов и программ лечения, порядка посещения врачей, проведения анализов и прочих исследований, а также контроля выполнения данных планов и программ), Система Расчета Жидкостного Баланса (программный комплекс, предназначенный для управления лечением новорожденных пациентов, которым требуется оказание срочного послеродового лечения) и др.; заказчики: Partners HealthCare, ООО «Прокси Групп Ресёрч», Центр Клинических Исследований, Nadim CRO;
- Сервисы «Взаимодействие лекарственных средств» (часто позиционируются как СППР, что признается не всеми экспертами; сервисы по анализу взаимодействий представлены на портале[9], а также в рамках справочников – rls, vidal).

Отдельные разработки ведутся в вузах и НИИ:

- ИСА РАН (в частности, разработано семейство специальных программных комплексов профессионального и популярного уровней для оценки и прогноза состояния здоровья и характеристик старения человека, а также для выработки рекомендаций и программ профилактики старения и общего оздоровления; Системы внедрены в практику деятельности Национального геронтологического центра и ряда других медицинских организаций, а также в образовательный процесс Московской медицинской академии им. И.М. Сеченова);
- ИТМО (Международная лаборатория «Системы поддержки принятия решений в медицине»; создана на базе Института трансляционной медицины совместно ФГБУ «СЗФМИЦ им. В.А. Алмазова». Объектом исследований лаборатории являются

[9] http://www.medkrug.ru/

модели, методы и технологии создания клинических СППР для персонифицированной медицины);

- Санкт-Петербургский Государственный Университет (разработка экспертной системы медицинской диагностики вариабельности сердечного ритма методом корреляционной ритмографии);
- Томский государственный университет (системы поддержки принятия диагностических и психокоррекционных решений по психосоматическим заболеваниям);
- ИПС им. А.К.Айламазяна РАН (субсидия в рамках ФЦП «Исследования и разработки…» по теме «Разработка новых методов и программных средств поддержки принятия решений в медицине на основе прецедентного подхода, онтологической модели предметной области, унифицированной модели лечебно-диагностического процесса и банка клинических данных», индустриальный партнёр – ООО «Интерин сервис»);
- ИППИ РАН и партнеры (автоматизированная диагностическая система ЭЭГ-ЭКСПЕРТ для описания и хранения данных визуального анализа электроэнцефалограмм, а также для формирования экспертного описания и заключения о функциональном состоянии мозга, ОСГ-ЭКСПЕРТ для выбора тактики обследования и типа операции при отслойке сетчатки глаза и ряд других);
- Рязанский государственный радиотехнический университет, кафедра биомедицинской и полупроводниковой электроники. (СППР для эндоскопии).

В качестве примера программы-тренажера при изучении клинических дисциплин можно назвать НЕФРОТРЕНАЖЕР (система для дифференциальной диагностики заболеваний почек у детей с синдромом гематурии, которая который содержит около тысячи диагностических задач различной степени сложности, позволяющих определить уровень знаний обучаемого).

Как указывалось выше, не все отечественные системы соответствуют современным требованиям к СППР. В частности, таким требованием является использование технологий data mining, text mining и интеллектуального анализа разнородной информации, в т.ч. неструктурированной, для обработки различных источников – контента электронной медицинской карты, истории болезни конкретного пациента, данных с носимых (в перспективе – также инвазивных) устройств, медицинских изображений (результатов применения технологий медицинской визуализации), корпуса научных статей и др.

Следует также отметить неготовность ЛПУ в их нынешнем состоянии в массовом порядке внедрять в свои бизнес-процессы более сложные ЭС последнего поколения.

IX. Заключение

Для разработки системных и компетентных рекомендаций по развитию СППР в отечественной медицине может быть полезно формирование рабочей группы, действующей согласованно с другими рабочими группами (например, по применению суперкомпьютеров и распределенных вычислений для сферы здоровья). При этом необходимо поддержать имеющиеся «точки роста», системы, обладающие практической значимостью, обеспечивая, при необходимости, возможность их интеграции. Перспективными сегментами являются как специализированные системы, так и гибкие, легкие сервисы, позиционируемые как отдельные приложения и интегрируемые между собой.

Для поддержки СППР в медицине необходимо развитие информационной и аппаратной инфраструктуры (обеспечение доступа к высококачественным источникам научной информации, в т.ч. международным, результатам испытаний и т.п., развитие вычислительных мощностей), а также других видов инфраструктуры (правовое обеспечение, развитие профильных акселераторов).

Необходимы меры поддержки развития смежных технологий (искусственный интеллект, обработка больших данных различной модальности и формата, новые способы представления знаний и т.п.; в данной сфере, как представляется, ситуация уже достаточно благополучна и продолжает улучшаться, в т.ч. благодаря усилиям крупных коммерческих компаний, таких как Яндекс, ABBYY, Mail.ru). Также следует уделить внимание развитию программ высшего образования и повышения квалификации в этой области (как для медицинских, так и для ИТ-специалистов, в т.ч. с привлечением к участию в реализации программ производителей программного обеспечения и персональных устройств), популяризации возможностей СППР, в т.ч., в медицинской среде.

Важнейшими элементами развития отечественных СППР могут стать меры по формированию и внедрению отраслевых и технологических стандартов, стимулированию ЛПУ к внедрению таких систем, а также по вовлечению пациента в процесс лечения и заботы о здоровье (сегмент b2c). Так, например, некоторые национальные службы здравоохранения поощряют использование ИС, позволяющих оценивать риск возникновения заболеваний у пациентов (см. также выше про акт HITECH). Представляется, что это создаст «окно возможностей» для отечественных разработчиков, поскольку прямой перенос зарубежных СППР на российскую практику, во многих случаях, невозможен (с учетом особенностей языка, специфики медицинских школ и традиций практики, региональных особенностей, характерных для некоторых заболеваний, и т.п.). Кроме того, драйвером развития СППР может стать распространение персональных устройств в сфере здоровья (за счет необходимости накопления и интерпретации данных). Широкое внедрение простых и интуитивно-понятных систем, реализованных, например, в виде технологически несложных и готовых к широкому использованию облачных сервисов, может дать новые возможности и системе здравоохранения, и гражданам.

Поддержка

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INTELLIGENT DECISION SUPPORT SYSTEMS IN MEDICINE: STATE OF THE ART AND BEYOND

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Intelligent decision support systems in medicine are discussed in the paper. It is shown that the story of the modern decision support systems starts with the expert systems developed in 1970s. Tasks solved by “classical” expert systems and the case study for such systems are represented. The paper proceeds with the discussion on the state of the art in the field of decision support systems in medicine and healthcare in general, as well as on the promising areas in this field. Various types of applications, such as the ones aimed at solving complex tasks in prevention, diagnostics, treatment, patient monitoring and so on are examined. The paper considers more than 50 examples of the intelligent decision support systems in medicine.

Methods and Algorithms for Solution of Problem of Diagnostic Information Gathering

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***Abstract*—This work is devoted to the analysis of methods and algorithms of the solution of a problem of Diagnostic Information Gathering. The general properties of information being processed by the methods and algorithms are revealed. Structured analysis of the methods is submitted in uniform designations.**

Keywords*—*intelligent activity, knowledge base, problem solver, solving method, algorithm, operations.

I. Introduction

Automatization of an intelligent daily activities means support of the intelligent and other tasks solved by specialists. Analysts aim to reveal in daily activities and domain those intelligent subtasks, for which solving methods are known.

An intelligent activity being automated is often related to the solution of a task of management (of control) in widespread understanding - support of a certain mode of functioning of difficult system. Such the support is often covers interpretation, the forecast, planning, modeling, optimization of decisions, monitoring [1]. So in medicine the problem of management of health of the patient is being solved. It is the complex problem similar to management problem "in general", which includes several known tasks: diagnostics, treatment, forecast of change of patient state, observation (monitoring).

During the decades of AI techniques a number of methods and algorithms of solving such problems are suggested - both specific and universal. Their analysis shows existence in algorithms of the solution of similar operations (search and comparison of information, designing of fragments of decisions). There are differences depending on number of types of relations in the used model of knowledge, from used heuristics, from the factors influencing hypothesis (solution).

However the methods of heuristic search are presented and classified in literature at too abstract level (Depth-First Branch-And-Bound, Recursive Best-First Search, etc.), and at the detailed level are presented for specific tasks in concrete subject domains. This makes it impossible to develop and accumulate of software solutions (components) for use in constructing systems for decision intellectual tasks.

Therefore the structured analysis of methods and algorithms for decision of practically useful intelligent tasks and identification inside them a reusable operations is issue of the day. And the purpose of this work is to give structure for describing methods and algorithms for their uniform representation and to demonstrate such representation on the example of one practically useful intellectual task.

II. Problem of Diagnostic Information Gathering

Medicine - a typical example of subject domain with a number of complex and responsible tasks of various types, where many expert systems (research prototypes) were created. After patient's Information Gathering the doctor makes decisions on the diagnosis, its treatment and the forecast of change of the patient's state as a result of medical actions. On the basis of this forecast further monitoring is being planned. If results of such observation don't correspond to the forecast, solutions on correction of the diagnosis and/or the plan of treatment are being accepted which changes the forecast, etc

In medicine there are expert systems both for the solution of separate tasks, and for several. As a rule, ES support a problem of diagnostics, offering additional useful hypotheses that it is very important as doctors often "are fond" of a narrow set of hypotheses. The set of hypotheses being expanded by means of ES more likely (ideally – with guarantee) contains the correct hypothesis. To reveal it, the expanded set of hypotheses has to be reduced further by careful analysis of knowledge and selection of symptoms capable for differentiation of hypotheses with guarantee.

In some publications the need of definition what information isn't enough to decide the problem is mentioned.

This task is considered important, at the same time without separating it from a problem of diagnostics, but devoting to it separate steps in decision algorithms such researchers as: Weiss S. M., Kulikowski C.A., Safir A., 1978; Patil R.S., Szolovits P., Scwartz W.B., 1982; Pople, H. E., 1982; Soltan R.A., Rashad M.Z., El-Desouky B., 2013 [2], [3], [4], [5].

Diagnosis consists of two fundamental activities: the generation of one or more differential diagnoses (each for a separate problem area), and the resolution of individual differential diagnoses) [2].

Thus, search of "way" to reduction of a set of hypotheses – a problem of request of additional information for recognition – a separate task in the offered earlier multilevel classification [1]. Its essence follows. If for any situation represented by some results of observations there are more than one hypothesis of the diagnosis (about a class), then it is required to offer additional observation which will allow to reduce a set of hypotheses.

The major components of task of Diagnostic Information Gathering (request of additional information for recognition of diagnosis) can be summarized as follows:

Givens:

- R (system' case findings and characteristics), such that the cardinality of set of hypotheses (HR) for them not less than two.

Goals:

- to find such request (Q) of additional information for results of R that if R' = R plus the answer to this request (AQ), then a new set of hypotheses of HR' has the smaller cardinality than a set of hypotheses of HR.
- KB - knowledge base meeting a condition of separation of classes.

Constraints:

- all assertions of KB are concordent to findings and characteristics;
- R coordinated with domain ontology.

III. The review of the offered methods

Some approaches and methods of the solution of the Diagnostic Information Gathering problem and realization of these methods are described in science literature. In order to make use of the available experience of creation of solvers of this task for programming of problem-oriented solvers (as intelligent systems' components) or domain-oriented software services solving different tasks, it is important to compare the basic data of a task, required result, structure of knowledge model and the scheme of an algorithm.

In our list of representations of methods the methods and algorithms published during the period "1978 - 2014" are analysed [2], [3], [4], [5].

Example of representation of one of methods from this list follows.

A. The name

Differentiate, Confirm and Explore.

B. The authors

Patil R.S., Szolovits P., Scwartz W.B., 1982.

C. The terms

patient, disorder, useful differentiator.

D. Task inputs

1) s_i - the found violation(s) (i.e. a state or internal process);
2) R_Σ - observation results, known manifestations of found violation;
3) $H_{R,KB,\Sigma}$ - a set of hypotheses h_j, which cardinality not less than two.

E. Required result

Q - signs required for differentiation - one $signName_i$ or several $signName_i$ and

their explanation (model of relations of the signs $signName_i$ and found disorders, violations S_i and differentiable diseases $h_j = disease_i$.

F. Structure of knowledge model

$KB = KB^{cause} + KB^{act} + KB^{cntx} + KB^{terap}$ - multivarious relations between various aspects of the reason (usually internal process of a f_{in}) and effect (an external sign f_{ex} or internal process f_{in}), taking into account of context and assumptions.

G. Scheme of an algorithm

Preliminary stage:

(* Check whether all hypotheses (disease-i)

are related with different plans of treatment *)

Cycle for h_j from set H_R:

find $plan_j(inKB^{terap})$ for h_j;

add $plan_j(fromKB^{terap})$ to set of plans;

end-cycle

check uniqueness of elements of a set of plans.

Main algorithm:

(* for each hypothesis *)

Cycle for $h_j fromset H_R$:

$disease_j = h_j$;

(* to find influences of a disease (hypothesis)

on the found disorders *)

construct (by KB^{cause}) chains of relations

from $disease_j$ to s_i:

$\langle f^{in}_{j-i1} = disease_j, f^{in}_{j-i2}, f^{in}_{j-in}, s_i \rangle$

(* for each element - not - a sign in each of such

chains of communications *)

Cycle for f^{in}_{j-i}

(* to find its influences on un-detected external signs *)

find (by KB^{cause}) relations

from f^{in}_{j-i} to f^{ex}_u

(¡ $f^{ex}name_u, f^{ex}value_u$ ¿),

not coincident with any $r_u \in R_\Sigma$,

(* among undetected external signs *)

Cycle for all couples of f^{ex}_{u1} and f^{ex}_{u2}

(* to find a differentiator *)

If ($f^{ex}Name_{u1} = f^{ex}Name_{u2}$,

but $f^{ex}Value_{u1} <> f^{ex}Value_{u2}$)

then

add $f^{ex}Name_{u1}$ to Q

end-cycle

(* to find influences of a hypothesis-disease

on un-detected disorders *)

find (by KB-cause) relations from

f^{in}_{j-i} to s_u, not coincident with any $s_u \in Si$,

(* for each such disorder *)

Cycle for s_u

(* to find its influences on

un-detected external signs *)

find (by KB^{cause}) relations from s_u to f^{ex}_u

(¡ $f^{ex}name_u, f^{ex}value_u$ ¿),not

coincident with any r_u from R_Σ;

(* among un-detected external signs *)

Cycle for all couples of $f^{ex}_u 1$ and $f^{ex}_u 2$

(* to find a differentiator *)

If $f^{ex}Name_{u1} = f^{ex} - Name_{u2}$,

but $f^{ex}Value_{u1} <> f^{ex}Value_{u2}$

Then add $signName_{u1}$ to Q

end-cycle

end-cycle

end-cycle

end-cycle

IV. Basic computing operations

The description of known methods in the specified structure allows to reveal numbers of computing operations presumably sufficient for designing of problem solvers of each type – so problem-oriented (for example, diagnostics), as domain-oriented (for example, medical diagnostics), including domain-and-method-oriented (for example, medical diagnostics by the method of Patil).

On basis of analysis of known algorithms the set of the required computing operations operating with information from input data and the stored model of knowledge are revealed. The examples are follows:

construct chains of relations from this disease to disorder sign

(input:

disease,

sign,

KBcauseName;

result: set of chains);

find not-found manifestations related with the specified internal processes

(input:

f-in-j-i,

observedResults,

KBcauseName;

result: set of f-ex-u);

find among two static manifestations distinction of its values at similarity of its names

(input:

f-ex-u1,

f-ex-u2;

result: boolean);

etc.

The revealed set of computing operations is designed to facilitate designing of reusable problem solvers, and they, in turn to facilitate design or construct of intellectual systems (from ready solvers, actual knowledge bases and user interface). Domain-oriented solvers of tasks can be created from problem-oriented solvers (for example, by ≪cloning≫ problem-oriented solvers and carrying out some modification).

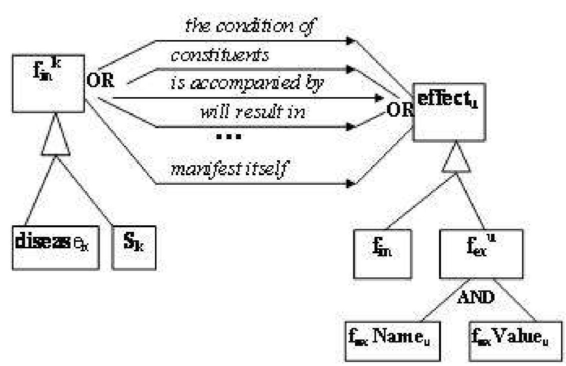

Figure 1. The semantic network for causal model

V. Discussion

An Using in development of viable intelligent systems of a declarative (not rule-based) KB dictates need of designing reusable components other than inference machine and universal means for explanation.

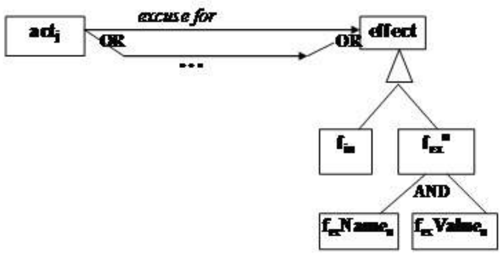

Figure 2. The model of influence of external impacts on signs or internal processes

Figure 3. The model of matching of plans of treatment to diseases

In spite of the fact that long ago distinctions between types of tasks are determined, reusable components for programming solvers at least of some classic tasks aren't offered. The leading collectives have designated as opportune "the researches on development reusable components allowing to perform flexible adjustment on various tasks of one type" [6], meaning "procedural PEAK which are embedded in intelligent application".

Within the conducted research a classification of methods solutions of tasks and their structural description designed to become a basis for development of solvers of tasks of search of hypotheses are proposed: recognitions, a request of the additional information for recognition, forecast, monitoring, linear planning, diagnostics, forecast of result of impacts, planning of management, etc. Such solvers of tasks are problem-oriented and presumably domain-independent (what will be a subject of a further research). The result of such research will mean big or smaller degree of a reusability. An implementations of an operations revealed in the known methods of the tasks solutions become candidates on above-stated "procedural reusable components"

It is expedient to implement the revealed set of computing operations as software agents of IACPaaS platform [7] for reusing during designing cloudy tasks solvers.

VI. Conclusion

The format of representation of results of the analysis of methods and algorithms for the known classes of intellectual tasks is offered. The structure of representation of groups of methods (for one problem task) includes the following parts: problem statements; the uniform designations used for terms; list of representations of methods; the general set of the operations of processing used by different algorithms; a generalized unified model of knowledge necessary for realization of the presented algorithms. The format of representation of methods and algorithms of the solution of tasks includes the following elements: authors (of a method), terms list, an input data of a task, an expected result, a structure of knowledge model; scheme of an algorithm.

In the planned sequence of tasks for which it is necessary to carry out the structured analysis of decision methods (from the point of view of the practical importance) the task of Diagnostic Information Gathering (request of the additional information) became the first. Further tasks will follow: recognitions, diagnostics, monitoring, management planning, forecast of impacts' results.

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МЕТОДЫ И АЛГОРИТМЫ РЕШЕНИЯ ЗАДАЧИ ЗАПРОСА ДОПОЛНИТЕЛЬНОЙ ИНФОРМАЦИИ ДЛЯ РАСПОЗНАВАНИЯ

Клещев А.С., Шалфеева Е.А.

Данная работа посвящена анализу методов и алгоритмов решения задачи запроса дополнительной информации для распознавания. Выявлены общие свойства используемой и обрабатываемой методами и алгоритмами информации. Введены единые обозначения терминов для единообразного представления методов, построена единая обобщенная модель знаний. Структурированный анализ позволяет выделить общее множество операций обработки, используемых разными алгоритмами. Для таких операций целесообразно реализовать типовые программные компоненты, из которых могут конструироваться конкретные решатели известных и новых задач. Тем самым обеспечивается многократное использование методов и алгоритмов реализации известных интеллектуальных подзадач.

Ontology-based Design of Batch Manufacturing Enterprises

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***Abstract*—The paper discusses the current, tactical and strategic aspects of increasing the industrial control level and uses batch manufacturing enterprise JSC «Savushkin product» as an example. Proposed ontological approach to the design of such kind of enterprises is based on the hierarchical system of formal ontologies built from a certain standard. In particular, we discuss the principles of formalization of standards on which the enterprise activity is based using the ISA-88 standard as an example.**

***Keywords*—ontology, subject domain, ontology-based design, intelligent system, Ontology of designing intelligent systems, batch manufacturing enterprise, formal ontological model, ISA-88 stadard, enterprise physical model**

I. Introduction

A. Objective and Relevance

This article considers tactical and strategic aspects of improving industrial control on the example of batch manufacturing enterprise JSC «Savushkin product». These studies are relevant due to the fact that without state-of-the-art automation and without its rapid improvement, modern enterprises can not be highly competitive.

The purpose of this article is to build ***an ontological model of batch manufacturing enterprise*** to improve industrial control quality of such enterprises and their ability to adapt to a constantly changing environment.

B. Requirements for Industrial Control Instrumentation of the Modern Enterprise

Automation tools of modern enterprises must quickly adapt to any changes in production itself – to expansion or reduction of product output, changes in the product nomenclature, changes in the equipment used, changes in the production structure, changing relationships with suppliers and customers, changes to the regulatory legal acts (including standards), which the company must comply with, to various emergencies. Adapting industrial control to all types of businesses changes and to changes in its interaction with the outside environment requires change to the business model first. These changes must fully reflect the current status of its activity.

Automation tools of the modern enterprise must be flexible enough not only for rapid adaptation to the reconfiguration of the production lines, but also for prompt changes and continuous improvement of said automation tools. It is essential not only to decrease the laboriousness of improving the industrial control level, but also to maintain a high rate of improvement. Well-thought-out process of transition from one level of automation to the next, during which both old and new version are used, is necessary, as well.

Current industrial control system operation and its continuous improvement process requires a coordinated and efficient cooperation between employees. The basis of such interaction is a well-structured, fairly complete business model, which can be updated on-the-fly. It should reflect all aspects of the current structure and activity of the enterprise, as well as approved and discussed plans for its development. Such kind of integrated model is called enterprise knowledge, which should be managed (produced, stored, updated, distributed, etc.) [38], [18].

Improvement of the industrial control level assumes a significant increase in the number of automatic or automated tasks. This, in turn, calls for automated solutions to intellectual problems, i.e. the use of artificial intelligence technologies. Intellectual problems to be solved in the enterprise include:

- analysis of manufacturing situation (including emergencies);
- decision-making at different levels;
- planning behavior in difficult circumstances;
- creating and maintaining documentation;
- training new and current employees;
- etc.

In order to ensure the widespread use of artificial intelligence technology in factory automation, all the corporate knowledge of the enterprise must be represented using a formal knowledge representation language. At the same time, this language should be useful not only for the intelligent computer systems, but also for employees. This means that the formal language of enterprise knowledge representation must be clear, concise and understandable not only for intelligent computer systems, but also for employees.

C. Problems that Need to be Addressed

- Existing industrial control instrumentation is expensive, difficult to learn and adapt to the specific manufacturing process. Typically, such tools, on the one hand, can only be applied to a limited class of problems, but, on the other hand, developers strive to make these tools as universal as possible, extending them with domain-specific solutions. This leads to the bulkiness and complexity of such systems;
- As a consequence of this approach to extending functionality, existing industrial control instrumentation has low flexibility (limited ability to make changes to it), resulting in a significant overhead in the adaptation of such tools to the new requirements. As a rule, changes in these tools require (often a third-party) developer intervention, which leads to significant costs in both time and money. Due to these problems, not every enterprise can achieve and maintain a high level of automation, even if there are appropriate solutions available in the market;
- The absence of common unified models and tools for building industrial control systems leads to a lot of duplicate solutions, both within industry as a whole, and within company in particular. This situation often arises when some special systems that solve particular problems within an enterprise, are incompatible with each other, which leads to additional implementation costs of coordination mechanisms (e.g., data format conversion);
- The absence of such models prevents further enhancements to the industrial control automation instrumentation, in particular in the field of automation of decision-making in emergency situations and event prediction;
- Industrial control systems are highly dependent on their developers. This leads to adoption and maintenance problems when developer staff changes;
- Lack of formal models of various standards governing industrial control and other enterprise activities leads to possible difficulties in the interpretation of certain regulations, in personnel training, and in business operation. Finding necessary information in a large volume of documentation can be difficult. Besides, this fact makes it difficult to perform compliance testing of the company and its divisions.

D. Analysis of Existing Approaches to the Aforementioned Problems

Currently, there are a number of approaches oriented at improving industrial control systems and their flexibility for various types of enterprises. We will now discuss some of them, in particular those that influenced the development of the approach proposed in this paper.

1) Enterprise Knowledge Management Models: Enterprise knowledge management is a systematic process of identification, use and transfer of information and knowledge, which are created, updated and used by people. During this process, company constantly generates, stores and uses knowledge in order to obtain competitive advantages, thus forming the intellectual capital of the enterprise [29]. In today's economy, difficult to replicate knowledge, represented in any form, should be considered as an important asset, since it is the source of competitive advantage. Thus, the focus is not the creation of knowledge, but their use and their flow within the company [19].

Enterprise knowledge management is currently implemented in the form of knowledge management systems. Methods and technologies of their construction are discussed in [37].

Main challenges in the enterprise intellectual capital management are due to the fact that at present there are no generally accepted models of its structure [34].

Current theories of the intellectual capital management concern particular spheres of management activity and do not structure knowledge in a way that allow for their effective use and transformation. [29].

The most recent trend in the formalization of enterprise knowledge accumulation and management processes is to construct their models using the ontological approach.

2) Enterprise Ontological Models: Ontological models, as the basic approach to designing various systems, is widely used nowadays [17]. In particular, researchers identify a special subject domain called "Enterprise ontologies" [38]. Proposed approaches amount to constructing a number of ontologies that describe the activities of an enterprise or its subdivisions. When necessary, various kinds of knowledge can be included in these ontologies to describe various aspects of the company activities.

Applying an ontological approach to structuring knowledge allows the enterprise to use this knowledge more effectively. It significantly decreases the complexity of updating the knowledge to adapt them to solving new problems, accelerates and simplifies the process of training new staff [20].

A number of studies examined the use of the ontological approach to solving domain-specific problems of some enterprise [25].

However, existing approaches share a number of common disadvantages:

- lack of a unified, universal representation of various classes of enterprise knowledge;
- lack of a unified approach to separation and development of ontologies, which, along with the previous point, often leads to the impossibility of integration and reuse of ontologies developed within an enterprise or even within different subdivisions of the company;
- lack of a unified approach to the construction of ontology hierarchy limits the possibility of constructing a complex interconnected system of ontologies, that is able to describe the enterprise with the necessary amount of detail.

3) Multi-agent Enterprise Models: Currently, multi-agent model is widely used in the design of industrial control systems of various levels. This approach is convenient and widely used because of its similarity to the real processes taking place in the enterprise. Indeed, in the classic multi-agent system for the agent refers to a subject, usally active and capable of interacting with the environment [13], [35]. Being united in groups, such agents are able to solve problems much more complex than could be solved by one agent. The advantages of multiagent approach include the ability to build distributed multi-tier systems on its base.

The most obvious interpretation of this kind of model, as applied to a particular enterprise, is to consider its employees as the agents, each of which is able to solve a certain class of problems and has to internally coordinate their actions in order to achieve a common goal. The hierarchy of structural units of a specific enterprise can determine hierarchy levels of agents belonging to relevant departments or shops. Furthermore, methods of organization and management, designed for multiagent systems can be used in the model of an enterprise built in such a way.

In particular, the [5] has introduced higher-level agents (meta-agents). Their task is to gather information from lower-level agents and coordinate them. Similar ideas are expressed in [14]. In the papers [11], [2], options for automatic selection of the optimum mechanism for the coordination of agents to achieve a common goal are presented. It also offers social and psychological models of coordination of agents activities, for example, based on some general «laws» [15].

Aside from the obvious aforementioned points, there are other areas of the application of multi-agent approach to building enterprise model or some of its parts. In particular, [Baker, 1998] provides an overview of similar solutions in the industrial control. In the [Leitao, 2013] paper the approach to optimize the operation of specific equipment through the integration of various optimization algorithms based on agent systems is shown. A more general overview of the agent-oriented approach in the enterprise is given in [10].

Currently, however, the principles of hierarchical multi-agent systems in which some agents may be included in other agents, which in turn, may also be components of other higher-level agents, are insufficiently investigated. This fact greatly complicates building of a common multi-level hierarchy of agents to describe the enterprise with various levels of detail, from an enterprise-wide model to the equipment and personnel of a specific shop or subdivision.

Another disadvantage of the multi-agent model is the lack of uniformity in the construction of formal models of agents and the orchestration of their interaction that prevents the use of similar solutions at different levels and gives rise to the additional overhead.

4) Situational Control Models: The term "situational control" first appeared in the works of D.A. Pospelov [30]. Then this line developed by him and his students and followers, which is reflected in [26], [31]. The basic idea of situational control is that there is no universal approach to management, in different problem situations it is necessary to take into account various factors influencing their decision-making strategy, thereby achieving effective decision-making.

Currently, this area of science is experiencing a kind of rebirth associated with the relevance of the proposed approach it in the management of various processes in enterprises, both directly in the management of manufacturing processes, and in resolving arising emergency situations. In particular, [28] discusses the possibility of using situational control in the energy sector. A number of papers discuss usage of the ontological approach in the implementation of situational control[33], [36].

Therefore, models and methods of situational control can be used in the construction of the ontological model of the enterprise to increase the efficiency of solutions intended for specific manufacturing situations, including emergencies.

5) Business Process Re-engineering Models: Business process re-engineering is the fundamental rethinking and radical redesign of business processes of enterprises to rapidly improve key indicators of their current activities: cost, quality, services and rates [4].

Re-engineering process is based on two basic concepts: "future corporate identity" and "business model". The future corporate identity is a simplified image of the original, reflecting its main features, and omitting the minor details.

Business model is a presentation of the main business processes of the company in their interaction with the company's business environment. Business models allow to identify the characteristics of the basic processes of the business unit and the need for re-engineering [16].

Thus, the object of re-engineering is not an organization, but the processes occurring in these companies.

To increase the efficiency of re-engineering, it is necessary to:

- allow the construction of formal models that describe the company with different levels of detail, including a description of all the processes taking place in the enterprise;
- ensure unification, integration and hierarchical organization of these models.

The main disadvantage of all of the above models is that none of them are sufficiently complete and comprehensive. Enterprise model should be an amalgamation of all of the aforementioned models to adequately represent all of the aspects of real enterprises.

E. Underlying Principles of the Proposed Approach

At the heart of our proposed approach to problem solution based on the following principles mentioned above:

- The company is viewed as a distributed, intelligent socio-technical system, which is based on well-structured enterprise-wide knowledge base.
- All of the above models (knowledge management, ontological, multi-agent, business process re-engineering) are integrated within the enterprise knowledge base.
- The enterprise is viewed as a hierarchical multi-agent system. Agents of such an enterprise include employees and software agents. Hierarchical organization of multi-agent system means that agents can be non-atomic (represent a group of interacting agents). Such structures can be infinitely nested.
- A complex of informational and physical tools, which ensures functioning of the company is made available as the integrated distributed intelligent system. We call it the ***enterprise intelligent system***. Primary users of this system are company employees;

- Enterprise ontology model design boils down to the design of the ontology-based model of an *enterprise intelligent system*. This ontology-based model of the enterprise is both the object and the result of its design.
- We propose to use the ***OSTIS technology*** [21], [22] to implement enterprise-wide intelligent systems. This means:
  •• Various kinds of knowledge are represented using unified, universal representation language – ***SC-code***;
  •• Developing a system boils down to developing its model in SC-code language (***sc-model***), which is then interpreted by one of the interpretation platforms.
  •• The knowledge base is a hierarchical structure that allows to store knowledge with various levels of detail. It is especially so with a hierarchy of ***subject domains*** and the corresponding ***ontologies***. [24].
  •• Tools for collaborative knowledge base and knowledge processing machine design are included in the technology.
  •• Knowledge processing model is based on multi-agent approach, which allows to build parallel asynchronous knowledge processing machines.It also allows to integrate various specific models of knowledge processing in a single system.
  •• All agents interact solely through the shared sc-memory, which stores SC-code structures. This approach ensures flexibility of the system and makes it possible to solve various problems in a parallel fashion [39].
  •• Agent programs are developed using an internal, inherently parallel language – SCP (Semantic Code Programming). It uses SC-code for representation of its texts. This ensures platform independence of agent programs.

F. Tasks to be Resolved for Proposed Approach Implementation

- Develop a unified structure of the integrated knowledge base of the enterprise intelligent system, represented in the form of a hierarchical system of subject domains and the corresponding ontologies. Subject domains, that are covered by the enterprise-specific standards, are a crucial part of it.
- Develop a knowledge processing machine model [39] of enterprise intelligent system.
- Develop user interface model [27] of enterprise intelligent system.
- Develop an information service model for different categories of users of enterprise intelligent system.
- Develop a model of enterprise intelligent system knowledge base engineering and re-engineering support tools.

At this stage, the work focuses on developing an ontology-based model of knowledge base, in particular, of those subject domains, that are covered by the fundamental standards. This is due to the fact, that the formal representation of those standards is the basis for coordination of all the key aspects of the company activity. Besides, it allows to build an all-encompassing ontological model of an enterprise and of its individual components.

To prove their relevance, we will now take a look at the current state and the history of the industrial control system development of a specific enterprise.

II. History and current industrial control state at JSC «Savushkin product»

In the late ’90s, the company faced a need to seriously upgrade itself to become a leader not only inside domestic market but also in Russia. Because of lack of finances and weak state of existing solutions, usage of third-party automation software systems was rejected but decision about own development was made. The goal was to develop a multipurpose framework as base for not only industrial control, but also for accounting, warehouse, etc. A small group of developers thus started to work on a SCADA system, which was later named EasyServer. The first EasyServer-based project performed temperature control of tanks inside the apparatus shop.

After the successful project launch we have confirmed the efficiency of the decisions we made. Some new projects were implemented afterwards – CIP station, milk acceptance shop, dried milk shop. These projects were successfully developed in spite of some difficulties. As a result, the SCADA-system EasyServer became the main development tool.

The automation level is constantly growing with the system development. Data acquisition from different sensors (volume, pressure) was developed first. Technological operation and devices control were implemented next. In the future, the batch production level is to be added.

CODESYS from 3S-Smart Software Solutions for WAGO controllers is also used as development tool . It is a free tool, can be used for the development using engineering languages for programmable logic controller (IEC 61131-3) – IL, LD, FBD, SFC, ST. Automation engineers use this approach to develop quite simple autonomous projects (milk accepting stations) without using help of programmers. Implemented projects are integrated into the system using open MODBUS TCP communication protocol.

Communication between individual projects (own, as well as third-party) also needs to be addressed to ensure effective operation of the shop. But there is no universal approach – some projects use MODBUS TCP, others use additional controller, like a communication gateway. Besides, physical connections for signals exchange are sometimes used. All this further complicates the system. Using in-house design for projects and the whole system has these advantages:

- Fast project development speed. All functionality accumulated during the development becomes part of the system. Now typical project gets done literally by one automation engineer over several hours. This allowed to implement over 200 projects to date.
- The relative cheapness of the in-house developed Easy-Server SCADA. Despite the costs of maintaining of the skilled development team, it proved to be much cheaper than a third-party solution. For example, typical Siemens based project (CPU 315-2 PN/DP, software STEP 7 and WinCC Basic, SCADA WinCC) costs nearly 9000€, while solutions from Wago and EasyServer (excluding development costs, PAC PFC200) cost less than 2500€(prices are as of November 2016).
- A comprehensive functionality of the EasyServer system. System features are comparable to commercial counterparts (Simatic Step 7 + Simatic WinCC), despite limited

resources. It is achieved by a very tight integration with the actual production.

Disadvantages of the current industrial control state implementation:

- Data presentation is implemented as a relatively simple reports. At the launch of the first projects the reports have been implemented as separate applications written in Delphi. Table data from the project server were exported to MS Excel via BDE. Later, in 2008, a FastReport Server report generator was purchased. During its usage developers were experiencing problems with insufficient system functionality and the end of support by the developer. At the moment, decision to organize the data processing (and reporting as well) at a higher level was made, and the control system level now only keeps basic projects reports. The question of the upper level platform (enterprise level in general – ERP) for reporting task solutions is therefore open.
- Since priority was given to (and is now given to) the development (and modification) speed, there is a relatively low level of the system-wide documentation, which is true for individual projects, as well. Therefore solutions, which becomes part of the designed system documentation, are required. For example, during the development of the documentation for the project "Hutorki" (2007) resulting MS Word file had a size of about 40 pages, containing picture inserts of various charts, descriptions of operations, etc. The functional automation chart and the layout description of cabinets were made in MS Visio. The IO modules description have been made in an in-house WagoEditor program which is able to export its outuput to MS Excel. The development of the first documentation version took a few days of one developer's time. The project is being upgraded every year, at the same time the process of making changes to the current version of the documentation takes about the same time as the development of the new one. Updating the documentation every time requires redrawing the circuits, developing communications within the projects, etc. The variety of data sources and formats, as well as their need for manual coordination makes matters worse. Thus, now the description of the functional automation chart, electric parts and design specifications are made in the Eplan CAD. Description of the technological process also made in Eplan CAD, but it is kept separately in the form of Lua scripting language script. Description of certain devices (frequency converters, valves) is stored in PDF format, and comes from the manufacturers.
- Limited time for testing and debugging. Current market state and extreme modern design methods are constantly accelerating pace of startup projects, resulting in no debugging time. The newly developed functionality has to work literally yesterday. Therefore, there is a great need for diagnostic and self-test modules for the projects.
- There is a growing enterprise automation coverage. Now it is not only individual shops, but also the whole enterprise. Therefore, the control system has to operate not on the level of "operator" – "human machine interface" – "separated technical process", but on the "production logistics manager" – "Intelligent web interface" – "the whole plant" level.
- Modern production conditions dictate strict rules for continuous reduction of the human involvement, so the introduction of robots (industry robotization) is an essential part of the development. Integrating robots and control systems into the enterprise-wide system as-is is very expensive, both from human and from financial standpoint. Thus, there is the need for solutions that can be integrated in a familiar way. They will allow to implement new manufacturing processes robotization projects, which indicate movement towards what is essentially a human-less industry.

For the successful integration into the world-wide market, it is desirable today, and certainly required in the future, to lead the organization of production in the "Savushkin Product" company in line with international standards (in particular, with the ISA-88 standard). However, standards can be a deterrent – they are bulky, relatively slow to develop, there are problems with their interpretation. Direct implementation attempt may require unreasonably high costs. Therefore, to bring the enterprise processes in line with international standards, it is necessary to use a more flexible production management, as well to more flexibly account for the standards' evolution.

III. Standards governing the company activities, and their formalization

A. General approach to standards formalization

Ontological approach to designing an enterprise is based on the standards formalization. Every standard is considered an *ontology* of a corresponding *subject domain*, which serves as a base to automated solution of a number of tasks, some of which include information services for employees, formal assessment of conformance to the standard, etc.

One of the most important problems when incorporating standard into an enterprise is a possibility of having multiple interpretations of some parts of a standard. Such interpretation has to be constantly adjusted to match the intent of the original document. Besides, there are some peculiarities of implementing standard into any given enterprise. Since every standart evolves constantly, it has to be updated accordingly. This causes changes to the enterprise structure and activity management to ensure standard compliance.

One way to solve such problems is by constructing its formal semantic model, which could be equally interpreted by a computer system and a human alike. Formal semantic model representation of a standard is not a standard itself – it is a subjective interpretation of a standard by a developer of a given model. At the same time, formal semantics-based representation of a standard provides a constructive ground for its mutual approval. Such representation also ensures clarity and unambiguity of its interpretation. Formal semantics-based representation of a standard ensures a substantial simplification of making changes to such representation, as well. These changes may be necessary due to the clarifying of its interpretation or due to the evolution of the standard itself. Given simplification is due to the fact, that in semantics-based representation of any kind of knowledge, including standards, signs of all entities and their relations are represented only once. This means, that changes to them are localized within knowledge base, unlike in the natural-language texts, where such relations are not explicit and therefore are hard to establish and maintain.

Formal semantics-based representation of a standard allows to supplement it with various kinds of didactic information (examples, explanations, analogies) to improve employees' comprehension of a standard, without changing the structure of said representation.

Constructing a formal model of a standard amounts to constructing an *integrated formal ontology*, which specifies the corresponding *subject domain*. It is necessary to translate structure and contents of a source document to a hierarchy of *subject domains* and corresponding *ontologies*. Isolating subject domains allows to localize solutions for tasks and problems within a small subset of a knowledge base. In other words, search for a solution of a task (problem) from a certain subject domain is limited to this subject domain.

Ontological approach to constructing a formal model of a standard allows to build an intelligent help system for this standard by implementing intelligent knowledge processing agents. Such system can provide a wide range of information services to its users, including ability to answer a variety of questions, answers for which may not be explicitly expressed in the text of a standard or are hard to find in such a text. Examples of such questions include:

- What is entity X?
- What is X needed for?
- Which entities are necessary for X?
- How entities X and Y are connected?
- What caused event X?
- What will happen if X?
- etc.

X, Y may be the names of a certain objects, situations, events, etc.

We will now formalize a specific standard using this approach.

B. ISA-88 formalization

Among multitude of standards governing manufacturing activities of enterprises, there is ISA-88 standard [7], which best covers the specifics of a batch manufacturing enterprises, such as JSC «Savushkin product».

The main virtue of ISA-88 is the decomposition of a batch manufacturing subject domain into a set of independent subject domains of recipes, equipment and control [12]. Such decomposition allows company specialists to solve their problems within a strictly defined subject domain, abstracting away from the rest. This fact fundamentally ensures flexibility of batch manufacturing and serves as a basis for constructing an ontology-based model of an enterprise.

ISA-88 consists of four parts, but the first one is particularly valuable for constructing formal ontology, since it provides terminology and a consistent set of concepts and models used in batch control. From now on, we will focus on Part 1 of ISA-88.

ISA-88 Part 1 document structure includes 6 sections

1) Scope of the standard
2) Normative References
3) Definitions
4) Batch Processes and Equipment
5) Batch Control Concepts
6) Batch Control Activities and Functions.

Document structure translates to a hierarchy of *subject domains* and corresponding *ontologies* as described. ISA-88 as whole corresponds to a ***Subject domain of batch manufacturing enterprises***. First two sections specify a document and do not concern the description of a subject domain of batch manufacturing enterprises and, therefore, do not map to any part of the hierarchy of subject domains and ontologies. Section 3 corresponds to a terminological ontology and a logical ontology [24] of ***Subject domain of batch manufacturing enterprises***. Subsection 4.1 corresponds to the ***Subject domain of process models of batch manufacturing enterprises***. Remaining subsections of this section correspond to ***Subject domain of physical models of batch manufacturing enterprises***. Section 5 corresponds to ***Subject domain of procedural control models of batch manufacturing enterprises***. Section 6 corresponds to ***Subject domain of batch control activities***.

Hierarchy of basic subject domains can be formally represented using SCn language [6] as follows:

Subject domain of batch manufacturing enterprises
=> *partial subject domain**:

- *Subject domain of physical models of batch manufacturing enterprises*
- *Subject domain of process models of batch manufacturing enterprises*
- *Subject domain of procedural control models of batch manufacturing enterprises*
- *Subject domain of batch control activities*

Here are the ***structural specifications*** [24] of partial subject domains, represented using SCn language.

Subject domain of physical models of batch manufacturing enterprises
∋ *maximal class of research objects'*:
equipment entity
∋ *non-maximal class of research objects'*:

- *process cell*
- *unit*
- *equipment module*
- *control module*
- *enterprise*
- *site*
- *area*
- *equipment relation*

∋ *researched relation'*:
*contains**

Subject domain of process models of batch manufacturing enterprises
∋ *maximal class of research objects'*:
process element
∋ *non-maximal class of research objects'*:

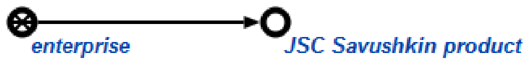

Figure 1. JSC «Savushkin product»

- *process stage*
- *process operation*
- *process action*

∋ *researched relation'*:
*process element link**

Subject domain of procedural control models of batch manufacturing enterprises
∋ *maximal class of research objects'*:
procedural element
∋ *non-maximal class of research objects'*:

- *process cell procedure*
- *unit procedure*
- *operation*
- *phase*
- *recipe procedural element*
- *equipment procedural element*
- *recipe process cell procedure*
- *recipe unit procedure*
- *recipe operation*
- *recipe phase*
- *equipment process cell procedure*
- *unit procedure*
- *equipment operation*
- *equipment phase*

∋ *researched relation'*:
*execution order**

We will now discuss examples of enterprise physical model description of JSC «Savushkin product» based on the terminology introduced in ***Subject domain of physical models of batch manufacturing enterprises***.

IV. Physical model of JSC «Savushkin product»

One can specify an enterprise in various aspects, some of which (processes, procedures, equipment and control) are governed by ISA-88 standard. As was mentioned in the previous section, these aspects correspond to hierarchically organized subject domains. To illustrate this, we will provide a fragment of JSC «Savushkin product» specification within a *Subject domain of physical models of batch manufacturing enterprises*. This specification has seven levels: enterprise, site, area, process cell, unit, equipment module, control module. We will start from the enterprise level.

A. Enterprise level

Enterprise is a largest manufacturing unit, which usually means company as a whole. In our case, we have JSC «Savushkin product» at the enterprise level. Formal representation of this fact is provided in Fig. 1. From now on we will use SCg language [6] for formal representation

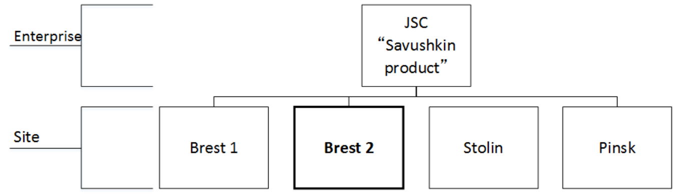

Figure 2. Areas of JSC «Savushkin product»

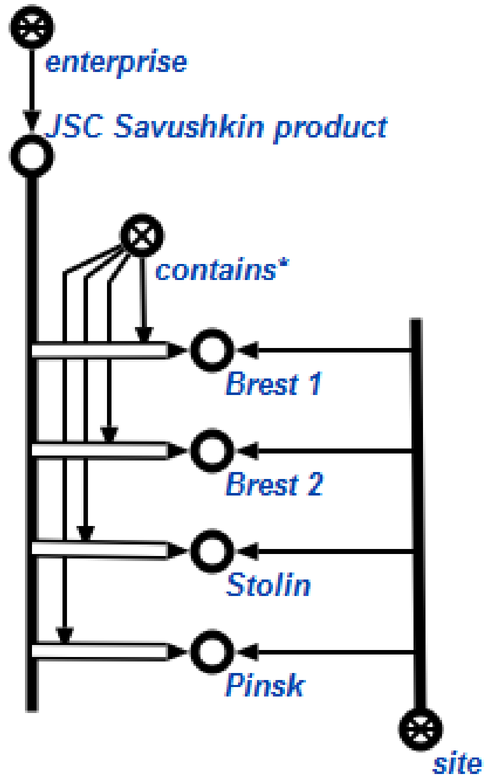

Figure 3. Formal representation of a connection between top two levels of a physical model

B. Area level

Enterprise consists of one or more areas. Area boundaries are usually determined based on geographical approach. Areas of JSC «Savushkin product» are shown in 2. Formal representation of this information is shown in Fig. 3. «Brest 2» area will now be considered (it is emphasized in Fig. 2).

C. Site level

Area contains one or more sites. As per ISA-88, not every part of an area will be a part of a site. Only those directly related to batch manufacturing process will be considered as a part of a site.

Sites of «Brest 2» area are shown in Fig. 4. Formal representation of a given part of enterprise structure is shown in Fig. 5. «Soft cheese and cottage cheese shop» site (emphasized in Fig. 4) will be discussed from this point onwards.

Establishing boundaries of the highest-level entities are beyond the scope of an ISA-88 standard, since there are many

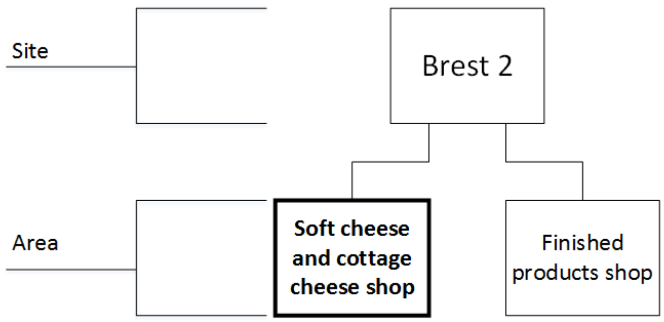

Figure 4. Sites of a «Brest 2» area

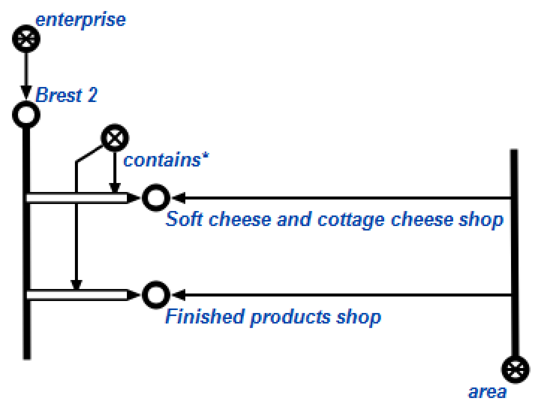

Figure 5. Formal representation of a connection between second and third levels of a physical model

factors that determine them, such as corporate politics or business requirements. And batch manufacturing needs may not be the most important factor [12]. Those entities are discussed in more depth in the ISA-95 standard.

D. Process cell level

Site contains all the equipment necessary to produce a batch. The term «train» is sometimes used to describe the site's equipment needed to produce a batch. Process cell can contain more than one train, and the order of the equipment in it is called a path. Process cell takes raw materials or work-in-progress substances and makes them into a product or into a different work-in-progress substance.

Soft cheese and cottage cheese shop of a «Brest 2» area contains two process cells – one for making cottage cheese and one for shaping and packing of the product (see Fig. 6). Fig. 7 shows the formal representation of this part of the enterprise structure. We will now focus on a process cell, which produces cottage cheese «Khutorok» (emphasized in Fig. 6)

E. Units, equipment modules and control modules

Lowest three levels of a physical model are discussed together, since, according to ISA-88, process cell can directly contain units, equipment modules, as well as control modules, which is shown in Fig. 8. In a similar fashion, unit can contain equipment modules, as well as control modules.

Units are the basic parts of batch manufacturing. Batch manufacturing process actually happens inside units. Units

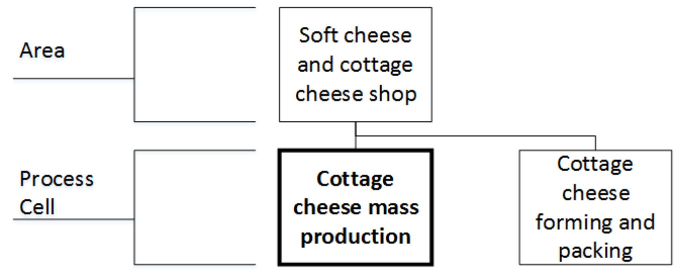

Figure 6. Process cells within a soft cheese and cottage cheese shop

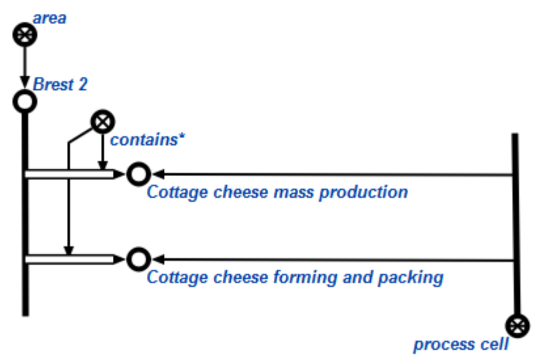

Figure 7. Formal representation of the connections between fourth and fifth levels of a model

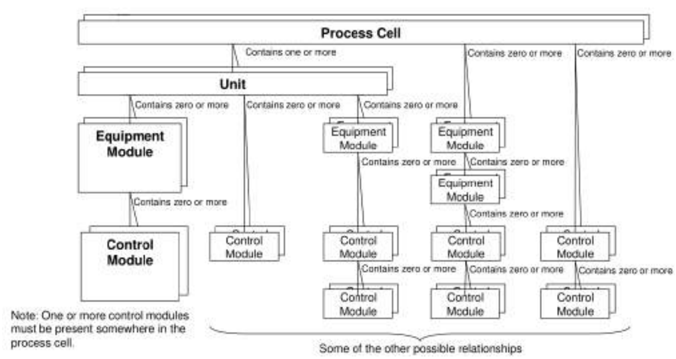

Figure 8. Some of the possible relations between the entities of lowest three levels of an ISA-88 physical model

perform major processing activities, which in some way add value to the final or the work-in-progress product – mixing, chemical reactions, etc. They are usually, but not necessarily, based around some container.

Equipment module is a group of equipment that can carry out a finite number of specific batch manufacturing functions. ISA-88 standard assumes that equipment module can implement decision-based logic. Monitoring pressure or level of liquid, maintaining certain temperature conditions can be used as examples.

Control module is a basic element of a physical model. It represents a connected set of sensors, valves, etc., which can be interpreted as a single entity. It is worth noting that control module does not have to be physically implemented. It can be an instruction or a group of instructions of a programmable microcontroller, or even a device driver.

The process cell we are looking at has 32 coagulators (units), two input trains, eight output trains, eight whey pumping trains and 16 boilers (equipment modules), as we can see in Fig. 9. Formal representation of the lowest levels of a physical model is shown in Fig. 10. Control module list is omitted for the sake of brevity. Some of them will be mentioned in the upcoming example.

F. Practical application of a physical model

Practical applications of a physical model include, in particular, formalization of the enterprise technical documentation, such as functional charts. Fundamental simplicity of mutual translation between a technological chart and its semantics-based representation makes it possible to ask questions about its parts, initiate commands to change physical equipment state, monitor equipment status over time. This functionality is provided by a collective of receptor and effector agents operating on the semantics-based representation of a documentation, stored in shared semantic memory. This allows to «liven up» enterprise technical documentation and to make it multipurpose.

For an example of a practical application we will consider a part of a previously mentioned process cell, which contains two coagulators (units) and a boiler (equipment module). It additionally has a number of sensors, pumps and valves, which are, according to ISA-88, considered control modules, because they are basic devices and implement atomic functions.

Fig. 11 shows a part of enterprise functional chart, which depicts equipment that is used during the cottage cheese heating phase. This chart is implemented using [23] standard. Chart shows two coagulators (№14 and №15) with two temperature sensors each (TE141, TE142, TE151, TE152), circulation tank and a heat exchanger. Temperature sensors monitor water temperature in coagulator shells. Arrows show water circulation through coagulator heating system (coagulator №14, circulation tank, heat exchanger and coagulator №15). Circulation tank has two level sensors – LS41 and LS42, that monitor water level to prevent water overflow or depletion. If water level in the circulation tank drops below LS41 level, the V41 valve is opened. V41 is closed, when water reaches LS42 level. V40 valve manages steam supply to the heat exchanger. This regulates water temperature, which is controlled by the TE4 temperature sensor. Pump N4 pushes water through coagulator heating system. Valves 14V1 and 15V1 manage hot water supply to the shells of coagulators №14 and №15.

We will now discuss a process of transforming a technological chart into its semantics-based representation. Each specific equipment item, such as sensor, pump, pipe or coagulator corresponds to a node in a semantic network. Specific equipment piece is an instance of a certain equipment class. This fact is denoted by a link between nodes, that represent them, as shown in Fig. 12.

Pipes are the special equipment, which interconnects other manufacturing equipment. If, during the manufacturing process, processed substance goes from one piece of equipment to another through a pipe, then there will be two binary links. First one connects a pipe and a source piece of equipment and belongs to a ***source equipment**** relation. The second one connects a pipe and a target piece of equipment and belongs to a ***target equipment**** relation, as shown in Fig. 13.

Pipes can be connected to sensors. However, such connections do not involve a substance movement. They are identified by a ***connection**** link between pipe and sensor instances (see Fig. 14).

Functional chart (see Fig. 11) also depicts constructional parts, such as temperature sensors, as a separate entities. To connect a piece of equipment to its constructional part we use ***part-of**** relation link, which connects corresponding nodes (See Fig. 15).

Such description would be sufficient for a standalone shop. But for a batch manufacturing enterprise with multiple shops, such as JSC «Savushkin product», there is a need to unify its semantics-based representation using a common ontology. Among other reasons, this is needed to simplify shop management and interaction. Ontology of physical models of batch manufacturing enterprises, constructed as a result of ISA-88 formalization, can serve as such ontology. Within ontology-based model of the enterprise, it is situated above an ontology of a specific industry, but below batch manufacturing ontology. Hierarchical organization of ontologies ensures independence between manufacturing recipes and a specific equipment, that implements it. Their link will be established at a higher level of abstraction, which is analogous to a Bridge design pattern used in object-oriented design [3].

To establish a link between the first description and a physical model terms, one needs to match specific pieces of equipment to the appropriate levels of a physical model mentioned before. Merging those descriptions enables better understanding of how are control modules and equipment modules linked. This link is the key to ensure generalization and reuse in batch control [8].

For example, to specify the fact, that a certain piece of equipment (say, a valve) is a control module, one needs to include the corresponding semantic network node in the equipment module set, as shown in Fig. 16.

Other physical levels are assigned to an equipment in a similar fashion. After performing these transformations, we end up with a fragment of a semantic network, which corresponds to the aforementioned technological chart. It is shown in Fig. 18.

Such representation allows to ask various questions about this chart. We will now take a look at two examples.

- «Give an example of equipment module with a heat exchanger». This question is answered by an ***sc-agent for finding constructions, isomporphic to given pattern***. Its single argument is an sc-node, which denotes a search pattern shown in Fig. 17. Natural-language interpretaion of this search query can be constructed as follows: «Find all such structures, that belong to an equipment module set and that contain one or more elements of a heat exchanger set». Answer to this question is shown in Fig.19 as a fragment of a semantic network.
- «Which kinds of equipment are used to heat a cottage cheese mass?» This question is answered by an ***sc-agent for finding subclasses of given class within a given***

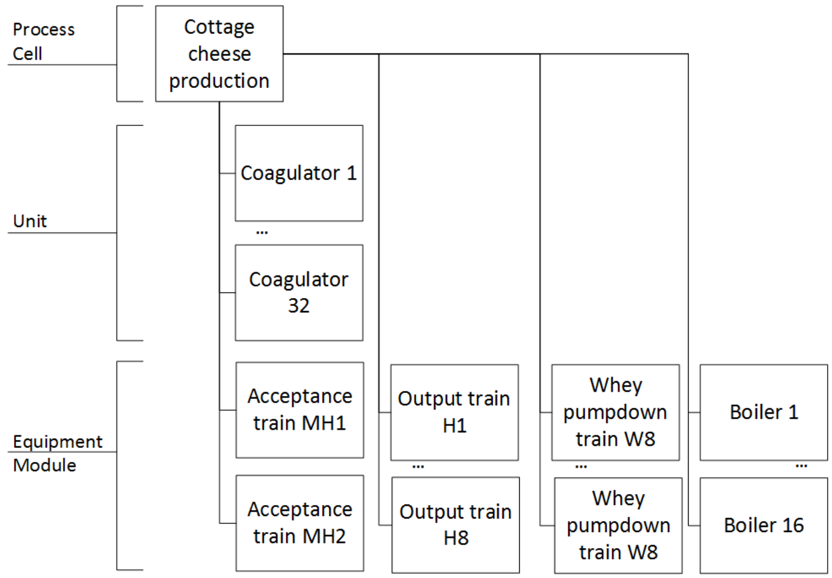

Figure 9. Units and equipment modules in a cottage cheese-making process cell

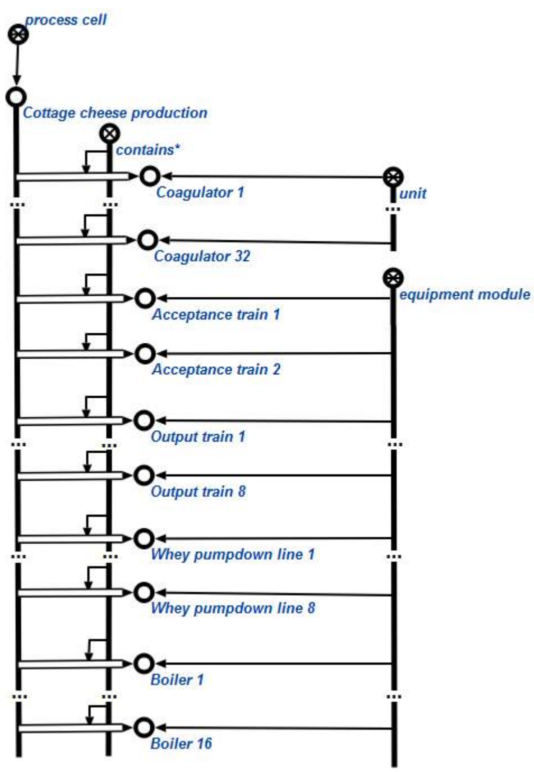

Figure 10. Formal representation of the lowest levels of the physical model

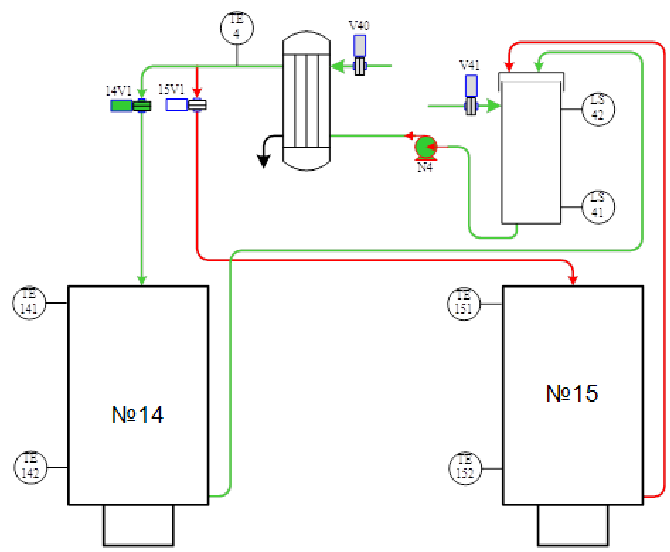

Figure 11. Functional chart implemented using GOST 21.404-85

Figure 12. Example instance of the equipment class

structure. Its accepts two arguments. First one is a node, representing a structure, within which to perform a search. Second one is a node of a class, subclasses of which are to be found. Argument values in this case are: (1) structure in Fig. 18 and (2) equipment node. Answer to this question is a set of classes coagulator, temperature sensor, valve, volume sensor, pipe, circulation tank, heat exchanger, pump. This agent is widely applicable and can answer any question of «Which X is used in Y?» kind.

V. Conclusion

This paper demonstrates basic principles of ontology-based design of batch manufacturing enterprises, using JSC «Savushkin product» as an example.

Key points of this paper:

- Enterprise is viewed as a knowledge-driven ***intelligent multi-agent system***. Knowledge are stored in a memory, shared between all of the agents. Such shared memory is

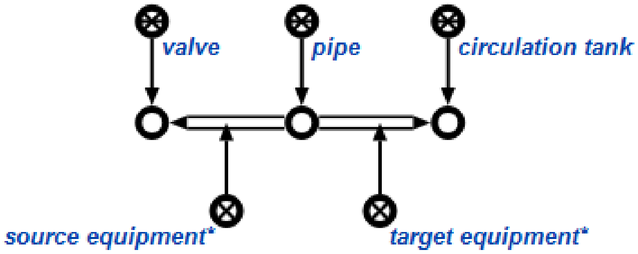

Figure 13. Two pieces of equipment connected with a pipe

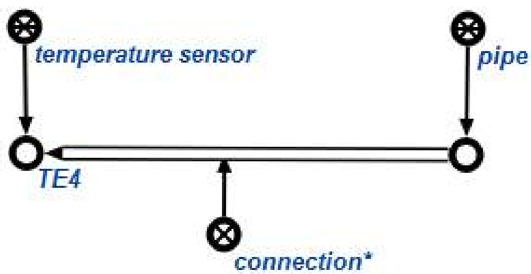

Figure 14. Connection between a pipe and a sensor

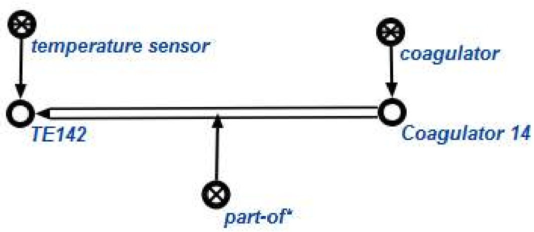

Figure 15. Connection between an equipment item and its constructional part

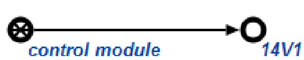

Figure 16. Valve is a control module

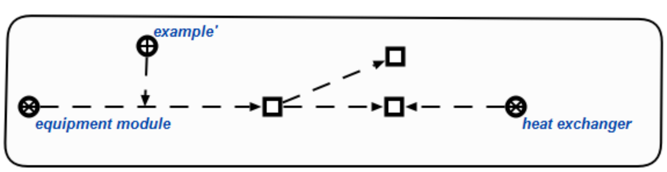

Figure 17. Search pattern example

called corporate memory of an enterprise. Agents of an intelligent enterprise include both programmatic agents, that work with corporate memory, as well as employees, who work and interact through this memory;

- ontology-based design of an enterprise is based on strictly specified, consistent ***system of a formal ontologies***. Each ontology describes principles behind certain aspects of operation management of a certain types of enterprises. Each formal ontology corresponds one-to-one to a ***subject domain***, which formally includes models (specifications) of various enterprises. These specifications describe these enterprises in an aspect, with which the ontology of that subject domain is concerned. ***Integrated ontology-based model of an enterprise being*** designed consists of a number of models, which describe the same enterprise but correspond to different ontologies;
- operation management principles, aimed at ***improving and adapting*** the enterprise to the changing conditions, have to be strictly specified as an ***enterprise improvement ontologies*** for a certain specified class of enterprises. Such ontologies are further subdivided into several partial ontologies, that describe various aspects of improving the structure or operation of the enterprise;
- the primary quality criterion of the produced ***system of formal ontologies*** for a certain specified class of enterprises is an ability to partition an enterprise improvement ontology for this class in such a way, that improvement of a various aspects of an enterprise could be carried out in parallel and relatively independently from one another. This criterion characterizes ***flexibility of enterprises***, built using this system of formal ontologies;
- the system of formal ontologies of ***batch manufacturing enterprises*** is built upon a formalization of the ***ISA-88 standard***, which is represented using the following system of ontologies:
  •• ***Ontologies of physical models of batch manufacturing enterprises***;
  •• ***Ontologies of process models of batch manufacturing enterprises***;
  •• ***Ontologies of procedural control models of batch manufacturing enterprises***;
  •• ***Ontologies of batch control activities***.
- ISA-88 is a remarkably high-quality standard, that facilitates the design of highly flexible batch manufacturing enterprises;
- Formalization of standards simplifies the process of making an enterprise conformant to the standards. It also facilitates the auditing process to ensure its conformance. Formalization of standards allows for a significant improvement of the information service level of an enterprise. It also facilitates employee education on the subject of a standard.

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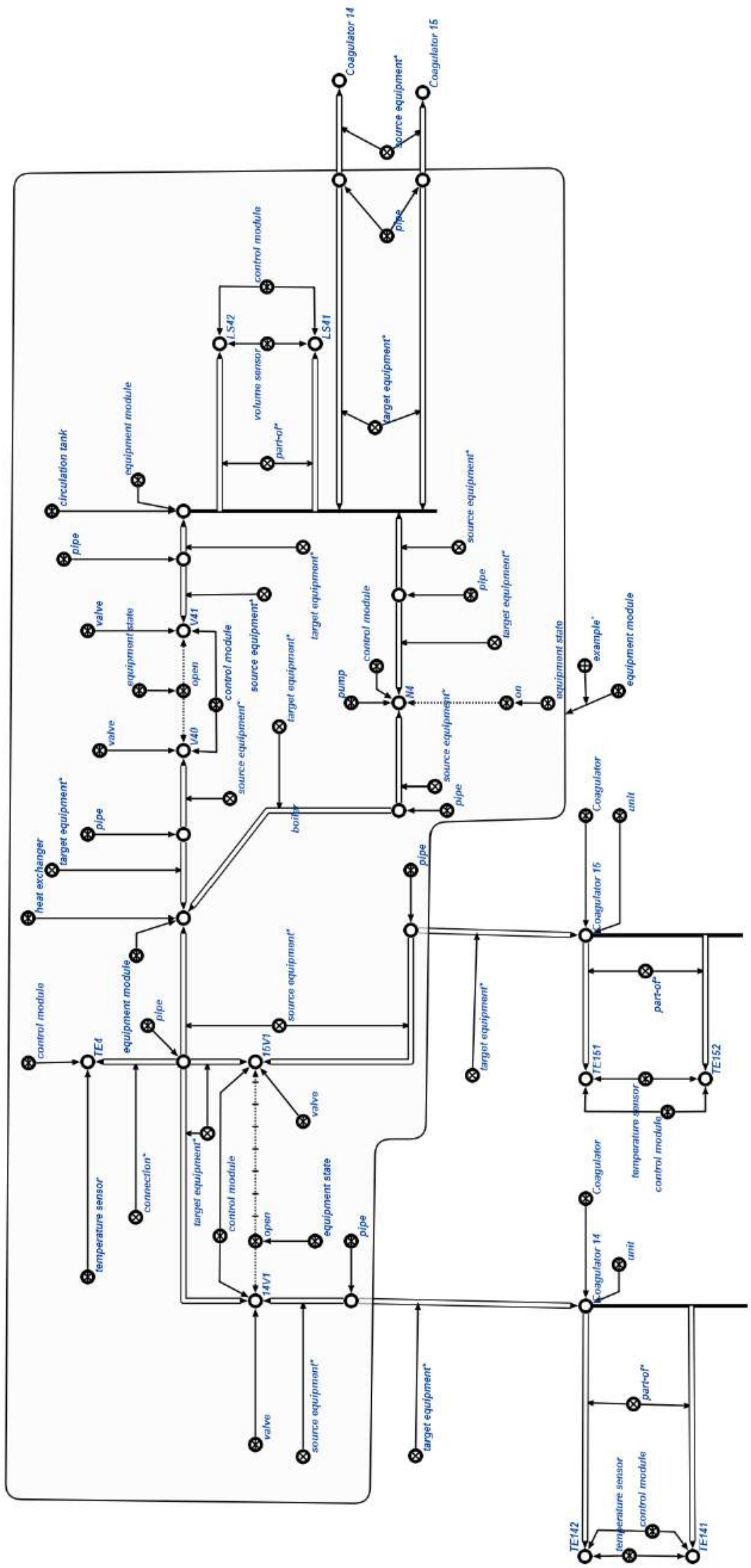

Figure 18. Fragment of semantic network, which corresponds to the technological chart

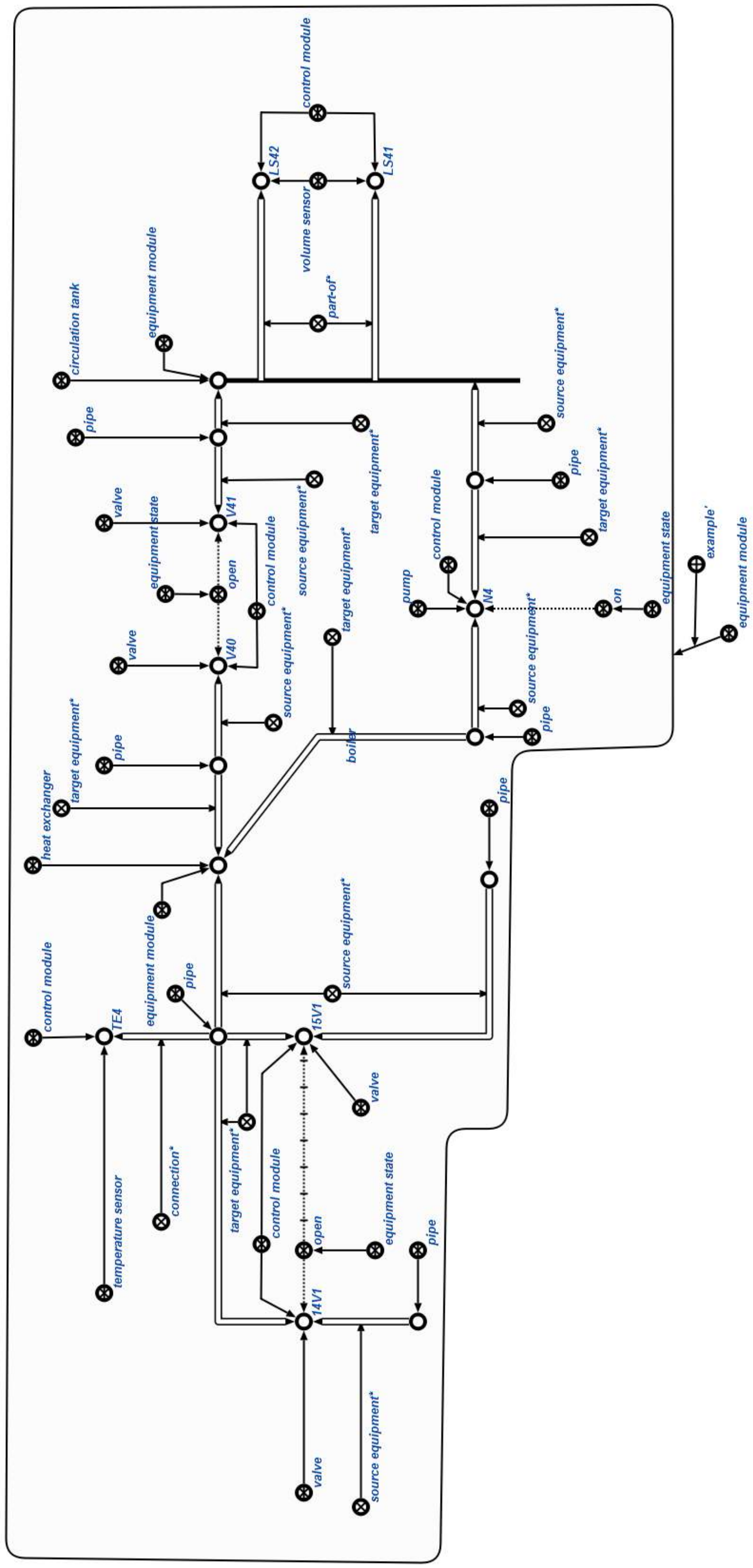

Figure 19. Answer to the question regarding an equipment module containing a heat exchanger

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Онтологическое проектирование предприятий рецептурного производства

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Данная статья посвящена рассмотрению текущих, тактических и стратегических аспектов повышения уровня автоматизации предприятий на примере предприятия рецептурного производства ОАО «Савушкин продукт». Предлагается онтологический подход к проектированию такого рода предприятий, состоящий в построении на основе текстов стандартов иерархической системы предметных областей и соответствующих им формальных онтологий. В его рамках предприятие рассматривается как распределенная, интеллектуальная, иерархическая, многоагентная система, в которой в качестве агентов могут выступать программы обработки знаний, технические устройства и персонал. В частности, обсуждаются принципы формализации стандартов, на которых основана деятельность предприятия, на примере стандарта ISA-88, касающегося предприятий рецептурного производства, каковым является ОАО «Савушкин продукт».

Средства автоматизации современного предприятия

должны оперативно и с минимальными затратами времени сотрудников адаптироваться к любым изменениям самого производства – к расширению или сокращению объемов производства, изменениям номенклатуры производства, изменению используемого оборудования, изменению общей структуры производства, изменению взаимодействия с поставщиками и потребителями, к изменению нормативно-правовых актов (включая стандарты), которым предприятие должно соответствовать, к различного рода непредвиденным обстоятельствам.

Средства автоматизации современного предприятия должны быть гибкими не только для оперативной адаптации к реконфигурации производства, но и для оперативного внесения изменений в сами средства автоматизации в направлении их постоянного совершенствования. Отметим, что здесь существенным является не только снижение трудоемкости повышения уровня автоматизации, но и поддержка высоких темпов повышения уровня автоматизации, а также четко продуманный переходный процесс от одного уровня автоматизации к следующему, в ходе которого одновременно используется и устаревший вариант и новый.

Повышение уровня автоматизации предприятия предполагает существенное расширение числа автоматически или автоматизировано решаемых задач, а это, в свою очередь, приводит к автоматизации решения интеллектуальных задач, т.е. к использованию технологий искусственного интеллекта.

Для того, чтобы обеспечить широкое применение технологий искусственного интеллекта в автоматизации предприятия, все корпоративные знания предприятия должны быть записаны на формальном языке представления знаний. При этом указанный язык должен быть удобен не только для использования в интеллектуальных компьютерных системах, но и для использования всеми сотрудниками предприятия.

Для построения онтологической модели предприятия необходимо решить следующие проблемы:

- Существующие средства автоматизации деятельности предприятия имеют высокую стоимость, трудны в освоении и адаптации к конкретному производству. Разработчики стремятся сделать такого рода средства как можно более функциональными, наращивая их частными решениями, что приводит к сложности и громоздкости таких систем.
- Как следствие подобного подхода к наращиванию функционала, существующие средства автоматизации деятельности предприятия имеют низкий уровень гибкости (возможности внесения изменений), что приводит к существенным накладным расходам при адаптации таких средств к новым требованиям.
- Отсутствие общих унифицированных моделей и средств построения систем автоматизации деятельности предприятия приводит к большому количеству дублирований аналогичных решений как в рамках различных предприятий, так и в рамках разных подразделений одного предприятия.
- Отсутствие такого рода моделей препятствует дальнейшему повышению уровня автоматизации предприятия, в частности, в области автоматизации принятия решений в нештатных ситуациях, прогнозирования дальнейшего развития событий.
- Высокий уровень зависимости системы автоматизации предприятия от разработчиков приводит к проблемам внедрения и сопровождения такой системы при смене разработчика.
- Отсутствие формальных моделей различных стандартов, регламентирующих деятельность предприятия, приводит к возможным трудностям в трактовке тех или иных положений стандарта и обучении персонала. Это также затрудняет процесс проверки предприятия или его подразделений на соответствие необходимым стандартам

В настоящее время существует ряд подходов, ориентированных на повышение уровня автоматизации и гибкости предприятий. Перечислим те их них, что наиболее сильно повлияли на развитие предлагаемого подхода:

- Модели управления знаниями предприятий
- Онтологические модели предприятий
- Многоагентные модели предприятий
- Модели ситуационного управления
- Модели реинжиниринга бизнес-процессов предприятий

Основной недостаток всех приведенных выше моделей заключается в том, что ни одна из них не обладает достаточной полнотой, и для наиболее адекватного соответствия реальному предприятию его модель должна быть результатом интеграции всех этих моделей.

Предлагаемый подход к решению указанных проблем основан на следующих основных принципах:

- Предприятие рассматривается как распределенная, интеллектуальная социотехническая система, в основе которой лежит хорошо структурированная общая база знаний предприятия.
- В рамках базы знаний предприятия интегрируются все вышеуказанные модели (управления знаниями, онтологической, многоагентной, реинжиниринга бизнес процессов).
- Предприятие рассматривается как иерархическая многоагентная система, в которой агентами являются как программно реализованные агенты, так и сотрудники предприятия. Иерархичность заключается в существовании неатомарных агентов (коллективов), включающих как атомарные, так и неатомарные агенты.
- Весь комплекс средств, обеспечивающих деятельность предприятия, оформляется в виде распределенной интеллектуальной корпоративной системы предприятия.
- Проектирование онтологической модели предприятия сводится к проектированию онтологической модели его интеллектуальной корпоративной системы. Онтологическая модель предприятия является одновременно и объектом, и результатом проектирования.

- Для реализации корпоративной системы предприятия предлагается использовать Технологию OSTIS [21],[22].

Чтобы реализовать предложенный подход, необходимо решить следующие задачи:

- Разработать унифицированную структуру общей (интегрированной) базы знаний интеллектуальной корпоративной системы предприятия в виде иерархической системы предметных областей и соответствующих им онтологий.
- Разработать модель машины обработки знаний [39] интеллектуальной корпоративной системы предприятия.
- Разработать модели интерфейсов [27] интеллектуальной корпоративной системы предприятия для разных категорий пользователей.
- Разработать модель средств информационного обслуживания разных категорий пользователей интеллектуальной корпоративной системы предприятия.
- Разработать модель средств поддержки инжиниринга и реинжиниринга базы знаний интеллектуальной корпоративной системы предприятия.

На данном этапе работы основное внимание уделено решению задачи разработки онтологической модели базы знаний, в частности -– построению набора предметных областей, описывающих содержание основных стандартов.

Основой онтологического подхода к проектированию предприятия является формализация стандартов. Каждый стандарт рассматривается как онтология соответствующей ему предметной области.

При внедрении стандарта могут возникать проблемы, связанные с неоднозначной трактовкой некоторых положений стандарта и особенностями применеиния стандарта на конкретном предприятии. Одним из путей решения такого рода проблем является построение его формальной семантической модели, которая могла бы одинаково интерпретироваться как компьютерной системой, так и человеком. Формальное семантическое представление стандарта создает конструктивную почву для его согласования, а также для обеспечения четкости и однозначности его трактовки и обеспечивает упрощение внесения изменений, вызванных как уточнением трактовки, так и эволюцией самого стандарта.

Построение формальной модели стандарта сводится к построению интегрированной формальной онтологии, специфицирующей соответствующую предметную область. Для этого необходимо отобразить структуру и содержание исходного текста документа стандарта на иерархию предметных областей и соответствующих им онтологий.

Использование онтологического подхода к построению формальной модели стандарта позволяет построить интеллектуальную справочную систему, предоставляющую широкий спектр информационных услуг относительно применения стандарта. Такая система способна отвечать на широкий спектр вопросов вида «что такое...?», «для чего необходим...?», «как связаны...?», «что если...?» и другие.

В данной работе формализация стандартов рассматривается на примере предприятия рецептурного производства ОАО «Савушкин продукт». Поскольку специфика рецептурного производство наиболее полно охватывается стандартом ISA-88, то именно он и выбран в качестве объекта формализации. Следует отметить высокое качество стандарта ISA-88, позволяющее проектировать предприятия рецептурного производства, обладающие высокой степенью гибкости.

Содержание первой части стандарта отображается на следующие предметные области в рамках интеллектуальной корпоративной системы предприятия:

- Предметная область предприятий рецептурного производства
- Предметная область физических моделей рецептурных производств
- Предметная область процессных моделей рецептурных производств
- Предметная область моделей процедурного управления оборудованием рецептурных производств
- Предметная область деятельности по управлению рецептурным производством

Здесь также следует отметить, что каждой из этих предметных областей будет соответствовать онтология совершенствования предприятия в соответствующем аспекте его структуры и деятельности, в которой строго описаны принципы организации деятельности, направленной на совершенствование и адаптацию предприятия к изменяющимся условиям. Такая организация системы предметных областей и формальных онтологий обеспечивает параллельное и в достаточной степени независимое совершенствование различных аспектов предприятия, что позволяет говорить о высокой степени гибкости предприятий, строящихся на ее основе.

Данная статья уделяет внимание физической модели предприятия ОАО «Савушкин продукт». Спецификация предприятия в рамках этой предметной области имеет семь уровней: предприятие, производство, производственный участок, ячейка процесса, аппарат, агрегат, блок управления. Предприятие – самая крупная производственная единица, соответствующая компании в целом. Элементы остальных уровней вкладываются в нее по иерархическому принципу. В статье последовательно рассматривается по одному элементу с каждого уровня модели до уровня аппаратов: ОАО «Савушкин продукт» – Производство «Брест 2» – Цех мягких сыров и творога – Ячейка производства творожной массы. Три нижних уровня модели разбираются на примере фрагмента ячейки процесса, иллюстрирующей также использование физической модели при формализации технической документации предприятия. Для каждого из приводимых фрагментов структуры предприятия приводится соответствующий фрагмент семантической сети. Семантическое представление позволяет задавать к документации разнообразные вопросы, обеспечивая тем самым эффективное информационное обслуживание сотрудников предприятия.

Intelligent Management of the Railway Transportation Process: Object Model

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***Abstract*—In the article an overview of existing intelligent approaches to the management of the railway transportation process is given and key takeaways of developed object model are described.**

***Keywords*—Intelligent management, railway transportation process, making up plan, car traffic processing**

I. Introduction

Railway transport is the united production and technological complex includes railway infrastructure, rolling stock and other assets to ensure individuals', legal entities' and governments' needs in transportation under the conditions of a public contract, and in performing other work (service) which are depended on such transportation. The goal of present-day railway transport is to shape competitive transport product which will meet customer requirements. Now it is more complicated to perform.

II. Overview

Even in the classical task of managing the transportation process and the satisfaction of all customers it is difficult formalized and has a large dimension. For example, the length of the Belarusian Railways is 5.5 thousand kilometers. Every day in the transportation process involved more than 25,000 wagons, 500 locomotives, which are organized into trains and transported millions of tons of cargo. At the same time the work of all departments of trains making-up and traffic handling should be connected in the unified technology.Development of the transport sector and improve the quality of the transport product implies the need to create a different kind of technical systems, which should have a high degree of autonomy, adaptability, reliability and quality of functioning in conditions of uncertainty.However, the major sources of uncertainty in the manifestation of management tasks are the following factors

- the complexity of the formal description of the control objects and tasks with taking into account the measurement errors of the necessary data and calculations;
- vagueness of the operation purpose and control problems;
- not stationarity of the object parameters and control system;
- priory uncertainty of situation and working conditions;
- the presence of random effects of the environment;
- distortion of the incoming input data in the remote transmission channels.

It becomes difficult to solve the problem of traffic management in such conditions by conventional methods, even using automated control systems, and in some cases impossible. The adoption of unsustainable management decisions leads to violations of the goods delivery timeliness, to inefficient rolling stock usage, to increasing of the transport operation cost.

To increase the efficiency of management of transportation process in railway transport is possible due to the introduction of intelligent technologies. Consider the international experience of using such systems in transport. Currently, considerable attention is given abroad in the creation of ITS (intelligent transport system) in railway transport . China, India and others have joined to the recognized world leaders (Germany, UK, USA, Japan).

For example the Traintic company provides technology solutions for the railway sector, focused on the intellectualization of communication and information systems. Primarily, these are modular system of train control center, manage and monitor of the rolling stock state, based on the communication standards TCN. They allow real-time control of locomotive unit temperature, train speed, fuel level, etc. The solutions of Traintic company implemented in Madrid and Brussels metro, commuter trains in Mexico and Northern Ireland, in the organization of high-speed movement in Turkey [1].

In EU countries developed ERTMS system, which provides information exchange between objects of infrastructure, rolling stock of different carriers and customers. The system also has the ITS elements: SIGNAL subsystem, providing passengers with information before and during the journey, reservation and payment systems, luggage management and management of connections between trains and with other types of transport; cargo transport requests subsystem, included information systems (real-time control of shipping and movement in the trains), distribution systems, reservation, transportation payments and billing, organization of information interaction with other types of transport and forming of electronic accompanying documents.

Construction of the system is based on the functional and technical standards of the TSI, that is aimed to the organization of the consistent data exchange between the railway infrastructure managers, carriers and other participants in the transportation process.

China Railways has achieved specific results in the creation of ITS [2]. They are developing Railway Intelligent Transportation System (RITS) that should be built as a new generation of railway transport system aimed at the integration of technology in various fields: electronics, communications, data processing, control and diagnostics, automation and mechanization, support management decision-making. The goal of this development is to improve the safety and efficiency of the transportation process, improve the quality of customer service at a lower price. As part of the system creation RITS architecture was designed and guidelines for intellectual infrastructure of national rail transport system have been identified.

Indian Railways put similar goals and objectives when creating the RITS (increase efficiency, improve safety and better quality of service) [3]. In the development is used smart navigation system technologies, emergency situations and security monitoring intellectual system, intelligent railway management system, intelligent train control center and monitoring system, modern communications technology.

Active work on creating RITS conducted in the UK. For this purpose, it establishes an independent ITS Association, which includes 160 corporate members. There are already a number of its applications that can help rail operators and passengers. Developed ITS technologies are combined in a categories: cost, carbon, capacity, customers.

Implementation of intelligent control technology in railway transport provided by Russian Railways JSC Development Strategy until 2030 [4]. For this purpose a project to create a Unified Intelligent rail control system is started. The need to create such a system on the railway due to the complexity of tasks and environmental dynamic environment that requires continuous adaptation of the system to external influences. Currently defined the overall architecture of the system, some theoretical problems are solved, accumulated experience in creating application solutions.

The importance attached to the ITS improve the efficiency of basic production processes with strict implementation of safety requirements. Creating ITS Russian Railways envisages the creation of an appropriate intellectual infrastructure, which includes:

- the creation of a common information space, which must necessarily include a high-precision coordinate system and a digital base, built using GLONASS / GPS technologies;
- digital radio system with all the facilities of the rolling stock and railway transport infrastructure;
- control system of the rolling stock location on the infrastructure facilities;
- system diagnostics and predictive condition monitoring wagons and locomotives;
- system of situational monitoring and prediction of critical situations on the basis of situational centers;
- intelligent operational work management system.

An analysis of existing management systems following conclusions can be made on the railways:

- ITS no unified structure, and are not formalized requirements and rules of its creation;
- for the majority of current ITS term "intellectual" is used incorrectly as soon as they can be attributed to information or computerized control systems, with the main signs of intelligence for them are missing;
- from the rest of the ITS Group, virtually all systems are " intellectual" a little, that is, for their inherent intelligence trait 1-2.

Thus, the task of creating intelligent rail transport systems remains unsolved. When creating intelligent systems of rail transport requires not only high-quality mathematical formulation, but also knowledge of the approaches to the maintenance of transport problems.

III. Object model

Since rail transport is a complex system that includes connected with each other elements, conflicted over resources agents, assumes achieve different, including conflicting, targets, to describe it is necessary to form the semiotic models. In general, the semiotic models can be specified by the fourth:

$M = \langle T, R, A, S \rangle$
where
T - a plurality of base elements;
R - syntax rules;
A - the system of axioms;
S - semantic rules.

Let's define a set of basic elements of the semiotic model T "Railway transport" and determine the object model. In rail transport, as the system can distinguish the organizational, functional and elemental content.

Organizational railway control system is built hierarchically (Figure 1).

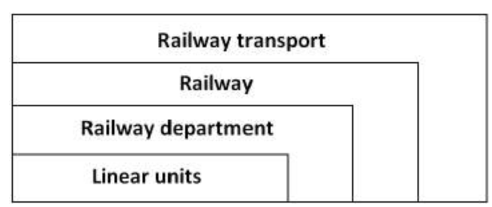

Figure 1. Organizational railway control system diagram

For example, the Belarusian Railway includes 6 departments (unitary enterprises). Departments include 362 large and small stations, 17 locomotive depots, 12 depots, 20 distances the way, 13 signaling and communication, 7 distances electricity and other enterprises. Each of the linear unit may include departments and workshops.

The functional content assumes the system decomposition by functional features. On a railway transportation the next relevant services are responsible for the basic functions implementation: transportation, passenger, locomotive, power supply, etc. Each service has its own organizational structure and implements control over the departments of departmental and on linear levels and the corresponding linear units.

Through the management process multiple services can both complement each other (when forming the trains responsible for the train set making up is a service of transport, for the technical condition of railroad cars - cars, for the provision of locomotives - locomotive) and conflict over resources (when organization train handling on the district there is a conflict in the priority handling of freight and passenger trains).

The elemental structure of the system is dependent on functional and defined list of solving operational problems. Let's take a look to the elemental structure of "transportation process management" subsystem.

The main model object is the station. According to its functional purpose and amount of work stations are divided into marshalling, district, freight, passenger and intermediates. Stations participating in the trains making up, belong to the technical category. Technical stations interconnected by rail districts.

According to the graph theory, the railway is the transport network, which can be described by a symmetric graph $G\left(\{i\},\{i,j\}\right)$, composed by node set S_i (stations) and oriented arc set (rail districts) $\{D\left(i,j\right)\} i,j=\overline{1,p}$ where p – the total number of stations. Arc $D(i,j)$ leads from node *i* to the node *j* and have weight t_{ij}^{G}. Weight of arc t_{ij}^{G} according to the optimization criterion can be **train travel time** between neighboring stations on the G polygon, **length** between stations *i* and *j*, **transportation cost** of car traffic unit by this arc [5].

Graph to describe of the Belarusian Railways polygon is shown in Figure 2.

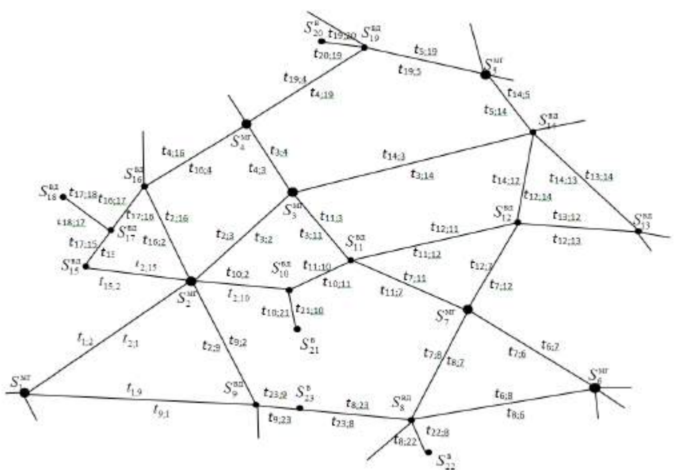

Figure 2. Graph to describe of the Belarusian Railways polygon

Transportation process can be divided into two parts: train operations and shunting operations. Train operations are performed on the rail districts and spans (graph arcs). Shunting operations are performed on stations (graph nodes).

Graph arc description example with span details are shown on Figure 3.

According to Figure 3 railway is composed by set of districts. Each district belongs to appropriate Railway department (NOD). NOD-2 includes districts Grodno-Kuznitsa,

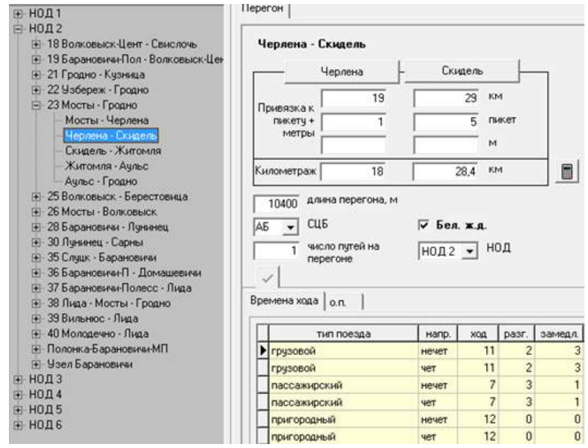

Figure 3. Definition of "span" object

Mosty-Grodno and others. District Mosty-Grodno includes spans Mosty-Cherlena, Cherlena-Skidel, Skidel-Zhidomlia and others. Train handling technology and parameters for solving the operational tasks are depend on span properties.

Each node S_i of railway network G is characterized by property set, that defines station functionality and possibilities on the train making up and handling.

Operational possibility *i*-station is defined by technically permissible processing cars limit n_{Ti} and can be described as a composed function

$$n_{TS}^{nal}=f_1\left(M_g;M_{vf};k_n;N_{tr};N_{trpr};N_{tny};N_g;\{t_{tex}^{z}\}\right)$$

where

M_g - locomotive number, that works on the yard;

M_{vf} - locomotive number, that works on the draw-out track;

k_n - train address number, that is made up on station;

N_{tr} - through train number, trains without processing;

N_{trpr} - through train number, trains with partial processing;

N_{tny} - track number in sorting yard;

N_g - estimated capacity;

$\{t_{tex}^{z}\}$ - set of time values of train set technological processing with z-category on station.

Time, that the cars spend on station, depends on freight flows correspondence capacity and time to process in the station subsystems, and can be described as

$$t_{tr_i}=f_2\left(N_pr;N_{tr};N_{trpr};\{t_{tex}^{z}\}\right)$$

$$t_{pr_i}=f_3\left(M_g;M_{vf};k_n;N_{tr};N_{trpr};\{t_{tex}^{z}\}\right)$$

$$t_{acc_l}^{i}=f_4\left(n_l;k_n;m_l;t_{pr_l};I;m_{gr_l};m_{z.gr_l};\pm\Delta m_l\right)$$

where t_{tr_i} - time is spent on i-station by car without processing, hours;

t_{pr_i} - time is spent on i-station by car with processing (not include wait time in sorting yard), hours;

$t_{acc_l}^{i}$ - wait time of l-address on i-station, hours;

N_pr - train number, that should be processed on station, trains;

n_l - l-address capacity, cars;

m_l - car number in train set with l-address, cars;

t_{pr_l} - gap time while train set with l-address accumulates, hours;

I - arrival interval of trains, that should be processed on station, minutes;

m_{gr_l} - car number in group with l-address, in train to break up on station, cars;

$m_{z.gr_l}$ - car number in closing group in train set with l-address, cars;

$\pm\Delta m_l$ - tolerances in car quantity of train set with l-address, cars.

Depending on the conditions of traffic formation the set of nodes $\{S_i\}$ can be divided into source nodes $\{S_{s_i}\}$ (mostly it is freight stations) and process nodes $\{S_{pr_i}\}$ (marshalling and district stations). On nodes Si the district trains, connected trains and shipper routes can be built. On nodes S_{pr_i} almost all kinds of trains can be built.

The traveling time of train between neighboring stations t_{ij}^G is the composed function of total train traffic on district N_{ij}, that depends on car traffic n_{ij}, district speed V_{ij}^{distr}, length train district L_{ij}^{distr}, district cash throughput capacity N_{ij}^{cash}, district equipment safety φ_{ij}^{tex}, strict compliance with schedule on this district φ_{ij}^{sch}

$$t_{ij}^G = t_{ij}\left(N_{ij}; n_{ij}; V_{ij}^{distr}; L_{ij}^{distr}; N_{ij}^{cash}; \varphi_{ij}^{tex}; \varphi_{ij}^{sch}\right)$$

Control object is the car traffic with certain logistic characteristics and receiving stations, that should be composed to train in accordance with train form plan. Conditions of train forming from the cars is defined by the station's resources (train locomotives, shunting locomotives, yards, and others) and by imposed technological restrictions (train length and weight for addresses, train schedule, and others).

Car traffic can be defined as matrix

$$n = \|n_{ij}\|; n_{ij} > 0; i, j = \overline{1, p}$$

where i – source station and j – destination station (receiving station).

For the control purposes car traffic should be decomposed in accordance with logistic characteristics. **Car traffic's logistic characteristics** are defined by:

- the structure of original freight traffic, that should be moved by the cars from the production point to the point of consumption;
- car traffic's characteristics;
- original car traffic's state;
- car traffic's transportation mode.

Depending on the **structure** of original freight traffic it can be picked out following signs of decomposition, that affect conditions car traffic's handling and processing:

- kind of freight – defines order of maintenance and commercial inspection of cars on station, car traffic conditions of processing on the yard, order of making up cars to trains;
- delivery speed – imposes on the making up variants time restrictions (timely delivery of goods);
- safety necessity – imposes requirements in militarized security while performed cargo delivery process.

IV. Conclusion

Transportation process management aims to achieve the optimal adjusted time and cost values for car's processing on stations and handling a determined car traffic through the considered polygon. Of course, presented in the article object model of transportation process management is simplified and does not solve all emerged operational tasks. However, its main advantage is the scalability and consistency. In the development of the field of research "intelligent management of transportation process in railway transport" object model will be expanded, both due to the emergence of new objects, and due to the detail of existing objects functions.

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ИНТЕЛЛЕКТУАЛЬНОЕ УПРАВЛЕНИЕ ПЕРЕВОЗОЧНЫМ ПРОЦЕССОМ НА ЖЕЛЕЗНОДОРОЖНОМ ТРАНСПОРТЕ: ОБЪЕКТНАЯ МОДЕЛЬ

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Рассмотрены особенности организации перевозочного процесса на железнодорожном транспорте как объекта интеллектуального управления. Проанализирован и систематизирован зарубежный опыт разработки и внедрения интеллектуальных систем управления на железнодорожном транспорте. Установлено, что в железнодорожном транспорте, как системе можно выделить организационную, функциональную и элементную сущности. Определены базовые элементы семиотической модели «железнодорожный транспорт» и сформулированы принципы описания объектной среды. Предложено описывать железнодорожную сеть с использованием математического аппарата теории графив, а в качестве объекта управления рассматривать вагонопотоки с определенными логистическими характеристиками и станциями назначения, которые в соответствии с планом формирования объединяются в поезда.

The Method of Engineering Tasks Composition on Knowledge Portals

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***Abstract*—The paper presents an approach to engineering tasks composition on engineering knowledge portals. The specific features of engineering tasks are highlighted, their analysis makes the basis for partial engineering tasks integration. The method of engineering tasks composition is developed that allows to integrate partial calculation tasks into general calculation tasks on engineering portals, performed on user request demand. The real world scenario "Calculation of the strength for the power components of magnetic systems" is represented, approving the applicability and efficiency of proposed approach.**

Keywords*—engineering task, knowledge portals, composition, parameters.

I. Introduction

Nowadays one of the major trends in the development of content management is moving from simple structure web-sites to large integrated portals of corporate knowledge. These portals contain a description of the different scientific, engineering or industrial tasks, information about methods of solving or providing services to implement them. Knowledge portal is an integrated portal designed to provide meaningful access to structured data and portal knowledge. Knowledge portals can be devoted to different subject domains. The knowledge portals that represent information on engineering subject domain (radio engineering, chemical industry, strength of materials, aerospace industry, materiology, casting manufacturing, etc.) are called engineering knowledge portals. The environment of such portals allocates great amount of different engineering tasks (ETs). This allow portal users to carry out real-time calculations related to the portal subject domain.

The main problem is the lack of a method of engineering tasks composition that will set the sequence of engineering tasks that should be included in complex engineering task on users demand. The use of such method for the engineering knowledge portals designing will ensure the efficiency of engineering tasks performance and improve the automation level of their composition.

This paper describes a novel method of knowledge portals engineering tasks composition, allowing to reduce the time of their performance as well as to automate the process of their interaction.

The paper is structured as follows: Section 2 provides the analyses of existing approaches to Web-services composition used for the performance of engineering tasks. Section 3 contains the description of engineering tasks characteristic features. Section 4 describes new method of engineering tasks composition. Section 5 highlights evaluation results, the evaluation has been applied using a real-world scenario within subject domain "Strength of materials". Section 6 concludes the work with a summary and outlook on future work.

II. Background and related works

Since the environment of engineering knowledge portal concentrates a large amount of information and software resources, the portal development platform should provide the ability to display these resources in different formats and the ability to integrate the applications for displaying of information resources using the means of workflow formation. Portal's workflow can be considered as means to automate the execution of tasks sequence related to the engineering tasks implementation.

Web Service Composition is a method to connect different web services that are used for creating high level business architecture by compiling of web services in order to provide functionalities that are not available during design [1]. Consequently, there is a possibility to develop a new functionality by simply reusing of components that are already available but unable to complete a task successfully on their own.

Various authors classify different WSC approaches:

- Static and Dynamic Composition ;
- Model Driven Service Composition;
- Declarative Service Composition;
- Automated and Manual Composition;
- Context-based Service Discovery and Composition.

The ability to select and compose heterogeneous Web services over the Web efficiently and effectively at runtime is an important step towards the development of the Web service applications [2]. By utilizing Web services end user is able to create composite services to fulfil the requirement when single service unable to do it.

Most of the approaches related to the Web service composition [3, 4, 5, 6] realized the fact that the prerequisite tasks to generate the composition solution are the service discovery and service selection of the candidate Web services stored in the service repository.

Semantic web services [7,8,9,10] provide an open, extensible, semantic framework for describing and publishing semantic content, improved interoperability, automated service composition, discovery and invocation, access to knowledge on the Internet [11].

Automatic Web service composition consists of four phases: Discovery, Planning, Selection, and Execution [12]. The first phase involves creating a plan, i.e., sequence of services in desired composition. The plan creation could be manual, semi-automatic, or automatic. The second phase embodies service discovery due to the plan. Planning and discovery are often combined into one step. After discovery of suitable services, the selection phase starts. It embodies a selection of the optimal composition from the available combinations of web services judging on nonfunctional properties like QoS properties. The final phase involves executing the services due to the plan. If some service is not available, another one takes it place. Concerning ET performance on engineering knowledge portals the most time-consuming is the phase of Discovery. As it is in need to choose from ETs variety only those that are to be composed for complex engineering calculation performance [13].

III. The characteristic features of engineering tasks

This section offers the detailed description of engineering tasks, their peculiarities and types. All engineering tasks can be divided into 2 types: complex and partial. Complex engineering tasks consist of partial and allow to perform complex engineering calculations. Partial engineering tasks allow only to determine certain feature or parameter and they do not show overall picture of how to perform engineering calculations [13]. In the process of complex ET formation the composition of partial ETs is held. Thus, to improve the efficiency of ETs performance on the engineering knowledge portals it is necessary to reduce the time of partial ETs composition as well as to automate the process of their composition.

Let us describe characteristic features of ETs that influence on their effective execution on the engineering knowledge portals:

- the decomposition of complex ET into partial ET;
- hierarchical subordination of ET;
- usage of the same partial ET in different complex ET;
- dependents of the ET execution order from their topic, parameters and characteristics;
- different directivity of ET.

One of the main problem with ET representation on knowledge portals is the description of their parameters (basic loading, winding radius, critical length, maximal diameter, etc.) that form the basis for partial ET integration.

Partial ET structure is similar to the complex ET structure and includes ET name and parameters. Search of the partial ET, to be included into the complex ET may be based on comparing of ET parameters, as complex ET includes only those partial ETs that have common parameters or parameter ranges of values overlapped. The formal description of partial and complex ETs sets is given below.

Let the set of complex ET to be:

$$ET^c \ni ET^c_k, ET^c_k = \left\langle T^{cET}_k, p^{cET}_{gk} \right\rangle \quad (1)$$

where

ET^c–complex ETs set,

ET^c_k–k-th ET from complex ETs set,

T^{cET}_k–title of k-th ET from complex ETs set,

p^{cET}_{gk}–q-th parameter of k-th ET from complex ETs set.

Partial ETs set is:

$$ET^p \ni ET^p_l, ET^p_l = \left\langle T^{pET}_l, p^{pET}_{tl} \right\rangle \quad (2)$$

where

ET^p–partial ETs set,

ET^p_l–l-th ET from partial ETs set,

T^{pET}_l–title of l-th ET from partial ETs set,

p^{pET}_{tl}–t-th parameter of l-th ET from partial ETs set.

As discussed approach deals with engineering tasks of knowledge portal, assume that each ET is uniquely identified by set of its parameters. It means that two ET with the same parameters could not have a different semantic in what they do and meanings of partial and complex ETs parameters could be used for partial ET integration into the complex one. Using such formal description, specific method can be used to automate ET composition.

IV. The method of engineering tasks composition

Proposed in section 3 allows to develop the method of ETs composition, allowing correctly and dynamically generate a sequence of partial ETs that are in need to be included into the complex ET when the portal is functioning.

ETs composition using proposed method can be presented as an ordered tree. Whereas the ordered tree is a tree with a root, which defines the order of child nodes, the usage of ordered tree for representation of complex ET composition process will specify the sequence of partial ETs included in a complex one execution.

The stages of proposed method are represented on Fig.1.

Stage 1. Comparing ET parameters.

At the first stage it is in need to discard from the set ET^p those ETs, for which p^{pET}_{tl} is not equal to p^{cET}_{qk}. It is in need to compare and select those partial ETs which parameters match the complex ET parameters. It is necessary to analyze the partial ETs set and choose from it those ETs, which parameters match the complex ET parameters according to the rule:

$$p^{cET}_d = \cup^m_i p^{pET}_i \quad (3)$$

whereby possible the fulfilment:

$$p^{pET}_i \cap p^{pET}_j \quad (4)$$

where $i, j = \overline{1, m}$

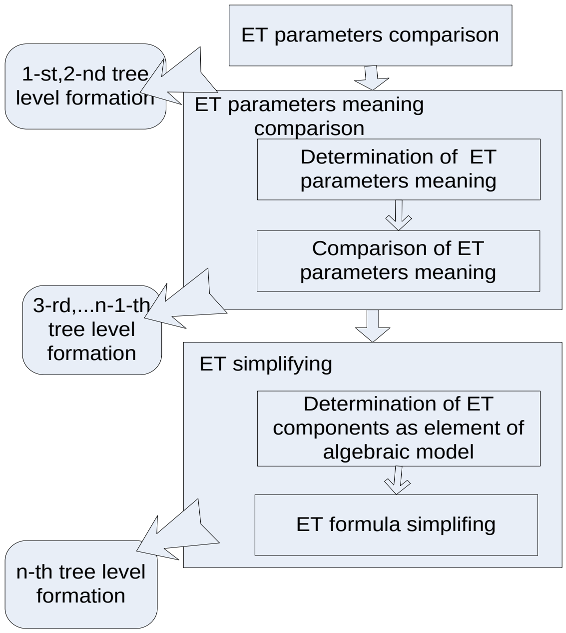

Figure 1. Stages of ETs composition method

The result is a subset of partial ET set satisfying the rule (3) and complex ET tree with second level tops, which are elements of this subset.

Stage 2. Checking ETs parameters values.

It is necessary to compare meanings of p_{tl}^{ET} to cut the subset of partial ETs, that has common parameters but their meanings are not equal. The comparison is done based on the occurrences or equality of these parameters meaning range of values.

Thus, on the second stage ETs parameters values from partial ETs set, formed on the first stage, are compared to complex ET corresponding parameters. The comparison is held due to the rule:

$$M\left(p_{il}^{ET}\right) <> M\left(p_{jr}^{pET}\right) \tag{5}$$

under the condition that $p_{il}^{ET} = p_{jr}^{pET}$

Stage 3. Simplifying ET formula.

The third stage operates with specific rules and operations to represent the formula of ET (described using specific algebraic model) in minimized form. Such simplifications rules are based on properties of operations [14, 15].

The resulting complex ET tree can be saved in the knowledge base as a pattern for further use with the possibility of its modification. It can be modified using standard operations on trees.

Presenting the complex engineering tasks in the form of tree structure allows to process each node of the tree, which represents a different partial ET, simultaneously, avoiding tree branches, which are independent of each other, which will minimize time for complex ET composition.

V. Example of the complex engineering task composition

To confirm the efficiency of the proposed method the test group of complex ETs for problem domain "Strength of materials" was selected. Let us show the example of complex ET from the test group formation using proposed method. This ET is "Calculation of the strength for the power components of magnetic systems". At the 1-st stage the analysis of partial ETs set was done. It was in need to choose from this set only those partial ETs that satisfies condition (5). Such ETs are:
–calculation of basic parameters – ET_1^p ;
–verifying calculation – ET_2^p ;
–strength calculation – ET_3^p ;
–critical constant calculation – ET_4^p ;
–resistance calculation – ET_5^p ;
–resistance calculation – ET_5^p ;
–calculation of reducing the strength of welds – ET_7^p ;
–calculation of flanges, rings and fasteners – ET_8^p ;
–calculation of static strength – ET_9^p ;
–calculation of stability – ET_{10}^p ;
–calculation of cyclic strength – ET_{11}^p ;
–calculation of crack resistance – ET_{12}^p ;
–calculation of voltage variation – ET_{13}^p ;
–calculation of seismic impacts – ET_{14}^p ;
–calculation of the vibration strength – ET_{15}^p ;
–calculation of the limiting value of deformation– ET_{16}^p ;
–calculation of the vibration stability – ET_{17}^p .

Formed complex ET tree is shown on Fig. 2. The root node show complex ET: ET_1^c – "Calculation of the strength for the power components of magnetic systems", intermediate nodes are ETs: ET_1^p – "Calculation of basic parameters" and ET_2^p – "Verifying calculation", leaves are the rest described ETs.

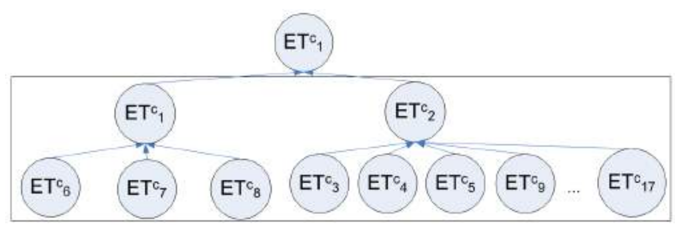

Figure 2. Complex ET tree after first stage

At 2-nd stage, the comparison of ETs parameters meanings was held according to the rule (5). Some partial ETs were discarded from the set formed on the first stage, as some of their parameters are out of range of values with values of the same parameters of general ET. The following ETs were discarded:
–critical constant calculation – ET_4^p ;
–calculation of stability – ET_{10}^p ;
–calculation of cyclic strength – ET_{11}^p ;
–calculation of voltage variation – ET_{13}^p ;
–calculation of the vibration stability – ET_{17}^p .

Complex ET tree after 2-nd stage is shown on Fig. 3. Tree includes the same nodes and leaves as tree represented on Fig. 3, but ET_4^p, ET_{10}^p, ET_{11}^p, ET_{13}^p, ET_{17}^p – were removed from the tree as the result of the 2-nd stage.

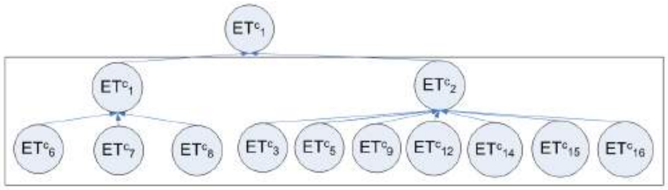

Figure 3. Complex ET tree after 2-d stage

VI. Conclusions

The paper presents method of engineering tasks composition on engineering knowledge portals. Proposed method of engineering tasks composition allows to integrate partial engineering tasks into a complex one on engineering knowledge portal, performed on user's request. It also allows to represent the process of complex engineering task composition as ordered tree that improves the efficiency of their performance through parallel processing of independent tree branches.

Future work is aimed on implementation of suggested method to different types of complex engineering calculation tasks. This will allow to approve its applicability and efficiency on real world scenarios. Developed software tool will be tested and verified on real world scenarios when engineering knowledge portals are developed. Quantitative evaluation of the proposed approach and tool efficiency will be obtained for different subject domains: the average time of engineering task composition, engineering tasks correctness and quality will be validated.

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МЕТОД КОМПОЗИЦИИ ИНЖЕНЕРНЫХ ЗАДАЧ НА ПОРТАЛАХ ЗНАНИЙ

Глоба Л.С., Новогрудская Р.Л.

В статье предложен подход к композиции инженерных задач на инженерных порталах знаний. Описаны характерные особенности инженерных задач. Разработан метод композиции инженерных задач, который позволяет интегрировать простые инженерные задачи в общий расчет на порталах инженерных знаний. Предложено описание процесса формирования общего расчета "Расчет на прочность силовых элементов магнитных систем ИТЕР который подтверждает повышение эффективность композиции простых расчетных задач при использовании предложенного метода.

Big Data in Service Delivery System by Communication Operator

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***Abstract*—In work complex analysis specialties of degree of subscribers' satisfaction taking into account both the services' technical parameters of and economic characteristics are considered when communication operator provides services. Object is achieved by methods of fuzzy logic for collaborative accounting of the impact of clear and fuzzy parameters. And it uses and a transition from unstructured data to the fuzzy knowledge base with a well-structured rules, that allows to implement a strategy typical for Big Data: data - information - knowledge, and thus significantly reduce the amount of calculations when data transmitting and processing.**

Keywords*—*data, information, parameters, Big Data, metagraph, knowledge base.

I. Introduction

At the present development stage of information and communication technologies, the term Big Data (BD) means a number of approaches, tools and methods of processing of structured and unstructured vast amounts of data and considerable diversity.

Accumulating data from network nodes rapidly increase every year. We need powerful computers to increase processing speed and data access. In connection with this, necessity to improve large amounts of data processing algorithms becomes more urgent.

According to research were conducted by a number of leading companies in the world [1] telecom operators are faced with the urgent need the complex account of different characteristics of provided services (technical, economic, experience of using services by end-user) due to the rapidly growing range of services and the transition to digital space. They want a clear understanding and process management, that occurring between the operator and its subscribers. This whole range of parameters is too large and complex data for the collecting, processing and analysis with the use of current computing infrastructure and is characterized by:

- significant amount of data (from terabytes to petabytes);
- necessity of high processing speed in real time in order to reduce the volume of storage;
- heterogeneity (can be structured, unstructured, semi-structured);
- necessity respond reliability requirement (may be disrupted due to the variety of data sources and processing methods, violations of safety requirements);
- importance (using of forecasted methods and methods of analysis allows to predict the direction of companies development).

Telecommunication companies are investing a lot of money in analytical tools and services development. With such data telecom operators aim at:

- increase sales;
- assure revenue (detect and prevent revenue leakage);
- reduce churn and fraud;
- improve risk management;
- decrease operational cost;
- improve visibility into core operations, internal processes and market conditions;
- discern trends and establish forecasts;
- cross-sell/up-sell products and service plans.

Therewith data analysis is often performed based on data, which is obtained as a result of the economic operator's activity, or base on sociological interrogations, or based on technical parameters of the operator's infrastructure functioning (for example, the decision to invest in one or another part of the system does not consider the influence and analysis of all possible factors and consequences) to achieve the objectives. If we consider the degree of users'satisfaction by services (it offered by telecom operator) problem, it is quite obvious that the frequent technical failures affect degree of satisfaction, pricing operator's policy and the services quality also have an impact on the final evaluation of the customer services quality.

Modern facilities of Big Data analysis require a transition from unstructured to structured data, thus forming, relatively speaking, "volume data compression volume to their meaning" and generating data processing strategy for Big Data as "data - information - knowledge - prediction" (Fig. 1), in this case the entered processing steps are understood as [1]:

- data - streams of raw facts such as business transactions;
- information - clusters of facts that are meaningful to human beings such as making decisions;

- knowledge - data/information organized to convey understanding, experience, accumulated learning, and expertise.

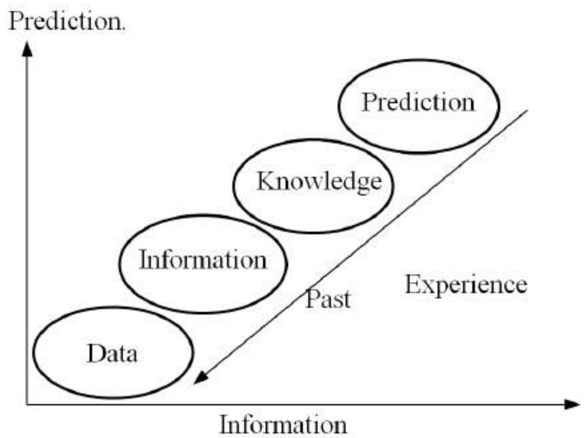

Figure 1. Scheme of the transition from unstructured data to information and to knowledge

II. Existing mathematical methods for Big Data

To implement the collection processes, storage, processing, analysis and forecasting such DB processing methods are now widely used:

- association mining;
- classification;
- clustering;
- neural networks;
- support vector machines;
- decision tree learning;
- others.

But there no data analysis algorithm, by which it would be possible to to combine all the components (technical, economic and social).

III. Proposed approach for collection, analysis and processing Big Data for communication operator

In this work joint assessment of all unbound clear and fuzzy parameters is proposed to use for constructing a fuzzy rule base, which would allow to produce a complex analysis of the expected quality of service delivery by telecom operator.

According to the considered features of Big Data processing, which are widely discussed in several papers [2; 3], the approach is proposed. This approach is based on fuzzy logic methods for taking account the impact of clear and fuzzy parameters, and using the transition from unstructured data to the fuzzy knowledge base with well-structured rules, that can significantly reduce the amount of calculations in the transmission and data processing. The main steps of this approach:

Step 1 Data stream forming (functional and sense dependencies extraction, meta description forming, parameters' impact rate determination).

Step 2 Fuzzy Knowledge Base (FKB) forming.

Step 3 FKB reorganizing and learning with the help of metagraph theory.

Step 4 Fuzzy conclusion.

Step 5 Fuzzy prediction.

One of the most difficult steps of the proposed approach is precisely the first step, where you should create define, organize and classify the data streams to get the possibility of applying algorithms of fuzzy knowledge base rules formation. It will allow to use this base in future for making decisions and predictions.

For this purpose, it is necessary to determine the parameters for forming a knowledge base, and methods for obtaining the values of these parameters.

Note, that telecom operators have already carried out analysis of economic efficiency, an analysis of the technical network infrastructure by monitoring system, also conducted a polls of subscribers for communication quality evaluation and services satisfaction. But the analysis processes of three components are isolated and are not included in the complex.

IV. Parameters definition of the knowledge base

In the context of the degree satisfaction with the quality of services assessment by end-users and the possible churn influencing this process parameters are divided into the following groups:

- parameters characterizing the technical state of the system;
- the cost of using voice and Internet services;
- quality of provided services.

To collect data as the sources of initial statistical data for the task solution is proposed to use:

- for technical parameters - operator's functioning monitoring system;
- for economic parameters - available estimates of economic indices at companies;
- for sociological parameters - available subscribers' opinion poll at companies.

These data are combined into one or several tables in accordance with the timing parameters for the formation of a fuzzy base rule. To get an array of statistical data for each parameter parameters calculation is carried by using existing data, which were collected by the system. Structuring and classification of these data allows getting a table (Fig. 2).

Based on the statistical data (data were presented in the table) rules represent knowledge are formed (for example, the forecast of degree change of customer satisfaction in the future periods). These rules have the form of:

Subscriber's satisfaction (Y1)	Technical parameters (Y2)					Economical parameters (Y3)			
	Network Operability	Call Setup Failure Rate	Subscriber Perceived Congestion	Call Drop Rate	...	Churn rate	Appetency	Gini index	...

Figure 2. Structuring and classification of data streams to form the rules of fuzzy knowledge base (FKB)

<< IF Y2 AND Y3 ..., THEN Y1 >>.

Using these rules the analysis of the social component of the network for the next period can be carried.

To solve the objective of satisfaction degree assessment of quality of service by subscribers it is necessary to determine integral index, which can characterize the quality of the services and which can be obtained from the data network monitoring system. Such parameter may be considered the integral index of quality of network functioning.

A. Integral quality index calculation

To determine the integral quality index (KQI_D) it is necessary to calculate such additional parameters:

- Connection Success Rate - successful data connections 2G/3G, %
- Connection Block Rate - the percentage of line lockout due to overload
- Connection Drop Rate - the percentage of breakages data connections 2G/3G, %
- PS Attach Success Rate - the percentage of successfully completed procedures Attach 2G/3G, %
- PDP Context Activation Success Rate - the percentage of successfully completed activation procedures PDP Context 2G/3G, %
- Speed DL - the average daily speed HSDPA of transmitting data to the subscriber, kbit/s
- Iub Congestion - the share of 3G BS with high overloads on Iub interface, %;
- Backhaul Accessibility - zonal transport network availability, %
- DNS Success Rate - successful DNS resolution, %
- DNS Response Latency - DNS resolution time, ms
- Peering Utilization - peering interface load level, %.
- Backbone Abnormal Latency - exceeding the normal delay between trunk transport network's nodes, %
- $w1 \dots 13$ - weighting coefficients of parameters.

Fig. 3 shows the structure of mutual influences parameters, which are components of the integral quality index.

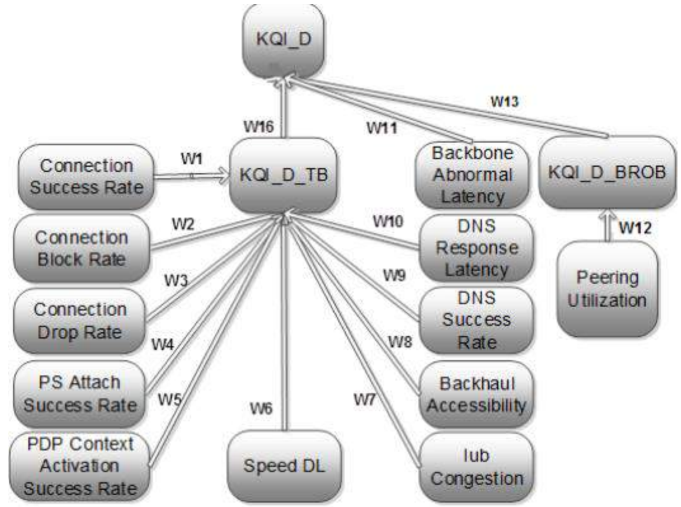

Figure 3. Scheme of integral quality index calculation

B. Average means of use voice services of 1 minute for all subscribers coefficient calculation

Average means of use voice services of 1 minute for all subscribers coefficient (KVS) defined by (1):

$$KVS = \frac{P}{t}, \frac{USD}{min}, \quad (1)$$

where $P = \sum P_i$, USD - the total cost of all voice services; $t = \sum t_i$, min - the total time of all conversations.

The cost of one conversation is offered to calculate by the following formula:

$$P_i = k_t * (p_c + t_i * k_d * p_o), \ USD,$$

where k_t - subscriber's tariff plan coefficient; p_c, USD - connection cost; t_i, min - one conversation time; k_d - call destination coefficient; p_0, USD - one minute conversation cost.

C. Average means of use internet services of 1 MB for all subscribers coefficient calculation

Average means of use internet services of 1 MB for all subscribers coefficient (KVS) defined by (2):

$$KIS = \frac{I}{m}, \frac{USD}{MB}. \quad (2)$$

where $I = \sum I_i$, USD - the total cost of all internet services; $m = \sum m_i$, MB - total amount of used traffic.

The cost of one internet session is offered to calculate by the following formula:

$$I_i = k_t * k_{type} * m_i * k_w * k_{dn} * I_0, \ USD,$$

where k_t - subscriber's tariff plan coefficient; k_{type} - traffic type coefficient; m_i, MB - amount of used traffic; k_w - day of the week coefficient; k_{dn} - time of the day coefficient; I_0, USD - cost of using 1 MB traffic.

D. Quality of services provided coefficient calculation

Quality of services provided coefficient is calculated by (3) [4].

$$F = \sum_{i=1}^{k} h_i * F_i \qquad (3)$$

where F_i - partial quality index; h_i - weightiness coefficient of partial quality index F_i , which is defined, as a rule, based on subjective considerations and is normalized by k partial quality index $\sum_{i=1}^{k} h_i = 1$.

V. Knowledge base formation

FKB is formed according to metagraph theory, that allows forming knowledge base rules based on clear and fuzzy values of its parameters [5].

Metagraph is generalized concept of graphic structures. Formally, metagraph is range

$$< V, MV, E, ME >$$

where V - range of vertices; MV - range of metavertices; E - range of edges; ME - range of metaedges.

Fig. 4 shows a modified decision making algorithm which use FKB [6; 7]. This algorithm is the most common method of inference in fuzzy systems using minimax composition of fuzzy ranges, which is effective for ordinary (non-adaptive) fuzzy systems.

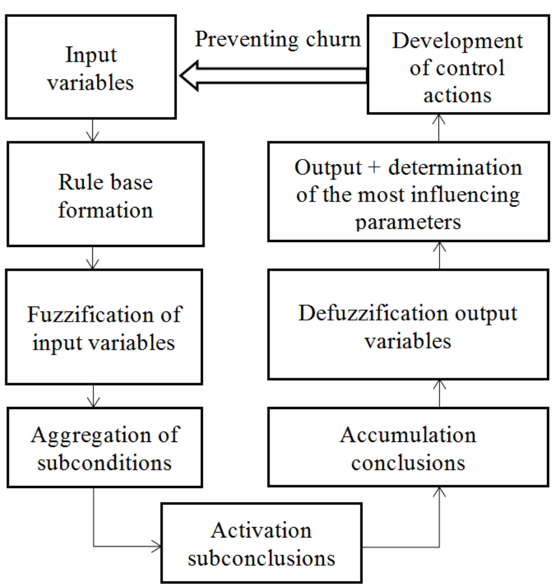

Figure 4. The process of preventing churn

Thus, the object is achieved by fuzzy logic methods, which use observed data in communication operator's network as input data. These methods take into account the combined influence of clear and fuzzy parameters and use transition from unstructured data to the FKB with clearly structured rules. It allows to implement typical strategy for BD: data - information - knowledge, and consequently significantly to reduce the amount of calculations when transmitting and processing of data.

VI. Conclusion

An approach, that allows to complex analyze the degree of subscribers' satisfaction based on the change technical parameters of the operator's infrastructure, and economic performances of the offered services is proposed.

The advantage of the approach is the use of the knowledge base and rules generated by automated path instead of the large amounts of processed information.

Further work will be connected with analysis and the determination of specific parameters (technical, economic, social), that have the greatest impact on the process of subscribers' satisfaction by provided communication services.

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BIG DATA В СИСТЕМЕ ПРЕДОСТАВЛЕНИЯ УСЛУГ ОПЕРАТОРОМ СВЯЗИ

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В работе рассматриваются особенности комплексного анализа степени удовлетворенности абонентов при предоставлении услуг оператором связи с учетом как технических параметров инфраструктуры предоставления услуг, так и экономических характеристик самих услуг. Поставленная задача решается методами нечеткой логики для совместного учета влияния как четких, так и нечетких параметров. Также использует переход от неструктурированных данных к нечеткой базе знаний с четко структурированными правилами. Данный подход позволяет реализовать стратегию, характерную для Big Data: данные – информация - знания. Такая стратегия позволяет существенно уменьшить объем вычислений при передаче и обработке данных.

Разработка семантических основ информационных систем при проектировании и производстве машиностроительных изделий

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Аннотация—В работе объектом исследования являются процессы формирования информационного и лингвистического обеспечения информационных систем (ИС) на основе онтологического анализа предметной области (ПрО). Предметом исследования являются семантические основы информационного и лингвистического обеспечения ИС в ПрО, связанных с проектированием и производством авиационной техники. В работе рассмотрено применение различных типов онтологий при решении задач в двух ПрО по схеме «ПрО – задача в выбранной ПрО – онтологическое представление решаемой задачи в выбранной ПрО»: проектирование – предварительное проектирование самолета – тезаурус проектанта; производство – производственное планирование на машиностроительном предприятии – онтология машиностроительного предприятия.

Keywords—семантические основы, информационные системы, проектирование, производство, машиностроительные изделия.

I. Введение

Анализ ситуации в области разработки, сопровождения и эксплуатации информационных систем (ИС), проведенный на основе отечественной и зарубежной практики создания и использования элементов таких систем, показал, что сложившиеся традиционные направления, базирующиеся в основном на совершенствовании математического моделирования объектов и процессов, перестали быть доминирующими в создании ИС [Андриченко, Боргест, Лукашевич, Мордвинов]. Современный период развития информационных технологий в значительной степени связан с интеллектуальной поддержкой процессов принятия решений, с совершенствованием методов и технологий взаимодействия пользователей с ИС, с онтологизацией ИС и дальнейшей содержательной формализацией [Смирнов, Шведин, Шпилевой, Шустова]. Интерфейсное обеспечение становится более эргономичным, наращивается мощность баз данных и знаний в предметных областях (ПрО), связанных с проектированием и производством авиационной техники (ППАТ), увеличиваются коллективы разработчиков ИС. Все это требует согласования данных и знаний, циркулирующих как в самих системах, так и находящихся в неформализованном виде у пользователей. В связи с этим, в современных ИС для ППАТ возникает необходимость в методах и средствах, ориентированных на обработку и анализ семантики информационных материалов при решении задач ППАТ [Шустова, 2015]. Междисциплинарный характер проводимых исследований в области ППАТ, вовлеченность узких специалистов в совместный процесс приводят к изменению терминов и самих понятий ПрО. Разрабатываемые терминологические стандарты не успевают за ростом номенклатуры и вводимых специальных терминов, при этом тезаурусы, содержащие сущности и связи между ними в выбранной ПрО, практически отсутствуют. Существующие терминологические соглашения в ПрО носят лишь локальный характер (объектный, проблемный), и при любом расширении области использования требуется их пересмотр. Для успешного развития ИС актуальной и практически важной является разработка их семантической основы – информационной модели ПрО ППАТ, содержащей информацию, обработанную с учётом анализа взаимосвязи терминов и понятий этой ПрО и отношений между ними. При этом разрабатываемые семантические основы ИС для ППАТ в виде методик, практик, технологий и инструментариев должны учитывать:

- особенности и специфику решаемых задач ПрО ППАТ;
- многопользовательский характер применения инструментариев;
- разный уровень компетенций и ответственности пользователей;
- сложившийся понятийный аппарат ПрО ППАТ;
- многообразие терминов и понятий.

Несмотря на то, что опубликованные работы формируют контур будущих интеллектуальных систем, в них в недостаточной мере рассмотрены и решены методические вопросы разработки семантической основы ПрО ППАТ, а также практическое применение семантических основ ПрО ППАТ при разработке ИС.

II. Цель и задачи

Целью работы является повышение качества и сокращение времени подготовки решений с помощью ИС за счет разработки и реализации в ИС семантических основ, построенных в результате онтологического анализа исследуемой ПрО ППАТ. Для достижения цели при создании семантических моделей поставлены следующие научные задачи:

- провести анализ существующих стандартов, языков моделирования, редакторов онтологий с целью исследования возможности создания семантических моделей ПрО ППАТ;
- для ПрО ППАТ разработать методику создания онтологий, являющихся семантическими основами при создании ИС в этих ПрО;
- на основе разработанной методики создать тезаурус ПрО «Проектирование самолета», который будет являться семантической основой разрабатываемой ИС - интеллектуальный помощник проектанта (робот-проектант);
- на основе разработанной методики создать базовую онтологию машиностроительного предприятия, которая будет являться семантической основой при создании ИС для производственного планирования на этом предприятии.

В соответствие со стандартом ISO 15926 классы в онтологии упорядочены в структуру (Рисунок 1). Стандарт ISO 15926 на сегодняшний день является одним из наиболее перспективных стандартов организации онтологических баз данных, определяющих структуру объектов и систем. В нем специфицируется принимаемая модель данных, определяющая значение сведений о жизненном цикле промышленного объекта в едином контексте.

Рис. 1. Структура онтологии на базе стандарта ISO 15926

III. Методика

Предлагаемая методика включает в себя совокупность правил и принципов разработки тезаурусов и онтологий, а так же правила и принципы, включенные автором в соответствие с проведенным анализом и спецификой ПрО ППАТ. Разработанная методика включает в себя:

- Определение ПрО создаваемой онтологии.
- Определение причин создания онтологии.
- Рассмотрение вариантов повторного использования существующих онтологий.
- Исследование ПрО и определение масштаба создаваемой онтологии.
- Определение предполагаемых вариантов и сценариев использования.
- Выбор онтологического редактора.
- Определение терминологической базы.
- Определение и соблюдение ведущего типа отношений между сущностями, построение онтологии и дополнение ее ассоциативными связями.
- Корректировка масштаба онтологии.
- Использование онтологии в соответствие с выбранным сценарием.

Созданный тезаурус «Проектирование самолета» является семантической основой и интегратором компонент в ИС «Робот-проектант», который используется для обучения студентов и магистрантов предварительному проектированию самолета и является прототипом будущих интеллектуальных и ИС. При создании тезауруса реализовывался семантический подход, суть которого в рассмотрении ПрО как взаимодействии целого и составляющих ее частей. Общая терминология, включенная в тезаурус, основана на Авиационных правилах, учебниках и учебных пособиях, терминологических словарях, справочниках для логического анализа определений терминов, энциклопедий, научно-технических публикациях и базах данных в ПрО ППАТ, а также на матрицах проектов и используемых проектных процедурах, включая математические модели. Установление родо-видовых отношений между терминами в тезаурусе реализуется в соответствии с ГОСТ 7.25-2001. (Тезаурус информационно-поисковый одноязычный. Правила разработки, структура, состав и форма представления). Понятия в онтологии, представленной в виде тезауруса, организованы в таксономию.

Выявлены проблемы при построении тезауруса и предложены пути их решения:

1. Проблема выявления ассоциативных связей

Для решения проблемы выявления ассоциативных связей предложено устанавливать связи-ассоциации между терминами, не подлежащими родо-видовым отношениям, с помощью предикатов. Например, «самолёт» - «конструкция», «самолёт» - «двигатель», «самолёт» - «параметры» и т.д. Между этими терминами отсутствуют иерархические родо-видовые отношения («конструкция» не является одним из видов «самолёта») и они не являются синонимами, но состоят в отношениях принадлежности: «самолёт» имеет «конструкцию», «самолёт» имеет «двигатель», «самолёт» имеет «параметры» и т.д. В таком случае устанавливаются ассоциативные связи.

2. Проблема синонимии (проблема контекста)

Для решения проблемы синонимии предложено при включении синонимов в тезаурус использовать пояснительные слова. Например, дескрипторы «устройство» и «прибор» являются синонимами, в то же время, под устройством в авиационной отрасли часто понимается «строение механизма», но ряд: «прибор = устройство = строение механизма» не является логически верным. Таким образом, при создании эквивалентных классов предложено в скобках указывать значение, в котором употребляется данный термин. На рисунке 2 приведен пример использования пояснительных слов для класса «Устройство».

3. Проблема расширения и слияния тезаурусов

Для решения проблемы расширения и слияния тезаурусов сформулированы и предложены некоторые решения основных проблем. Расширение тезауруса подразумевает наполнение существующих классов иерархии подклассами, а также заполнение классов экземплярами. К настоящему моменту тезаурус «Проектирование самолетов» содержит 1226 терминов и 505 логических ассоциативных связей. Слияние тезаурусов подразумевает расширение выбранного тезауруса путем добавления в него нескольких тезаурусов. При слиянии тезаурусов необходимо учитывать родо-видовые и ассоциативные отношения, наличие синонимов и омонимов, а так же уровни иерархии. Проверка и установление недостающих ассоциативных связей между сущностями в тезаурусе, полученного путем слияния двух тезаурусов, является трудоёмким процессом и может привести к ошибкам. Тем не менее, возможность слияния тезаурусов позволяет распределить задания между несколькими разработчиками и одновременно создавать несколько тезаурусов с последующим их объединением.

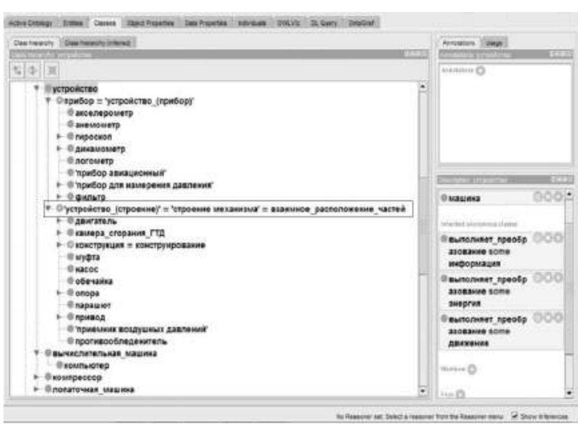

Рис. 2. Класс «устройство». Использование пояснительных слов

Одной из важных составляющих самолёта является крыло. На рисунке 3 представлена семантическая сеть фрагмента тезауруса – класс «Крыло», формализуемая и представленная в онтоkönnen Protégé и один из экранов ИС «Робот-проектант» сформированный на основе этого фрагмента тезауруса (класс «Крыло»). Онтология машиностроительного предприятия является формализованным представлением исследуемого предприятия и выступает в роли семантической основы на этапе разработки ИС, предназначенной для производственного планирования. Онтология определяет выбор методов и технологий решения задач, а на этапе запуска системы в производство является связующим звеном между работниками предприятия и программным обеспечением.

Рис. 3. Экран ИС «Робот-проектант» с сущностями фрагмента тезауруса

Семантическая основа в виде онтологии машиностроительного предприятия способствует интеграции разнородной информации, распределенной на предприятии, а также позволяет повысить эффективность коммуникаций. Онтология предприятия строится на основе информации о предприятии в форме регламентов и структурно-функциональных схем. При создании онтологии всем сущностям предприятия сопоставлены понятия, атрибуты, экземпляры, роли, а между ними выстроены иерархические и ассоциативные отношения. В онтологии машиностроительного предприятия выделены восемь основных сущностей:

- предприятие и все его сущности являются объектами управления;
- управление предприятием – субъекты предприятия (работники);
- документы – средства управления;
- материальные ресурсы – производственные ресурсы;
- выпускаемая продукция – результат деятельности (управления);
- оборудование – средства для получения результата деятельности;
- процессы – процессы, выполняемые сущностями;
- заказчики – субъекты, оказывающие воздействие процессы, выполняемые сущностями.

Эти сущности предприятия являются фундаментальными и практически неизменны для любого машиностроительного предприятия, в зависимости от специфики исследуемой ПрО их можно дополнить. Большинство машиностроительных предприятий работают в среде «производство на заказ», когда заказчик размещает конкретный заказ на конкретную продукцию, указывая при этом требуемое количество и дату поставки. На рисунке 4 приведен фрагмент семантической сети процесса выполнения заказа. Например, мастер смены получает и выполняет сменно-суточные задания, а также проставляет отметку о выполнении задания.

Мастер смены подчиняется начальнику участка, который в свою очередь подготавливает производственное расписание. Таким образом, описана семантика рабочего процесса, выполняемого мастером смены и начальником участка, все сущности этого процесса связаны между собой, а знания формализованы и использованы в виде онтологии, которая является семантической основой при создании ИС. На рисунке 5 представлены сущности процесса планирования работ онтологии машиностроительного предприятия, которые используются в ИС производственного планирования «Smart Factory», разработанной НПК «Разумные решения», при создании диаграммы Ганта. Наряду с мультиагентной парадигмой распределения ресурсов и работ на предприятии в онтологии предприятия используется принцип ответственности, основанной на традиционной иерархической парадигме.

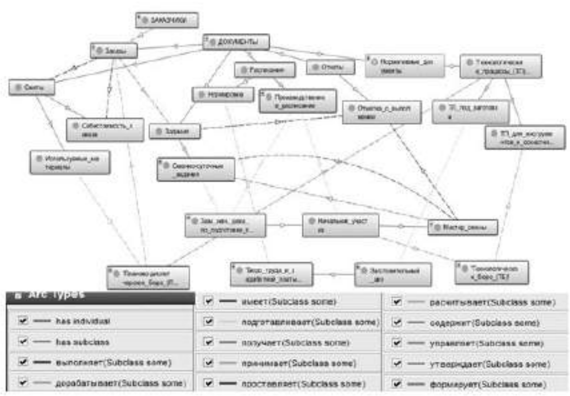

Рис. 4. Фрагмент семантической сети процесса выполнения заказа

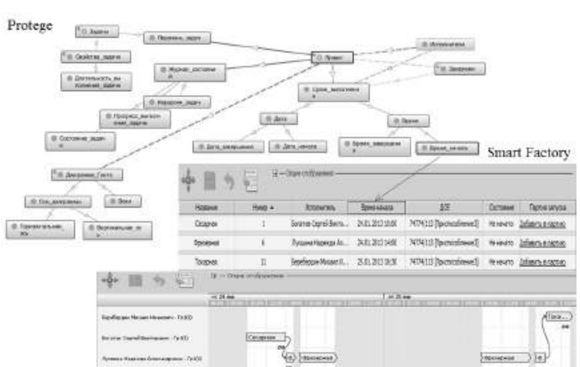

Рис. 5. Сущности процесса планирования работ

В разработке ИС производственного планирования базовая онтология машиностроения явилась прикладным инструментом и обеспечила разработчиков ИС полной информацией о предприятии, его структуре, протекающих в нём бизнес-процессов. Онтология, построенная на основе обработки и анализа информации, позволила не только описать исследуемую ПрО и решаемые в ней задачи, и тем самым зафиксировать знания о ПрО, но и использовать эти знания при формировании шаблонов экранов, структуры баз данных, отработке сценария работы с ИС.

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DEVELOPMENT OF SEMANTIC FOUNDATIONS OF INFORMATION SYSTEMS IN THE DESIGN AND MANUFACTURE OF ENGINEERING PRODUCTS

Shustova D.V., Borgest N.M.

In this paper the object of study are the processes of the Information and Linguistic Support of Information Systems (IS) on the basis of ontological domain analysis. Subject of research constitute the semantic foundations of information and linguistic support of IS data domain related to the design and manufacture of aircraft. The application of different types of ontologies for solving problems in two data domain on a "domain - task in the selected domain - ontological representation of the problem being solved in the selected domain ": design - preliminary design of the aircraft - the thesaurus designer; production - production planning for the machine-building enterprise - ontology engineering enterprise.

Методы поддержки принятия решений с использованием гипервариативных интерфейсов применительно к проектированию сложных технических систем

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Аннотация—В работе рассмотрено применение методов гипервариативного представления информации в системах поддержки принятия решений. Описаны модели принятия решений, показана связь между принятием решений и другими когнитивными процессами.

Keywords—интерфейс, принятие решений, моделирование, проектирование.

I. Введение

Актуальным направления развития современных пользовательских интерфейсов систем поддержки принятия решений является уменьшение когнитивной нагрузки на лицо, принимающее решение (ЛПР), что позволяет повысить уверенность ЛПР в результатах собственной деятельности, а также увеличить эффективность его работы за счет снижения времени, необходимого на восприятие информации [Borgest et al. 2015]. Одной из техник, позволяющих достичь уменьшения когнитивной нагрузки на ЛПР является применение гипервариативных интерфейсов.

II. Принятие решений

Теория принятия решений позволяет выбрать оптимальную стратегию в условиях наличия множества альтернатив В многоуровневой эталонной модели мозга [Wang et al., 2003] процесс принятия решений описывается как фундаментальный высший когнитивный процесс, связанный с когнитивной деятельностью сознательных форм жизни [Wang et al. 2006]. На рисунке 1 представлено сопоставление естественного интеллекта и уровней многоуровневой эталонной модели. Высшие когнитивные функции на уровне 6 обеспечиваются мета когнитивными процессами на уровне 5.

К ключевым мета когнитивным функциям 5 уровня относят поиск, категоризацию, запоминание и представление информации, которые обеспечивают восприятие, обучение, мышление, принятие решений, решение проблем, анализ, синтез, планирование и количественную оценку, относящиеся к 6 уровню. На рисунке 2 представлены когнитивные функции уровней 5 и 6, участвующие в когнитивном процессе принятия решений [Wang et al. 2004].

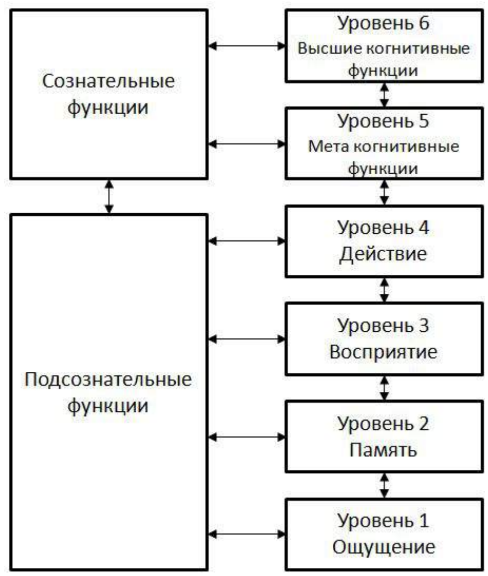

Рис. 1. Сопоставление естественного интеллекта и уровней многоуровневой эталонной модели мозга

Таким образом, процесс принятия решения это высший когнитивный процесс мозга по выбору предпочтительной альтернативы или действия среди некоторого множества вариантов на основании некоторой информации [Wang et al., 2003]. Восприятие - это действие или способность осознавать путем выявления связей между данным объектом или атрибутом и другими объектами. Одним из представлений восприятия является модель отношения объект-атрибут [Wang et al. 2003], в рамках которой объекту или атрибуту сопоставляется соответствующий кластер в долгосрочной памяти. На рисунке 3 представлено взаимодействие трех мета когнитивных функций и восприятия как высшего когнитивного процесса [Wang and Gafurov, 2003].

Стоит отметить, что эти мета когнитивные функции

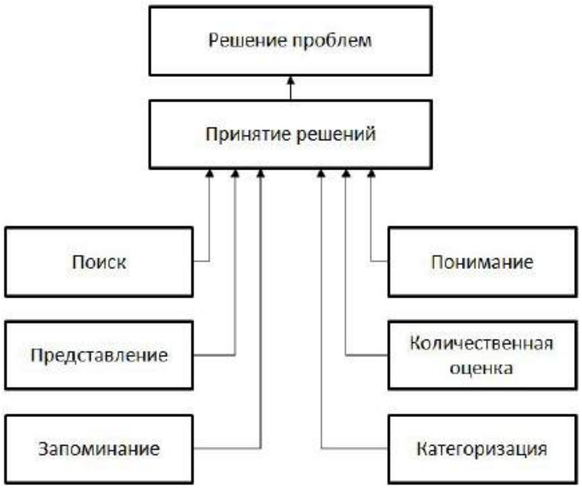

Рис. 2. Связь между принятием решений и другими когнитивными процессами в рамках многоуровневой эталонной модели мозга

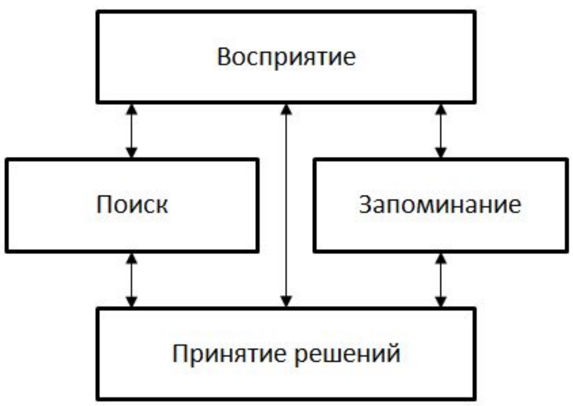

Рис. 3. Взаимодействие трех мета когнитивных функций и восприятия как высшего когнитивного процесса

(поиск, представление знаний и запоминание), связанные с восприятием, также связаны с процессом принятия решений (рисунок 2). Таким образом, повышение качества восприятия информации, выраженного как совокупность трех мета когнитивных функций поиска, представления и запоминания информации, является ключевой задачей в улучшении эффективности пользовательского интерфейса и предотвращению когнитивной перегрузки. Согласно [Paul and Nazareth, 2010] совместная работа позволяет повысить эффективность получения и распространения больших объемов информации, однако одновременно усложняет её обработку что может привести к информационной перегрузке. Эти выводы были сделаны на основании группового исследования эффективности совместной работы и использованием программных систем поддержки групповых проектов. В результате исследования была выявлена обратная U-образная зависимость между сложностью информации и необходимым временем для её восприятия и обратная зависимость от строгости временных ограничений. Исследование также показало, что представление пользователю аналитически обработанной информации в значительной мере снижает информационную перегрузку и позволяет воспринимать больший объем информации. Также результаты этого исследования не противоречат описанию высшего когнитивного процесса восприятия согласно многоуровневой эталонной модели мозга.

III. Человеко-машинное взаимодействие

Человеко-машинное взаимодействие изучает взаимодествие человека и компьютерных систем и их влияние друг на друга [Dix et al., 2003]. Человеко-машинное взаимодействие позволяет уменьшить необходимое количество человеческих действий, требуемых для решения задачи с использованием компьютерных систем до разумного набора стандартных процедур на основе когнитивных моделей действий в рамках пользовательского интерфейса [St. Amant, 1999]. Понимание того как и почему пользователи интерпретируют визуальные подсказки - это вопрос, относящийся одновременно к науке о человеко-машинном взаимодействии и науке о процессе познания. В работе [Shneiderman et al., 2009] задача разработки пользовательского интерфейса формулируется как понимание возможностей восприятия и понимания информации предполагаемого пользователя в абстрактной предметной области, включая поиск и обработку информации, решение проблем и логический вывод, принятие решений, оценку рисков, восприятие и выработку новых знаний через обучение. Все эти абстрактные процессы имеют место при решении задач проектирования сложных технических объектов. Под расширенной средой понимается применение методов нескольких научных дисциплин, включая нейрологию, психологию и информатику, для идентификации когнитивных проблем и адаптации пользовательского интерфейса для снижения когнитивной нагрузки и повышения эффективности работы пользователя [Shmorrow et al., 2006]. Базовая расширенная среда восприятия предполагает постоянный мониторинг контекстуального состояния пользователя, наличие механизма логического вывода, осуществляющего оценку когнитивного состояния пользователя, адаптивный интерфейс, снижающий когнитивную нагрузку на пользователя путем ситуационного изменения своих параметров, и компьютерную систему, интегрирующую все компоненты среды. В работе [Preece et al., 2011] был предложен общий принцип проектирования интерфейсов - представление информации в форме, максимально способствующей её восприятию и пониманию её смысла путем стимуляции творческого поиска и манипуляции пользователем с помощью графических элементов и динамически меняющихся представлений информации при поддержке решения пользовательских задач. Подобный подход был реализован в прототипе системы автоматического проектирования самолета "Робот-проектант пользователь следует заранее заданному сценарию расчета, в рамках которого он может в значительной мере влиять на изменение проектных параметров [Borgest et al., 2015]. Выделяют следующие восемь правил проектирования пользовательских интерфейсов [Shneiderman et al., 2009]:

- единообразие, подразумевающее выполнение пользователем схожих действий при решении схожих задач;

- повышение универсальности через возможность создания пользователем шаблонов для часто решаемых задач и сокращения повторяющихся операций;
- реализация обратной связи с пользователем через графическое представление пользователю информации об интересующих его сущностях;
- выделение отдельных этапов в решении пользовательской задачи и подтверждение их выполнения;
- предотвращение ошибок путем ограничения пользовательских вариантов действий и реализации возможности вернуться к предыдущим этапам решения задачи;
- реализация механизма быстрой отмены изменений, внесенных в проект, для развития стремления пользователя исследовать интерфейс и экспериментировать с новыми для себя функциями;
- создание у пользователя ощущения контроля путем инициализации выполнения действий после проявления соответствующей инициативы пользователя;
- снижение нагрузки на краткосрочную память пользователя путем учета человеческих ограничений на возможности обработки информации и создание возможностей для мнемонической тренировки пользователя при выполнении последовательностей действий.

Создание интерфейсов, манипулирующих пользователем, имеет множество преимуществ, включая возможность визуального представления задачи, упрощение обучения и поддержки навыков использования интерфейса и предотвращения ошибок ввода данных, что позволяет повысить степень удовлетворения пользователя [Shneiderman et al., 2009].

IV. Гипервариативные интерфейсы

Несмотря на наличие большого количества техник визуализации больших массивов информации, проблема их успешного применения в контексте систем поддержки принятия решений до сих пор весьма актуальна [Zhu et al., 2008]. Выделяют три основных стратегии визуализации, способствующих снижению когнитивной нагрузки на пользователя [Bhavnani, 2000]:

- представление пользователю исключительно релевантной информации;
- одновременная демонстрация информации о связанных сущностях;
- реализация навигации пользователя по меню на высоком уровне абстракции с одновременной демонстрацией детализированной информации по выбранному элементу.

Методы обработки информации могут помочь в реализации выдачи пользователю исключительно релевантной информации. Применение методов обработки информации совместно с методами визуализации информации делает возможным снижение когнитивной нагрузки на пользователя. В 2001 году была сформулирована концепция гипервариативного представления информации [Spence, 2001]. Основной идеей метода является одновременная демонстрация пользователю не менее чем трех связанных атрибутов одновременно. Пример такого представления изображен на рисунках 4 [Yang et al., 2004] и 5 [Hauser, et al., 2002].

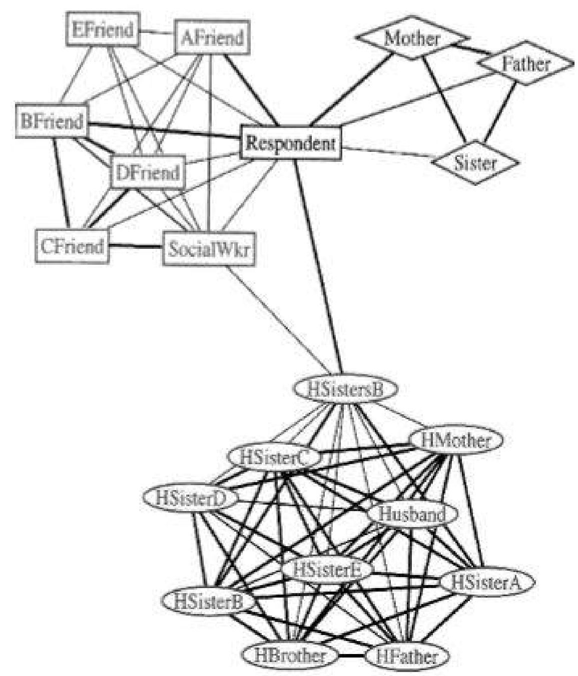

Рис. 4. Гипервариативное представление возможности социального выбора в виде графа

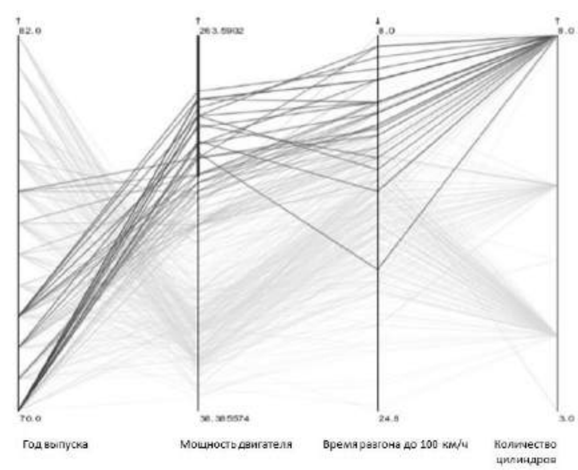

Рис. 5. Гипервариативное представление статистики о мощности автомобилей, произведенных в США в период с 1970 по 1982 годы

Предполагается, что применение методов визуализации объектов предметной области с использованием дополнительных символов, представляющих значения их атрибутов, позволит упростить сравнение между объектами [Muller, 2010]. Одной из ключевых проблем при реализации гипервариативных представлений информации является сложность визуализации данных для пользователя в случае необходимости одновременной демонстрации большого количества проектных переменных. Одним из потенциальных решений этой проблемы может быть использование методов машинного обучения с целью выделения переменных, оказывающих наибольшее влияние на результат. Другим возможным подходом является использование трехмерного представления наборов графических представления наборов взаимосвязанных данных как показано на рисунке 6 [Fanea et al., 2005].

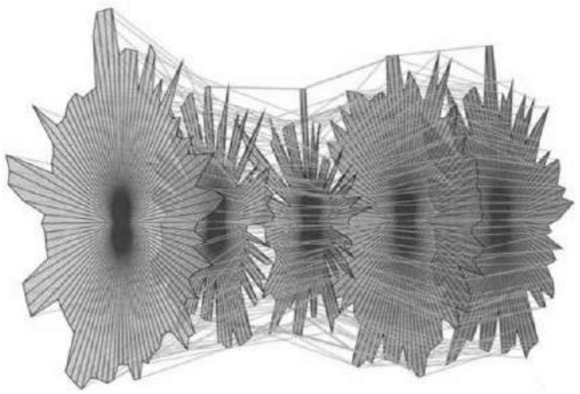

Рис. 6. Использование трехмерного представления наборов графических представления наборов взаимосвязанных данных

V. Заключение

Применение рассмотренного метода поддержки принятия решений на основе гипервариативного представления информации в интерфейсах информационных систем позволяет потенциально снизить когнитивную нагрузку на пользователя за счет более наглядной демонстрации связи между проектными параметрами. Практическое применение этого метода, однако, требует проведения значительного объема работы по созданию графических шаблонов, которые можно было бы использовать для отображения информации пользователю.

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METHODS FOR DECISION-MAKING AID IMPLICATING HYPERVARIATIVE DISPLAY TECHNIQUES FOR INTERFACES OF COMPLEX TECHNICAL ARTIFACTS DESIGN SUPPORT SYSTEM

Korovin M.D.

The article describes modern state in the domain of decision-making aid using hypervariative information display techniques in interfaces of decision-support systems. Several models of human cognition and decision-making are discussed, including the Layered Reference Model of the Brain. The necessity of diminishing of the cognitive load on the user was shown based on data obtain from several research reports. Several issues of human-computer interaction regarding the data representation in the interface for a decision-making support system have been shown. Hypervariative techniques of data display were discussed in their application towards the design of complex artifacts. Several problems regarding their usage were outlined.

The Information System of Evolution Control of Multistage Processes of Production and Technical Systems in Fuzzy Dynamic Environments

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Abstract—**The article takes up the information model of evolution control of multistage processes in fuzzy dynamic environments. A multistage process is considered as a multiagent system whose efficiency depends on a coordinated behavior of the center and agents, their interest in the search and implementation of solutions, skills of analyze capabilities of evolutionary development. For this model the algorithm of information support of the process is described.**

Keywords—information technologies, evolution control, multiagent systems, innovation solutions, coordinated optimization, algorithms.

I. The control of production and technical systems evolution on basis of innovations

In the articles [1, 2, 3 et al.] it is considered the evolution production problem by force of capitalization knowledge, experience and intellect of industrial personnel and the formal model of the evolution mechanism of intelligent production is proposed and researched.

It is determined conditions which provide progressive production development actively using knowledge.

The base of this development composes innovative activities pointing at searching and new decisions implementations for improving quality of products, technological and industrial engineering development.

Innovative activities include detection of enterprise problems, innovative process realization and innovative activities organization.

Purposeful innovative activities can only be realized in the presents innovative potential which includes production, scientific and technical, intellectual and personnel, marketing, financial and investment and information potentials.

The general task of effectiveness enterprise increasing and long-term enterprise stability during a whole life cycle consist in creation of methods and means for optimal control of production and technical systems evolution in the context of dynamic uncertainty.

Productivity enhancement achieves by virtue of continuous improvement of the technical processes on basis of innovation in the course of production and technical systems evolution.

A control process of production and technical system evolution is characterized a number of features, for examples, an alternative and an uncertainty of goal achievement ways with a high risk, an impossibility of accurate planning, orientation on predictive estimates and contradictoriness in the sphere of economic relations and interests of process participants.

A multistage process underlies a production and technical system and consists of a number of stages. A process state on the output of the every stage is the input of next stage and as a result of using control on the output to form a state whose output value is unknown in advance.

It is only known the fact that output and input variables are linked together by a fuzzy relation with a fuzzy set adjective depending on values of output and input states and a control variable. At each process stage an output and control are linked together by a respective fuzzy relation.

A control objective is set by fuzzy set which defines qualitative indicators of a last stage output. The task consists in finding a control consequentiality which ensures maximal implementation of a fuzzy objective in an each stage.

Modeling of fuzzy multistage process by means fuzzy relations and composition rules permits to realize synthesis of control with feedback and the concerned processes.

A formal model of a production and technical system describes a hierarchical interaction between the center and agents which operate the certain technological stage of a production process.

An each agent has activity and autonomy properties and participates in operating of a certain technological stage of a production process.

The center makes planned decisions about the output on basis of state analysis of production and technical systems. At the same time the center doesn't have an accurate notion about technological capabilities of agents.

In order to form an full agreed plan in view of all global and local restrictions which reflect the center and agents interests it is necessary to develop special procedures of expert information acquisition and an exchange of this information between the center and agents.

In fuzzy dynamic environment a control process of production and technical systems evolution is characterized number of features, for examples, an alternative and an uncertainty of goal achievement ways with a high risk, an impossibility of accurate planning, orientation on predictive estimates and contradictoriness in the sphere of economic relations and interests of process participants.

Modeling of fuzzy multistage process by means fuzzy relations and composition rules permits to realize synthesis of control with feedback of the concerned process.

II. The information system of innovative support

Methodology of formation of information innovations support system for control of manufactured evolution it can be shown on a particular case of control of n-stages technological process (fig. 1).

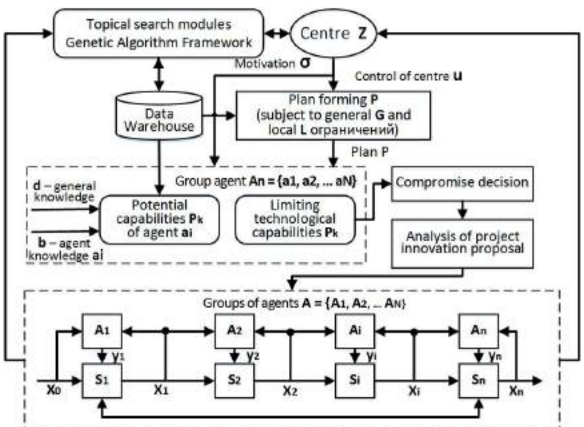

Figure 1. The scheme of control of n-stages technological process

An agents group A_n controls each stage s_n. The centre Z sets the plan p subject to local l and general g limitings and analysis of received information. It controls an agents group A_n when it controls a potential capabilities growth of an each agent a_n (fig. 2).

At the same time it is known that an agent has general knowledge d. This knowledge is known by both an agent a_n and the centre Z. In addition an agent has knowledge b which is known by only an agent a_n. And an agent a_n has knowledge, receiving as result of searching algorithms using. This knowledge is used by an agent for forming of information about its capabilities during execution of technological functions.

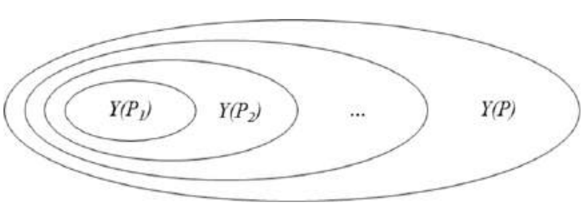

Figure 2. The growth of limiting capabilities agent during control process

The control algorithm of production and technical system evolution involves following blocks:

- a description of general tasks of technological system functioning. This part describes supporting subsystem such as means of production, resources, executives; technological means as mean technique, specific means, support of technological system performance and others.
- a description of a computational process in the performance of a tasks of information processing and control of equipment, apparatus, supervision systems. There are presented structure elements of technological system and their interaction.
- a description tasks of system evolution control. This part describes basic control ways of evolution technological system:
    - on basis of control of personnel potential capabilities increase, for example, new methods of motivation control and forming by personnel information about their capabilities (studying an experience of other analogous enterprises, professional development, studying new professional literature and etc.);
    - on basis of control of limit technological capabilities increase (for examples, an introduction of new ways and possibilities of equipment exploitation, production units, existing equipment modernization, technological stages adjustment etc.);
    - on basis of execution of production plan (for examples, solutions introduction which influence limitation)

The general algorithm description contains a description of block connections by output and input information [4]. The scheme of information processing in control process of evolution of a continuous industrial process which contains several technological subprocesses presents in the figure 3.

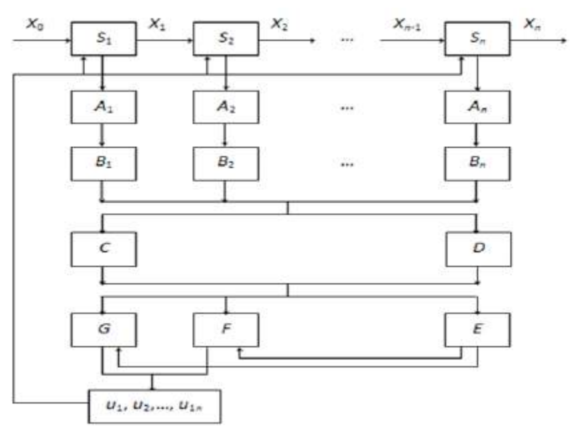

Figure 3. The scheme of information processing in control process of evolution

A continuous industrial process contains stages $S_1, S_2, \ldots, S_N$, where x_n – input process state of n stage, $x_n + 1$ - output process state.

$A_1, A_2, \ldots, A_N$ – first stage of information gathering concerned with manufacturing equipment and supporting subsystems. In addition, information about system state of control instrumentation is received by means of predefined time interval.

$B_1, B_2, \ldots, B_N$ - second stage of information gathering. Data B received on the first stage classify by characteristic group and information receipt time.

C – on basis of checking and analysis of a data set received on the stage B it forms conclusion about moral and technical state of equipment, supervision systems by means comparison actual data and the best characteristics of analogous production.

D – on this stage it realizes quality results check of an each stage of technological system.

Next stage of evolution control involves contraction following information:

E – search for innovative solutions for evolution control of a fuzzy system.

This stage is one of the most importance stage for technological system control, because deficient values of quality production parameters, supporting systems parameters and a deficient level of manufacturing equipment are discovered in the course of technological system functioning.

Therefore enterprise managers have to form a control decision for improving technological system state.

There are a lot of subsidiary information in data depositories of distributed information systems. Besides an every technological system contains an intellectual resource which can use by skillful construction of motivational control.

A task of searching, collection , generalization and synthesis of control solutions and preanalysis of innovation offers results for effectiveness increase of system functioning in the large is the challenge for enterprise managers at different level.

F – planning of collection and generalization source information functioning, applications processing of supporting systems. In accordance with technical regulation a chart of receiving and further processing primary information is forming. As appropriate an adjustment of this chart is realized.

In the monitoring of production system along with general tasks of receive information about stages of concerned technological system and their stable support it need to solve additional tasks about support of equipment operability, controlling and measuring apparatus systems and check of their state.

Applications for solving similar tasks cluster to priorities table

- 1 – applications of primary information processing;
- 2 – a list of periodical applications of secondary information;
- 3 – a list of official applications.

An objective of grouping applications is possibility of operative decision-making for addressing and prevention emergency situations with the support of technology regulation implementation and an adjustment of introduced innovative technology.

G – analysis, modeling and forecasting stage. This stage solve a problem of introduced innovations purposefulness in technological process and forming of control impacts connected with technological system evolution.

In developing programme complex realized algorithm of control of production and technological system evolution it need to use typical software which consist:

- components of primary fuzzy information processing;
- components of secondary fuzzy information processing;
- complex of exchange information with equipment and controlling and measuring apparatus and automatic systems;
- complex of technical state equipment check;
- complex of jobs planning involving components of forming of timing chart for control system functioning;
- complex of analysis, modeling and planning;
- complex of innovative solutions searching for improving a technological process;
- complex of results production check (economic efficiency, production quality and other)

The task solution of effective control of industrial production substantially depend on information support of innovations at an enterprise.

An enterprise information potential provides quality realization of all the other potential.

The information receiving by topical retrieval is used for:

- control of the growth centre of potential and limiting manufacturing capability of the agent;
- production plan developing by the centre;
- forming of information by the agent about its capabilities;

For information influence on intellectual agents subject conception it used searching and knowledge extraction means from distributed data warehouse and their implementation in decision support systems

Creating system of intellectual information innovations support at the enterprise is based on mechanisms integration of innovative solution searching, appropriate data warehouse, control methods of industrial production evolution with the use of the created warehouse of innovative solution including information exchange means in accordance with coordinated optimization algorithms and identification manufacturing characteristics.

Creating those systems is the central problem occurring during creation of enterprise evolution control system.

Effective use of global information knowledge stream includes competitive analysis and technological development forecasting which are based on scientometric analytical services and semantic systems of searching commercial valuable information.

In this connection a key role is play by effective algorithms oriented to an expert topical search of innovative solutions both in global and in local data specialized warehouse.

Execution of topical searching in documentary warehouse is the well-known procedure [5, 6, 7].

Documentation topical retrieval establishes document selection goal, containing coordinated information (interrelated facts, their retrospection and perspective) in a thematic segment or by the given object.

The result of this retrieval is document aggregate which are integrally relevant given themes not only information about specific cases, objects, phenomena.

Ranges of topical retrieval application: innovative solution searching, determination of new direction for business, information gathering about clients, competitive analysis and exploration, reviews of scientific and technical data source, project examination, patent research and instructional materials.

When topical retrieval is being realized, the key role is played by effective searching algorithms inasmuch as users impact with problems series troubling necessary information searching.

The effective searching algorithm is proposed in [8].

III. Conclusion

Example of how to use this approach for evolution control of chemical and technological systems on basis of innovations is proposed in [4].

Use of information system of innovative support permits to find and make a decision about inclusion in a technological scheme additional operations and raw material handling stages.

In addition, on basis of additional information analysis it made the decision about need of certain substances substitution, taking part in a technological process on stage n by other similar substances which have improved properties.

It allowed increasing a volume of production, indices of quality of finished products at the same time a finished products cost reduced on account reducing of an indirect material purchase cost for this stage.

Increase in profit occurred on account increasing enterprise functioning.

In this way, intellectual information support of innovations at an enterprise, based on integration of searching mechanisms of innovative solutions, models and methods of manufactured evolution control, use of coordinated optimization algorithms for manufacturing characteristics, allows to stimulate innovative searching and thereby improves technological and economical indices of enterprise functioning.

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ИНФОРМАЦИОННАЯ СИСТЕМА УПРАВЛЕНИЯ ЭВОЛЮЦИЕЙ МНОГОСТАДИЙНЫХ ПРОИЗВОДСТВЕННО - ТЕХНИЧЕСКИХ СИСТЕМ В НЕЧЕТКОЙ ДИНАМИЧЕСКОЙ СРЕДЕ

Палюх Б.В., Ветров А.Н., Егерева И.А., Козлова Ю.Г.

Рассмотрена информационная модель управления эволюцией многостадийных производственно - технических систем в нечеткой динамической среде. Многостадийный процесс рассматривается как многоагентная система, эффективность управления которой зависит от согласованного поведения центра и агентов, их заинтересованности в поиске и внедрении инновационных решений, умения анализировать возможности эволюционного развития. Для представленной модели описан алгоритм информационной поддержки процесса эволюционного развития. Рассмотрены вопросы осуществления экспертного тематического поиска инновационных решений в глобальных и локальных специализированных хранилищах данных. Приведены компоненты типового программного обеспечения необходимого для разработки программного комплекса, реализующего алгоритм управления эволюцией производственно-технологической системы.

The Simplest Problem of Fuzzy Dynamical Systems Optimal Control

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***Abstract*—Abstract–The paper explores the question of the terminal state control of fuzzy dynamical systems, characterized by classical fuzzy relations. A solution of the problem is traced to the functional equation solution such as Bellman equation.**

Keywords—fuzzy dynamical systems, terminal state control, Bellman equation.

I. INTRODUCE

The notion of fuzziness nowadays is widely used for processes description of technical, economical and other nature. This comes from the fact that this notion allows to operate simply and naturally on qualitative information which is in many cases mainly responsible for ambivalence (see, eg. [1, 2]).

Initially, the methods of fuzzy set theory have been directed to use logical methods of decision-making, based on the compositional inference rule (see., eg, [1]). Subsequently the methods of the dynamic programming theory and fuzzy sets theory was used to develop control problem-solving techniques of deterministic and stochastic systems with fuzzy objectives and restrictions (see., eg, [2]).

It enabled to form a general theory of mathematical programming and the theory of decision-making with fuzzy objectives and restrictions (see, eg, [3] - [5]). Further development of fuzzy dynamic programming can be found, for example, in [6] overview, where, in particular, the problem of deterministic and stochastic systems with the fuzzy end time and infinite horizon control are considered.

Let's now note that simultaneously with the development of the theory of dynamic and mathematical fuzzy relationship have been widely used in the control theory and theory of decision-making under fuzzy initial information. For example, in [3] and [7] papers there have been considered and studied in details the fuzzy preference relations of great importance to the problems of decision-making in fuzzy systems (including active ones). Let's also mention [8] paper, where on the basis of fuzzy relations questions of the theory of approximate reasoning in fuzzy control are considered.

The main goal of this paper lies in the further development of the [2]-[6] results. All the constructions are actually based on the almost apparent modification of classical composition operation of fuzzy sets shown below in par. II.

II. FUZZY SETS COMPOSITIONS

In considering the control problem further we'll need some important capabilities of fuzzy sets compositions.

Let X, Y and Z be certain sets. Let's assume that at a $X \times Y$ set a fuzzy relation A with membership function μ_A, is defined and at a $Y \times Z$ set a fuzzy relation B with membership function μ_B is defined. Therefore theis defined. Therefore the $A \circ B$ composition of fuzzy set A and B is the fuzzy relation in $X \times Z$ space with the membership function

$$\mu_{A \circ B}(x, z) = \sup_{y \in Y} \min[\mu_A(x, y), \mu_B(y, z)] \quad (1)$$

(see, eg. [1]).

Let's now assume that in X space the fuzzy set R with membership function μ_R s defined. Therefore the fuzzy relation μ_A induces the fuzzy set $R \circ A$ n the Y spase. In accordance with (1) the membership function $\mu_{R \circ A}$ of $R \circ A$ set is given by an equation

$$\mu_{R \circ A}(y) = \sup_{x \in X} \min[\mu_R(x), \mu_A(x, y)].$$

These compositions of fuzzy relations are widely used in the theory of fuzzy sets for the construction of compositional inference rules (see [1]). For the behavioral research of fuzzy dynamical systems we'll use the supplementary rule of fuzzy sets composition.

Let's assume that at X set the fuzzy relation S with membership function μ_S is defined. Further, let's assume that in X space G set with membership function μ_G s also defined. Therefore we can determine the $S \circ G$ composition of fuzzy sets S and G and following (1) the membership function $\mu_{S \circ G}$ of $S \circ G$ set will be defined by equation

$$\mu_{S \circ G}(x_1) = \sup_{x_2 \in X} \min[\mu_S(x_1, x_2), \mu_G(x_2)]. \quad (2)$$

One can readily see that $S \circ G$ composition allows to determinate the membership degree of element of X set to fuzzy G set with fuzzy relation S. Specifically for each $x_1 \in X$ the membership degree of $\mu_{S \circ G}(x_1)$ of x_1 the fuzzy set G is defined by equation (2).

III. Simplest Problem Of Optimal Control

Let X and U be certain compact metric spaces. Let's consider control system when X is state space and U is control space.

Let's assume that evolution of system state is characterized by the fuzzy relation S representing fuzzy set S in $X \times U \times X$ pace with membership function μ_S. Provided that the initial state $x_0 \in X$ is defined. As a result of choosing of $u_0 \in U$ control the system goes into some new state x_1 which was earlier unknown. It is only known that with u_0 and x_0 fixed, x_0, u_0 and x_1 variables are related by the fuzzy relation S with membership function $\mu_S(x_0, u_0, x_1)$. In other words with x_0 and u_0 fixed at point of time n=0 the state x_1 can be defined only by value of membership function $\mu_S(x_0, u_0, x_1)$. However at point of time n=1 we can observe exact value of state x_1.

In a similar way if at some point of time n the state x_n is known than a result of choosing of u_n control we can estimate the state x_{n+1} by fuzzy relation S with membership function $\mu_S(x_n, u_n, x_{n+1})$. Moreover, at the next point of time $n+1$ the state x_{n+1} becomes known.

Let's consider that the control aim is characterized by fuzzy goal set G in X space with membership function μ_G. Let's also assume that both functions μ_S and μ_G are continuous in the range of their definition.

Now let's assume that time N of end of system work is defined. The control problem is to search the sequence

$$u_0, u_1, \ldots, u_{N-1} \tag{3}$$

of points of U set maximizing the membership degree of x_0 states to fuzzy set G with fuzzy relations with membership functions

$$\mu_S(x_0, u_0, x_1), \mu_S(x_1, u_1, x_2), \ldots, \mu_S(x_{N-1}, u_{N-1}, x_N).$$

Therefore the fuzzy set G is the control aim and the problem consists in searching the control sequences (3) providing the maximal membership degree of the state x_0 to the fuzzy set G with that the evolution of system state is described be the composition of fuzzy sets S and G.

By equation

$$D_N = \underbrace{S \circ \ldots \circ S}_{N} \circ G$$

let's put for consideration the fuzzy set D_N being conditional for variables (3) in the X space with membership function μ_{D_N} satisfying the equation

$$\mu_{D_N}(x_0 \,|\, u_0, u_1, \ldots, u_{N-1}) =$$
$$= \max_{x_1, x_2, \ldots, x_N} \min[\mu_S(x_0, u_0, x_1), \mu_S(x_1, u_1, x_2), \ldots,$$
$$\mu_S(x_{N-1}, u_{N-1}, x_N), \mu_G(x_N)].$$

Therefore according to equation (2) $\mu_{D_N}(x_0 \,|\, u_0, u_1, \ldots, u_{N-1})$ he values of function μ_{D_N} have the form of the membership degree of the state x_0 to G set with the use of any fixed sequence of control of (3) kind.

Let's set

$$\mu_N(x_0) = \max_{u_0, u_1, \ldots, u_{N-1}} \mu_{D_N}(x_0 \,|\, u_0, u_1, \ldots, u_{N-1}). \tag{4}$$

Following [1] let's consider the initial task in the context of task family where x_0 and N are variable values. Therefore with $N = 0$ the required membership degree x_0 to G et with the fuzzy relation S is prescribed by the equation

$$\mu_0(x_0) = \mu_G(x_0). \tag{5}$$

Function μ_0 s continuous by convention over all of the intervals at X set. Moreover because of continuity of functions it is easy to note that for each function f which is defined and continuous over all of the intervals at X and possesses values at the interval [0,1], the function

$$g(x_0, u_0, x_1) = \min[\mu_S(x_0, u_0, x_1), f(x_1)]$$

is continuous over all of the intervals. But X and U spaces are compact. Therefore, the function

$$h(x_0) = \sup_{u_0, x_1} \min[\mu_S(x_0, u_0, x_1), f(x_1)] =$$
$$\max_{u_0, x_1} \min[\mu_S(x_0, u_0, x_1), f(x_1)]$$

is continuous over all of the intervals at X set. Provided that

$$\max_{u_0, u_1, \ldots, u_N} \mu_{D_{N+1}}(x_0 \,|\, u_0, u_1, \ldots, u_N) =$$
$$= \max_{u_0, x_1} \min[\mu_S(x_0, u_0, x_1),$$
$$\max_{u_1, u_2, \ldots, u_N} \mu_{D_N}(x_1 \,|\, u_1, u_2, \ldots, u_N)]$$

(see, eg. [9]). Then by virtue of (4) for certain N the equation

$$\mu_{N+1}(x_0) = \max_{u_0, x_1} \min[\mu_S(x_0, u_0, x_1), \mu_N(x_1)], \tag{6}$$

is executed where $\mu_{N+1}(x_0)$ is the maximal membership degree of the statex_0 to the G set with the relation S and the condition where end of system work time is equal to $N+1$, and $\mu_N(x_1)$ is the maximal membership degree of the state x_1 to the G set with relation S and the condition where end of system work time is equal to N.

One can readily see that recurrence relationship (6) with the condition (5) is similar to Bellman's functional equation for classical problems of dynamic programming. This relationship interprets the control u_0 as function of time N and the state x_0, i.e.

$$u_0 = u_0^*(x_0, N), \quad N = 1, 2, 3, \ldots \tag{7}$$

IV. ASYMPTOTIC PROPERTIES OF RELATIONSHIP (6)

In many practical cases it is appropriate to replace control law (7) by autonomous law

$$u = u^*(x) \tag{8}$$

(see, eg. [3]). In order to understand the availability of getting such a law let's study asymptotic properties of relationship (6).

Let's set as an set closure operation. Let $C(X, [0,1])$ be a space of continuous functions defined at X set and possessed value at interval [0,1]. For certain function $\varphi \in C(X, [0,1])$ let's assume

$$A\varphi = \max_{u_0, x_1} \min[\mu_S(x, u_0, x_1), \varphi(x_1)],$$

where A is an operator mapping the space $C(X, [0,1])$ into itself. Therefore the following sentences are correct.

Proposition 1. Let's assume that the X space is finite. Therefore the set

$$\Omega(\mu_0) = \bigcap_{N \geq 0} \left(\bigcup_{k \geq N} A^k \mu_0 \right)$$

isn't empty, it is compact in the topology of simple convergence and is invariant. In such a case the equation

$$\lim_{k \to +\infty} A^k \mu_0 = \Omega(\mu_0). \tag{9}$$

Proposition 2. Let M be a set of functions

$$\mu_0, \mu_1, \ldots, \mu_N, \ldots \tag{10}$$

Therefore if the X space is finite then the set

$$\Omega(M) = \bigcap_{N \geq 0} A^N M \tag{11}$$

isn't empty, is compact in the topology of simple convergence and is invariant. In such a case the equation

$$\lim_{N \to +\infty} A^N M = \Omega(M). \tag{12}$$

The assumption of the X space finiteness in each specific case requires justification. However let's note that in our case the X space is initially considered as compact. Accordingly it is separable, i.e. in X here is dense set being countable everywhere. Thus there is a countable -netcovering the X space. But in virtue of the X space compactness out of each of its countable covering the finite subcover can be chosen. In other words there is a finite -net overing the X space.

Thus in general case the X space can be approximated by a finite set to a high accuracy. Thus the conditions of sentences 1 and 2 are shown with prescribed accuracy . In addition the compact space approximation by its certain finite part is justified in many practical situations for modeling of fuzzy systems (see, eg. [1]). For this reason sentences 1 and 2 set asymptotic properties of relationship (6) applicable for practice.

V. ASYMPTOTIC AUTONOMOUS CONTROL LAW

Asymptotic properties of relationship (6) set by sentences 1 and 2 prevent from thinking directly of the optimal autonomous control law existence without any additional requirements.

Actually we can speak about the existence of such a law only with sequence convergence (10). In this case according to A operator continuity in some cases the function μ defined at the X set by the equation

$$\mu(x) = \lim_{N \to +\infty} \mu_N(x), \tag{13}$$

is a continuous solution of the equation

$$\mu(x_0) = \max_{u_0, x_1} \min[\mu_S(x_0, u_0, x_1), \mu(x_1)]. \tag{14}$$

For the purpose that the equation (14) is followed by existence of the equation (14) continuous solution it is sufficient the convergence (13) is uniform at Xset and control laws (7) are continuous. Again the necessary and sufficient condition of uniform convergence in the equation (13) as is known lies in the fact that the set (10) is equicontinuous (see, eg. [9]). Then in the case under consideration the check of equicontinuity of the set (10) is rather difficult in virtue of representation of A operator.

Let's note that the situation is extremely rare where at the X set the equation is simply (even nonuniformly) satisfied (see, eg. [9]). The situation becomes complicated by the fact that even if the equation (14) has a unique solution it doesn't mean that the control law (8) corresponding to this solution will be unique. Thus we have to speak in the majority of practical situations only about the existence of suboptimal autonomous control law.

For the development of such law let's assume that the X set is finite. Therefore according to the sentence 2 the closure M of the set (10) isn't empty, is compact and invariant. But each compact, invariant set contains compact minimum set (see attachment 2). Thus under conditions of sentence 2 the set $\Omega(M)$ contains the compact minimum set . In this case by the finiteness of the X set one can find such finite system of compact, invariant set

$$\Omega(M) \supset M_1 \supset M_2 \supset \ldots \supset M_N, \tag{15}$$

that equation

$$\mathcal{M} = \Omega(M) \cap M_1 \cap \ldots \cap M_{N_M}, \tag{16}$$

is satisfied where N is a certain sufficiently great positive integer (see, eg. [9]).

If the system (15) is built then according to the equation (16) the set is also built. Let μ be arbitrary function of the set. Therefore by virtue of the fact that is a minimum set the function

$$A\mu = \max_{u_0, x_1} \min[\mu_S(x, u_0, x_1), \mu(x_1)] \tag{17}$$

belongs to and v.v. (see [10]).

One can readily see that maximum in the equation (17) is attained with the use of the certain control law

$$u = u_\mu(x). \tag{18}$$

Moreover by equation (13 and (14) it is easy to note that if the optimal law (8) exists, the law is the same as law (18).

Thus a certain kind of control law (18) corresponds to each function $\mu \in$. Any of these laws in general case is only suboptimal. However by sentences 1 and 2 the equation (17) not only sets the existence of such suboptimal laws but provides a procedure of its construction.

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ПРОСТЕЙШАЯ ЗАДАЧА УПРАВЛЕНИЯ НЕЧЕТКИМИ ДИНАМИЧЕСКИМИ СИСТЕМАМИ

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В работе рассмотрена задача управления конечным состоянием нечетких динамических систем. Эволюция состояний рассматриваемых систем характеризуется классическими нечеткими отношениями. Решение задачи сведено к решению функционального уравнения типа уравнения Беллмана. На основе современных методов общей теории динамических систем изучены асимптотические свойства решений полученного функционального уравнения. Изучена проблема существования и построения субоптимального автономного закона управления с обратной связью.

Decision-Making of Agent with Selectable Structure of Preferences

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***Abstract*—The article considers a model of decision-making by the agent capable of forming an internal goal and using subjective ideas of the choice situation. The approach is based on the ideas of subjectively rational choice.**

***Keywords*—reflexive control; decision making, choice model; compromise.**

I. Introduction

Reflexive control is the information influence the purpose of which is to persuade a subject to make a decision that will be beneficial to a controlling party [1]. Its realization has become possible when there appeared decision models of a subject with internal images of himself and the party influencing him.These models take into account his subjective understanding of the choice situation properties.Their use permits to make performance evaluation of information influence before it is introduced. Note, that the decision-making process is thought of as an uncontrollable factor in the normative decision theory. The development of subjectively rational choice concept has opened up the opportunity: a) to explain decision-making of a subject in specific situations, b) to predict possible reactions of another subject by decision-maker in different situations, c) to make active forecast when a controlling party brings the party being influenced to take a desired image of the future. Subjectively rational choice suggests that the choice motivation is determined by both external and internal factors. The internal factors reflect subject's interests prompted by his needs and the ethical system he adheres to. The assessments of current purposeful state situation satisfaction made by a subject, as shown in [2], may lead to changes in the structure of subject's interests, and he can choose it. Since subject's preferences in the choice situation reflect his interests, we can determine the set of alternatives G in a preference structure. According to [3], we shall call them structural alternatives.

II. Assumptions

1) The choice made by a subject is based on the ideas of purposeful state situation.
2) Idea components reflect different aspects of the subject's understanding of purposeful state situation and produce the information structure of his ideas. The set of possible idea options shall be designated as X.
3) For the set of environment states S, a set of observable environment states satisfies the condition $S \cap X \neq \varnothing$, that is, the subject's ideas can contain both objective and phantom components.
4) The subject selects structural alternatives depending on the assessments of satisfaction with purposeful state situation property values.
5) Ideas are formed driven by procedures of perception, awareness and analysis, in accordance with the cognitive abilities of a subject.

In accordance with the assumptions introduced, a subject uses three sets of alternatives in decision-making: controlling alternatives C (modes of action), structural alternatives G and identification alternatives X. Hence, we can assume the existence of three virtual parties involved in the choice of appropriate alternatives. Rules for the choice of these alternatives, depending on the subject's understanding of the environment and the structure of his interests, shall be designated as strategies.

Suppose that a decision-making is performed in several cyclic stages, and modes of action are selected at every stage n = 1, 2, ... of set C in accordance with the environment state idea $\in X$. This is due to the fact that the joint superconscious (intuitive) and conscious (formal) analysis of the environment state allow taking first vaguely aware and then more and more clearly formulated and sound decision in multiple iterations. At the same time, there are restrictions $C_x \subseteq C$ on the admissibility of alternative choice, depending on the idea of environment state $x \in X$. Dynamics of the processes in the environment of a subject are not available to direct perception, so the idea of them is formed by the identification procedures. They reduce to the choice of options presented depending on the observed state. At the same time, there are known restrictions on the admissibility of views $Xs \subseteq X$, which are taken as alternatives to identification depending on the observed states $s \in S$.

Based on these assumptions and following [3], we introduce the definition of strategies.

Single-valued transformation $\lambda : X \to C$ is such that $\lambda(x) = C_x, \ \in X$, is called choice or control function; we refer an ordered set $(\lambda_1, ..., \lambda_n) \equiv \lambda_1^n$ to strategy selection on the horizon of length n<∞; $lim \lambda_1^n = \lambda_1^{n\infty}$ with n→ ∞, is called the strategy aimed at achieving the local ideal that determines a reason for the subject's existence.

Monotone single-valued transformation $\xi : S \to X$ is such that $\xi(s) \in X_s, s \in S$, is called an identification function; ordered set $(\xi_1, ..., \xi_n) \equiv \xi_1^n$ is identification strategy on the horizon of length n<∞; we refer sequence $\{\xi_1^n, n = 1, 2, ...\}$ to identification strategy on the limited horizon. Since a subject strains after useful ideas, there exists lim$\{\xi_1^n\} = \xi^\alpha$ with n $\to \infty$.

Since sets S and X satisfy the condition $|S| > |X|$, then single-valued transformation ξ :S→ X generates a partitioning of set S into subsets

$\xi^{-1}(x) = \cup\{s \in S : \xi(s) = x\} \subset S, x \in X$

The subsets $\xi^{-1}(x) \subset S, x \in X$ are connected sets, that is, any element s $\in \xi^{-1}(x)$, uniquely determines the corresponding ideas $\in X$. Consequently, we can say that subsets $\xi^{-1} \subset S, x \in X$ form classes of equivalent representations. For the purpose of formalization of subject's ideas, this allows using the methods of a fuzzy-set theory, for example, as described in [4].

Structured alternative $\gamma_n \in G$ selected at moment n is a structural choice at the n - th decision-making stage; ordered set $(\gamma_n, ..., \gamma_1) \equiv \gamma_1^n$ is meant to be structural choice strategy on the decision-making length horizon $n < \infty$; sequence $\gamma_1^n, n = 1, 2, ...$ appears as structural choice strategy γ_1^n on the limited horizon. As much as a subject wants the structure of his interests to meet the requirements of the adopted by him ethical system, there is $lim\{\gamma_1^n\} = \gamma^\infty$ with $n \to \infty$.

III. Model of Decision-Making with Selectable Preference Structure

According to [2], the criterion of control strategy choice means the expected specific value of a purposeful state based on the result. Its formalization is written as the ut$S \times C$ to Sility function $E\phi^g(C \times S \times X)$ which depends on structural alternative $g \in G$ viewed as a parameter. Since the control process begins with a certain situation $x \in X$, criterion $E\phi_n(\gamma_1^n \mid \gamma_1^n)$ also depends on situation $x \in X$ viewed as an initial condition. So far as many situations X are finite, criterion $E\phi_n(\gamma_1^n \mid \gamma_1^n)$ comes down to vector in space R^X of dimension $|X|$. Its components can be written as $E\phi_n(\gamma_1^n \mid \gamma_1^n)(x), x \in X$. According to the result of choice, a subject is having an emotional experience, so the quality of structural choice strategy is to be described as the criterion having a sense of 'satisfaction with the choice result'. Consequently, the strategy quality γ_1^n can be described as convolution of the expected utility vector $E\phi_n(\lambda_n \mid \gamma_1^n) \in R^X$ to a certain composed function. Hence, the criterion of strategy quality can be written as

$$\mu_n(\lambda_1^n \mid \gamma_1^n) = \mu(E\phi_n(\lambda_1^n \mid \gamma_1^n)) \in R^1.$$

A subject associates the quality of his ideas with the assessments of possibility to achieve the desired states, providing $c \in C$, as well as possibility to expand set $\uparrow$ by means of introducing effective alternatives. The terms of linguistic variable "utility" which are based on values $E\phi_n(\lambda_n \mid \gamma_1^n)$ were used in [5] as an idea assessment criterion. In this connection the utility assessments depend on the control strategies λ_1^n and structural choice viewed as given conditions. Let us write down the criterion "utility" as $\psi_n(\xi_1^n \mid \lambda_1^n, \gamma_1^n)$. Since the identification process begins with a certain state $s \in S$, this criterion will depend on state $s \in S$ specified as an initial condition. As much as this set of states is finite, the identification criterion is represented by vector $\psi_n(\xi_1^n \mid \lambda_1^n, \gamma_1^n)$ in space R^S of dimension $|S|$.

In the situation of purposeful state, the quality of control strategies and structural choice is determined by criteria $E\phi_n(\lambda_1^n \mid \gamma_1^n) \in R^X$ and $\mu_n(\lambda_1^n \mid \gamma_1^n) \in R^1$ having a sense of specific value based on the results and satisfaction with the choice. The quality of identification strategy is determined by criterion $\psi_n(\xi_1^n \mid \lambda_1^n, \gamma_1^n) \in R^S$ that makes sense of utility of ideas for the purpose of achieving the desired states. The criteria applied require adequate information structures and models to be used in order to make the corresponding choice. Let us assume that there is the information structure of ideas I reflecting subject's knowledge and experience of: modes of actions (control), their interests and preferences, and dynamics of environment transition into different states. In that case we may suppose this structure to be structurally transformed into the information structure that can provide an opportunity to construct the criterion of a specific value $E\phi_n(\lambda_1^n \mid \gamma_1^n)$ and a subject domain model. The transformation will be referred to as specific value transformation, the structure induced will be referred to as information structure of specific value for the purposeful state based on the result and denoted $U = U(I)$. Similarly, with a structure I being transformed into an information structure to establish an identification criterion $\psi_n(\xi_1^n \mid \lambda_1^n, \gamma_1^n)$ and identification procedure models, the transformation will be referred to as identification transformation and denoted R, and the information structure induced will be designated as identification information structure and denoted $R = R(I)$.

The subject's ideas of purposeful state situation are subjective, qualitative, and based on observations and analysis of the environment transition under control $c \in C$ into different states $s \in S$. Let the transition rule be $q^g(S \mid S \times C)$ from $S \times C$ to S. Actually, to assess the value of possible results a subject uses model $Q^g(X \mid X \times C)$ from $X \times C$ to X based on identification strategy results ξ_1^n. When constructing a model, we consider control strategies λ_1^n and structural choice γ_1^n, or it is specified by such strategies. This means the transformation of actual function $q^g(S \mid S \times C)$ into the function of the subject's understanding of environment processes $Q^g(X \mid X \times Y)$ is only possible a posteriori and depends on the strategies used $(\lambda_1^n, \gamma_1^n, \xi_1^n)$.

Transforming and constructing the measure of expected specific value $E\phi_n(\lambda \mid \gamma_1^n)$ is possible when the 'utility' of information structures is formed sequentially depending on the strategies applied. This condition may be written as $U_n = U(\lambda_1^n, \gamma_1^n, \xi_1^n)(I), n = 1, 2, ...$ Since the condition is a prerequisite for a criterion of expected utility and a model of subject domain, it is to be identified every time it is used. Note that the criterion $E\phi_n(\lambda \mid \gamma_1^n)$ is implicitly dependent on a diagnostic strategy ξ_1^n owing to the structure U_n induced in a choice model. As mentioned above, the criterion of structural choice quality $\mu_n(\gamma_1^n \mid \lambda_1^n) \in R^1$ is determined by convolution of criterion $E\phi_n(\lambda_1^n \mid \tau_1^n) \in R^X$ The generality of their construction information structures leads to

$$\begin{cases} E\phi_n(\lambda_1^n \mid \xi_1^n) \\ mu_n(E\phi_n(\xi_1^n \mid \lambda_1^n)) \\ U_n = U(\lambda_1^n, \gamma_1^n, \xi_1^n)(I) \end{cases}$$

The construction of an identification criterion requires some 'utility' function. The construction of an identification criterion requires some 'utility' function. So it is necessary to construct some verbal estimates with the utility function values $E\phi_g(S \times X \times Y)$. The transformation required exists and may be done a priori (i. e. before the decision choice).

The transformation is determined by a subject with regard to a fuzzy measure that can be constructed if function $q_g(S \mid S \times C)$ is identified from to $(S \times C)$ to S.

Since its analog of subject's consciousness is of the form $Q_g(X \mid X \times C)$ and may be uniquely identified in the information structure I, no additional transformations are required. The construction of the 'idea utility' function exhausts the required structural transformation which is referred to as the structural transformation of 'identification' and denoted R, with the information structure induced being called the information structure of 'idea utility' and denoted $R = R(I)$.

Accordingly, the identification criterion is finalized as

$$\begin{cases} \psi_n(\xi_1^n \mid \lambda_1^n, \gamma_1^n) \\ R = R(I) \end{cases}$$

The definitions and constructions introduced show that the quality criteria of strategies are different and interdependent. Hence, the choice problem is of a game character and reduces to searching for a persistent compromise between the aspiration for maximizing the expected specific value of purposeful state based on the result and that of minimizing potential losses from wrong ideas. The compromise is referred to as equilibrium.

Note that since the information structure of 'specific utility' $U_n = U(\lambda_1^n, \gamma_1^n, \psi_1^n)(I)$, under which the criterion $\mu_n(E\phi_n(\gamma_1^n \mid \lambda_1^n)$ is determined, is to be constructed sequentially and depends on the strategies applied, the desired equilibria are not only interdependent at each stage $n = 1, 2, ...$ of decision- making but are dependent on the decisions chosen at the previous steps. Accordingly, the equilibria are naturally referred to as dynamical equilibria.

The triple of strategies

$\{o\ \overset{}{_{\lambda^\infty}}, \overset{o}{_{\gamma^\infty}}, \overset{o}{_{\xi^\infty}}\}$

obeying

$$\begin{cases} \begin{cases} E\phi_n(\overset{o}{_{\lambda^n}} \mid \overset{o}{_{\gamma^n}}) \geq E\phi_n(\lambda^n \mid \overset{o}{_{\gamma^n}}) \forall \lambda_1^n, \\ \mu_n(\overset{o}{_{\gamma^n}} \mid \overset{o}{_{\lambda^n}}) \quad \geq \quad \mu_n(\gamma^n \mid \overset{o}{_{\lambda^n}}) \forall \gamma_1^n, \\ U_n = U(\overset{o}{_{\lambda^n}}, \overset{o}{_{\gamma^n}}, \overset{o}{_{\xi^n}})(I) \end{cases} \\ \begin{cases} \psi_n(\overset{o}{_{\xi_1^n}} \mid \overset{o}{_{\gamma_1^n}}), \overset{o}{_{\lambda_1^n}}) \geq \psi_n(\xi_1^n \mid \overset{o}{_{\gamma_1^n}}), \overset{o}{_{\lambda_1^n}}) \forall \xi_1^n, \\ R = R(I), n = 1, 2, ... \end{cases} \end{cases}$$

are referred to as dynamical equilibriums.

The number of decision cycles is not assumed to be limited. Hence, dynamical equilibria must make sense, even if $n \to \infty$.

The following additional conditions are naturally to be fulfilled:

1) If $n \to \infty$ the strategy quality criteria must converge to some limits.
2) Such limits must not depend on initial conditions.

Since the criteria are not given explicitly, the fulfillment of the conditions is not obvious. This requires the necessary conditions. Then the explicit type criteria which meet these conditions are to be given.

According to the assumptions made, the quality criteria of stationary strategies $lambda^n, gamma^n, xi^n$, when $n \to \infty$ have some limits and then the triple of stationary strategies $(\overset{o}{_{\lambda_1^n}}, \overset{o}{_{\gamma_1^n}}, \overset{o}{_{\xi_1^n}})$ are referred to as stationary equilibria if they have limits meeting the conditions:

$$\begin{cases} \begin{cases} E\phi_n(\overset{o}{_{\lambda^\infty}} \mid \overset{o}{_{\gamma^\infty}}) \geq E\phi_n(\lambda^\infty \mid \overset{o}{_{\gamma^\infty}}) \forall \lambda_1^\infty, \\ \mu_n(\overset{o}{_{\gamma^\infty}} \mid \overset{o}{_{\lambda^\infty}}) \ \geq \ \mu_n(\gamma^\infty \mid \overset{o}{_{\lambda^\infty}}) \ \forall \gamma_1^\infty, \\ U_n = U(\overset{o}{_{\lambda^\infty}}, \overset{o}{_{\gamma^\infty}} \ \overset{o}{_{\xi^\infty}})(\mathrm{I}) \end{cases} \\ \begin{cases} \psi_n(\overset{o}{_{\xi_1^\infty}} \mid \overset{o}{_{\gamma_1^\infty}}), \overset{o}{_{\lambda_1^\infty}}) \geq \psi_n(\xi_1^\infty \mid \overset{o}{_{\gamma_1^\infty}}), \overset{o}{_{\lambda_1^\infty}}) \forall \xi_1^\infty, \\ R = R(I), n = 1, 2, ... \end{cases} \end{cases}$$

Thus, the problem of choice modeling consists in searching for a compromise between the aspiration for maximizing the expected specific value of purposeful state based on the result and that of minimizing potential losses from wrong ideas, with their interdependence being taken into account. According to the principle of equilibrium decisions, choice modeling must be 'not improved' for all the components of interest simultaneously. When compromising, it is fair to say that the subject's interests are realized with 'the best result'. Provided dynamical equilibria meet the requirements of asymptotic stationarity, we can also argue that the subject's interests are implemented with 'the best results' on the whole endless horizon, including n[U+F0AE][U+F0B5]. Hence, dynamic equilibria specify the sense and the way of interest realization with 'the best result'. In this regard dynamic equilibria naturally specify the internal aim of decision-making.

The above assumptions allow finally defining the concept of decision-making in the adopted axiomatic environment by means of the following basic ideas.

1) Observation and detection of the state is a necessary but not sufficient condition for the control choice feasibility.
2) A sufficient condition for the control choice feasibility is determined by specifying the subject's relation to the state defined by a qualitative index called a purposeful state situation.
3) Due to the fact that the cause-effect relations defining the environment behavior are inaccessible to the direct observation, it is necessary to perform the environment state identification procedures. The goal of these procedures is to select the observable state situation model.
4) The control rule selection is performed on the basis of the expected utility criterion.
5) The identification rule selection is performed on the basis of risk criterion.
6) The problem of selecting the control and identification rules has a game character; the "best" solution of it is to reach the invariable compromise called "equilibrium."
7) The development and usage of equilibrium rules for control and identification procedures is an internal control objective.

The formulated ideas define the concept of "purposeful control of active systems with internally generated goals". The assumptions introduced formalize the existence of two aspects of subject's interests. One of them is determined by the interest in the evolution of object, and the other – by selecting the scope of interests. The concept of purposeful control brings forth the third aspect of interests associated with the necessity to identify the situation depending on the observable state. According to these three aspects, the information structure of ideas assumes to designate sets of controlling, structural and identification alternatives. It is expected as well to introduce the utility function and the function of transition from the initial purposeful state situation to the desired one. This allows designating the control choice quality criterion with the meaning of expected utility, and the identification rule quality criterion with the meaning of risk. To select structural alternatives, we can introduce the quality criterion reflecting, for example, the degree of satisfying the interests.

Thus, when making a decision on the mode of action, a subject uses three sets of alternatives to comply with his interests. Selection of the alternative from a corresponding set is made according to the individual quality criterion, so it is natural to associate this selection with a certain virtual operating party that can keep options open within the scope of its competence. Subject's interests are dominant for the selected parties, and he acts as their control center. Since the interests of all players are interdependent, this game can be subsumed under the category of corporate interests. Its solution is based on a set of agreed compromise derivatives. It will be stable if it cannot be improved without deterioration of at least one of the criteria. This choice modeling is possible if the structure of ideas will be provided with a set of data media in order to construct the required criteria. In this case each selected party is sure to solve the task of standalone "best" alternative selection according to the relevant criteria. Then we can expect that the joint task of finding a compromise to satisfy the corporate sustainability requirements will also be solved.

In line with the concepts introduced, we can determine the information media corresponding to objects of interests as a set of the following formal objects: S – a set of states; $\beta(S)$ – priori distribution on a set of states; X – a set of situations; $X_S \subset X$ – restrictions to validity of situations as identification alternatives depending on state $s \in S$; C – a set of control alternatives; $C_x \subseteq C$ – restrictions to validity of control alternatives depending on situations $x \in X$; G – a set of structural alternatives; a transition function from $S \times C$ to S; utility function representing priori preferences based on alternatives $c \in C$ depending on conditions $s \in S$, situations $x \in X$ and structural alternatives $x \in X$. The information structure feature I is that the choice of control actions depends on the choice situation ideas that are based on identification procedures. Under these conditions, the regularity of situation dynamics cannot be set a priori. Therefore, an agent uses subjective assessments of the state dynamics regularity determined by transition function from $S \times C$ to S. If a subject is sceptical about his ideas of information structure elements, he uses the additional information to formulate some plausible approximation. For example, if an explicit form of transition function is not known a priori, it is always possible to formulate a set of hypotheses on it.

IV. Conclusion

The paper examined the model of making-decisions by an agent being capable to specify an internal aim and applying subjective ideas of the choice situation. The authors showed that the choice aimed at maximizing the specific utility of choice situation based on the result. The choice result was shown to be determined by the agent's ideas of the choice situation and his own interests. When making decisions, he uses three sets: control alternatives C (actions), structural alternatives G, and identification alternatives X. Therefore, three virtual parties choosing appropriate alternatives being equilibrium strategies are assumed to exist. The research was financially supported by Russian Foundation for Basic Research as part of project 14-01-003284.

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ПРИНЯТИЕ РЕШЕНИЙ АГЕНТОМ С ВЫБИРАЕМОЙ СТРУКТУРОЙ ПРЕДПОЧТЕНИЙ

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Рассмотрена модель принятия решений агентом, способным формировать внутреннюю цель выбора. В основу подхода положены идеи субъективно рационального выбора. Развиваемые идеи субъективно рационального выбора позволяют: 1) объяснить принятие решений субъектом в конкретных ситуациях; 2) предсказать принимающим решение возможные реакции другого субъекта в различных ситуациях; 3) решать задачу активного прогноза, когда управляющая сторона создает у управляемой стороны нужный образ будущего. Основное принимаемое предположение состоит в том, что мотивация выбора определяется как внешними, так и внутренними факторами. Внутренние факторы отражают интересы субъекта, индуцируемые его потребностями и этической системой, которой он придерживается. Оценки удовлетворенности текущей ситуацией целеустремленного состояния субъектом могут приводить к изменению структуры интересов субъекта, и он ее может выбирать. Предполагается, что выбор осуществляется на основе субъективных представлений о свойствах ситуации выбора. Компоненты представления отражают различные аспекты понимания субъектом ситуации целеустремленного состояния и образуют информационную структуру представления. Конкретный вариант представления также является результатом выбора.

Activity Recognition Based on Artificial Neural Network Approach using PIQ Robot

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***Abstract*—This paper presents and explains an implementation of Learning Vector Quantization neural network for tennis activity detection and recognition using PIQ ROBOT device. The gesture recognition market is estimated to grow from 2013 till 2018 and is expected to cross $15.02 billion by the end of these five years. Analysts forecast the Global Gesture Recognition market to grow of 29.2 percent over the period 2013-2018. In terms of industry it means that currently consumer electronics application contributes to more than 99 percents of the global gesture recognition market. This paper starts our ambitious research in the area of artificial neural networks for activity recognition.**

***Keywords*—activity/gesture recognition, PIQ Robot, Artificial Neural Networks, LVQ neural network, time series classification.**

I. Introduction

The gesture recognition market is estimated to grow at a healthy Compound Annual Growth Rate (CAGR) from 2013 till 2018 and is expected to cross $15.02 billion by the end of these five years. Analysts forecast the Global Gesture Recognition market to grow at a CAGR of 29.2 percent over the period 2013-2018. In terms of industry it means that currently consumer electronics application contributes to more than 99 percents of the global gesture recognition market [1].

There are a lot of researches on gesture recognition in the modern literature that incorporate the use of different types of sensors and models for several real life and virtual applications. On the basis of data acquisition, systems can be divided into two types: Vision-Based and Sensor-Based systems.

Vision-based recognition systems like Microsoft's Kinect [2], Nintendo Wii Remote [3], Oculus Rift [4], etc. cover several application areas such as surveillance, detection, control and other analysis of captured motion data. The problems with vision-based systems are of their high computational cost as most of them incorporate usage of GPUs, the range of use is limited by the camera viewing volume, a large number of cameras require to cover large spaces and light conditions and camera settings.

Glove-Based gesture recognition systems use a specific part or parts of the body to recognize gestures using a limited number of sensors. The striking example of such system is 'Acceleglove' [5] created by George Washington University. The systems based on the limited number of sensors have become more apparent in recent work because of the increasing popularity of wearable fitness devices. Unfortunately, such systems require a single training sample for each pattern and require users to define their own personal gestures.

State-of-the-art. The Hidden Markov Model (HMM) is the popular approach for gesture recognition. Thus Yamata et al [6] used discrete HMM and vector quantization for transforming the dynamic feature vectors to symbolic. Marcel et al. [7] trains an Input–Output HMM and apply it to recognize hand silhouette gestures.

The Finite State Machine (FSM) is another popular model in the area of gesture recognition. For example, Davis and Shah [8] proposed to use a FSM for modeling of different phases of a gesture.

Besides these models other approaches were implemented for gesture recognition. Thus, Suk et al. [9] propose to use dynamic Bayesian Networks to represent the relationship among gesture features based on motion tracking, and Flórez et al. [10] propose to use a self-organizing neural network to determine hand postures and gestures.

In this paper we present the first results of the implementation of artificial neural network approach for tennis sport activity detection and recognition. The structure of presented neural network can be implemented within the context of restricted computational resources. The rest of the paper is organised as follows. Section 2 gives the basic information about the characteristics of PIQ ROBOT as well as describes the artificial neural networks approach. Section 3 provides some experimental results for activity recognition for such kind of sport as tennis. The final section concludes this paper.

II. Artificial Neural Network approach for activity detection and classification

A. PIQ Robot

PIQ Robot is the ultimate sports tracker [11] (figure 1). PIQ integrates the latest inertial sensor technologies, BLE, NFC, pressure sensor and cutting edge microprocessor. PIQ Robot has been designed to be positioned in the ideal place for data collection whatever the sport. PIQ is a small, ultra-lightweight, waterproof and flexible multi-sport motion sensor connected to your smart device via BLE.

Figure 1. PIQ Robot

In scope of current research, PIQ Robot was switched to special engineering mode for having of access to inertial sensors data through BLE interface.

A special tool for Android smartphones, PIQ Log, was developed by Octonion Technology for reading of sensors data. It stores received time series into files (sensor data files) on memory of the smartphone.

Each sensor data file contains a header with service information. Sensor data files are friendly to comma-separated format and they can be easily exported to Microsoft Excel or any other tools for processing of CSV files.

Sensor data files contains the following fields:

1) Acceleration with gravity along 3 axis in local reference frame;
2) Angular velocity along 3 axis in local reference frame;
3) Quaternion for conversion of PIQ local coordinates to global coordinates.

PIQ Robot was fixed on wrist of tennis players during the game and transferred sensor data to PIQ Log application.

Sensors data associated with tennis strokes was used as a source information for training of neural networks at the following stage.

B. The structure of an ANN

Learning Vector Quantization (LVQ) neural network was selected for the classification task [12]. Since the internal resources of the PIQ Robot is quite limited (primarily because of the random access memory space) we have no possibility to use big-sized architectures of neural networks. In this case LVQ neural network provides good results using limited computational resources. The proposed architecture of neural network for activity recognition consists of three layers (Figure 2).

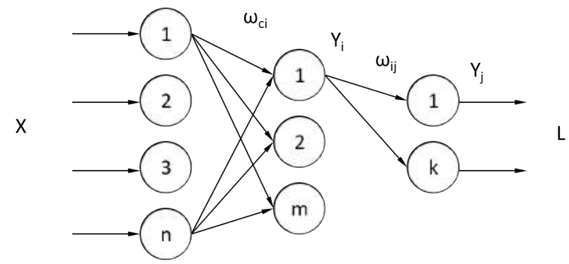

Figure 2. The structure of the ANN

The first (input) linear layer performs the function of distribution of an input signal to hidden layer. The number n of nodes in the first layer is defined by the dimension of the sliding window. The optimal dimension of sliding window directly depends on the nature of data and can be defined experimentally. In our case we use two different dimensions for sliding window. For such movements as Forehands, Backhands and Serves we use the dimension equal to 46. For Volleys activity the dimension of sliding window equals to 25. These parameters were chosen by the different length of different activities from collected sensor data files. Thus Serves are more long-term actions then Volleys, but Forehands and Backhands are almost equal and not so much differ from Serves.

The second layer (hidden layer) is competitive layer. It consists of m Kohonen neurons [12] and represents a vector quantization layer, which gives the cluster label of the input pattern. The competitive learning rule (winner-takes-all) is used for training of hidden layer [12]. During the training process neurons of hidden layers compete with each other. As a result the winner neuron (with the maximum weight) that characterized the class of data is defined. For this purpose the Euclidean space between input and weight vectors can be used:

$$D_i=|X-\omega_i|=\sqrt{(X_1-\omega_{1i}^2)+(X_2-\omega_{2i}^2)+...+(X_c-\omega_{ci}^2)},$$

where ω_{ci} is weight between c-th neuron of the input layer and i-th neuron of the competitive layer;

$X=[X_1, X_2, ..., X_c]$ is input pattern.

During the training process the synaptic connections are increased for winner neuron and stayed unchangeable for other neurons. Thus, after the training at the presenting the input pattern the activity of winner neuron is accepted to *"1"* while other neurons of hidden layers are accepted to *"0"*. The hidden layer training algorithm can be represented as the following set of steps:

1) Weight coefficients ω_{ci} of hidden neurons Y_i are initialized by random.
2) Input pattern is distributed on the neural network and next parameters are calculated:
   a) Euclidean distance between input and weight vectors of neuron elements from the Kohonen layer is calculated (equation 1)
   b) The winner neuron with the index k is defined

$$D_k = min_j D_j.$$

c) The weight coefficients of the winner neuron are modified according to the next equations:

$$\omega_{ck}(t+1) = \omega_{ck}(t) + \gamma(X_c - \omega_{ck}(t)),$$

if activity of the output neuron is corresponded to the class of inputted data;

$$\omega_{ck}(t+1) = \omega_{ck}(t) - \gamma(X_c - \omega_{ck}(t)),$$

otherwise.

3) The training process is continued while achieving of the desired accuracy.

The optimal number of hidden nodes depends on the data and can be defined experimentally, but it cannot be less than the numbers of classes.

The third layer is output layer, it consists of the linear neurons and performs the mapping of clusters from hidden layer into the existing classes. The activity of output neuron (when his value equal *"1"*) is characterized one or another class. For example, for the first class the activity of the 1-st neuron of output layer will be equal *"1"* while the activity of other neurons will be equal *"0"*. The number of neurons in hidden layers equals to the number of existing classes.

The described approach has some advantages:

1) The model is trained significantly faster than other neural network techniques like Backpropagation.
2) It is able to summarise or reduce large datasets to a smaller number of codebook vectors suitable for classification.
3) Able to generalise features in the dataset providing a level of robustness.
4) Can approximate just about any classification problem as long as the attributes can be compared using a meaningful distance measure.
5) Not limited in the number of dimensions in the codebook vectors like nearest neighbour techniques.
6) Normalisation of input data is not required (normalisation may improve accuracy if attribute values vary greatly).
7) The generated model can be updated incrementally.

All these advantages are very critical in the case of limited power resources.

III. Experimental results

PIQ ROBOT provides a broad spectrum of measurable parameters that contain (but is not limited by that) accelerations, linear accelerations, gyros, quaternions, pressure etc. Figure 3 shows the time series data that can be received from the sensor.

Time	AccelerX	AccelerY	AccelerZ	LinAccX	LinAccY	LinAccelZ	GyroX	GyroY	GyroZ	QuatW	QuatX	QuatY	QuatZ
227	1.475332	-2.9315	9.129815	0.119868	0.335458	-0.01677	-4	-5.125	-6	-0.70416	0.072327	0.168579	-0.68585
327	1.475332	-2.96982	9.158555	0.10414	0.295096	0.013583	-4.25	-5.125	-6	-0.70453	0.071777	0.169067	-0.68549
427	1.475332	-3.05605	9.177715	0.089115	0.206326	0.034099	-4	-5.125	-5.875	-0.70483	0.071228	0.169495	-0.68506
527	1.437012	-3.19017	9.129815	0.033229	0.070129	-0.01186	-3.75	-5	-6	-0.7052	0.070618	0.170044	-0.68463
627	1.456172	-3.17101	9.053174	0.033998	0.086372	-0.0867	-2.75	-4.875	-6.375	-0.70557	0.069946	0.170593	-0.6842
727	1.465752	-3.16143	9.110655	0.027452	0.092392	-0.02796	-2.375	-4.5	-6.875	-0.70593	0.069336	0.171021	-0.68372
827	1.437012	-3.34345	9.110655	-0.01227	-0.08027	-0.02289	-2.25	-4.125	-7.375	-0.70624	0.069397	0.171753	-0.68323
927	1.427432	-3.35303	9.120235	-0.03048	-0.08295	-0.00947	-0.75	-3.75	-8	-0.7066	0.069458	0.172302	-0.68274

Figure 3. The set of parameters from PIQ ROBOT

As can be seen, at each instant of time we have the set of parameters that characterize the changing the position of the sensor in the space as well as the its speed. We can detect and classify any specialized action (movements, strikes, ets) by analyzing these parameters.

For the training process of the proposed neural networks we use a data set that already marked by experts. It means that we know the start and end points (the first column in Table 1) for different types of movements. In our tests we chose tennis sport data. In tennis there are 4 types of basic strikes. Each type can contain several sub-types (see figure 4). As a result, we have 9 classes of different strikes in tennis that a grouped into 4 types.

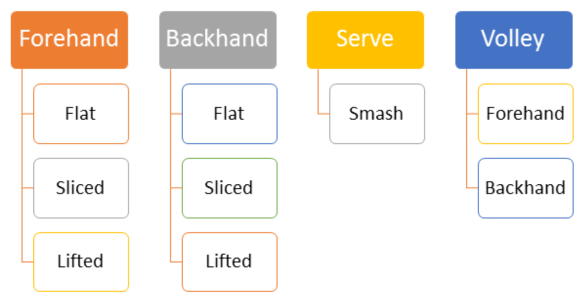

Figure 4. Existing tennis motions

For training of a neural network we used dataset "player_1" which contains marked data for different motions for one player. For the training of neural network we used 211 different motions. It is important to notice that different types of motion has different time period. Thus, Forehands motions take ≈ 185 ms on an average, Backhands ≈ 165 ms, Serves ≈ 230 ms and Volleys ≈ 124 ms. It means we care about the size of a sliding window and use different neural networks for different motion recognition.

In fact, in this work we use 4 neural networks. Here we can say about a combined classifier that consists of four neural networks. The first neural network is for detection and classification of Forehand, Backhand and Serve motions. The second neural network detects Volleys_forehand and Volleys_backhand motions. And finally, two neural networks classify the motions inside the Forehand and Backhand correspondingly. Thus we can detect and classify 9 possible different motions in tennis. Figure 5 represents the classification tree.

In the test for trained neural networks we used control files both for "player_1" and "player_2". Dataset

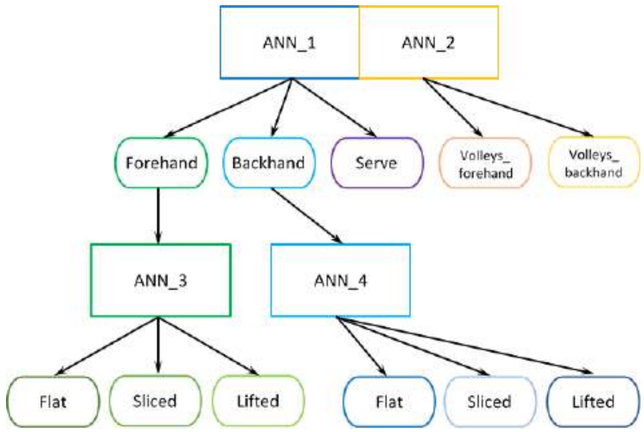

Figure 5. A combined classifier and classification tree

"player_1" contains activity of the same player that was "participated" in the training of neural network. Dataset "player_2" contains data from another player and his style of strikes can differs from player_1 significantly. The results of data classification are presented in table 1.

Table I. Classification results

Type of motion	Player_1, accuracy,%	Player_2, accuracy
Forehand	90	80
Forehand_flat	90	50
Forehand_sliced	90	90
Forehand_lifted	90	0
Backhand	90	90
Backhand_flat	90	0
Backhand_sliced	90	90
Backhand_lifted	90	0
Serve	90	90
Volley_forehand	90	90
Volley_backhand	90	90

It should be noted that on the current stage of research, the test files contain only a limited quantity of motions. As can be seen from the table 2, the proposed neural network shows good results for the main 4 motion types (Forehand, Backhand, Serve and Volley) equally good as for player_1, which data was used for training, and for player_2, which data absolutely new for classifier. For these motions we obtained the accuracy equals 90%. The accuracy for motions inside Volley (volley_backhand and volley_forehand) is also very good whether player_1 or player_2. But the results inside Forehand and Backhand types are not good even for player_1. In particular it can be explained by the similarity of flat and lifted motions and it is very difficult to distinguish them even if you do this manually.

IV. Conclusions

The paper presents the first results of an artificial neural network approach for activity recognition based on sensors data coming from PIQ Robot.

PIQ Robot is a powerful tool for mining and processing of inertial sensors data as it allows to apply different approaches to solving the problem of automatic segmentation and classification of sport motions.

In particular, this article demonstrates method of application of LVQ-nets to solving the problem of tennis motions classification. The implementation of neural networks for this task is quite new, innovative and carries a lot of advantages in comparison with traditional approaches. We showed that the combined classifier that contains several "small" Learning Vector Quantization neural networks can correctly detect and classify the basic motions using tennis dataset. Unfortunately, the proposed structure of neural network does not allow to solve the problem of detection of closely approximated motions like flat and lifted.

Based on the obtained results, it can be concluded that LVQ-nets are promising approach for enabling of automatic motions classification applied to sports.

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ИСПОЛЬЗОВАНИЕ ИСКУССТВЕННЫХ НЕЙРОННЫХ СЕТЕЙ ДЛЯ РАСПОЗНАВАНИЕ АКТИВНОСТЕЙ НА БАЗЕ PIQ ROBOT

Безобразов С., Головко В., Кислюк С., Шелег А.

Данная статья описывает нейросетевой подход для детектирования и классификации активностей в теннисе на базе устройства PIQ Robot. Прогнозируется, что в течение пяти лет рыночный спрос на технические средства для распознавания жестов будет расти и к 2018 году превысит сумму в 15 миллионов долларов. Статья описывает начало амбициозного проекта по использованию нейросетевого подхода для распознавания жестов и различного рода активностей используя сенсор PIQ Robot.

Семантический анализ визуальной сцены

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Abstract **— Переход от графического представления видеосцены к ее естественно-языковому описанию является естественным шагом в процедуре семантического анализа видеосцены, позволяющим снять вариативность изображений с одной стороны, а с другой – использовать уже сформировавшиеся механизмы анализа текстов для формирования семантических представлений в виде неоднородных семантических сетей. При этом видеокадры видеосцены переописываются из графического формата в представление в терминах характерных признаков, полученных на выходе сенсоров. Этим представлениям ставятся в соответствие шаблоны естественного языка, соответствующие сценариям, представленным на видеокадрах. Далее, последовательность шаблонов, полученных при анализе видеоряда анализируется статистически как квазитекст. И, наконец, связи пар вершин полученной в результате статистического анализа однородной семантической сети размечаются типами отношений с помощью лингвистических механизмов синтактико-семантического анализа предложений. Полученные в результате этих процедур квазитекст и его неоднородная семантическая сеть могут служить для анализа более высокого уровня.**

Keywords — видеоаналитика, характеристики видеокадра, лингвистический шаблон сцены, статистический анализ текста, однородная семантическая сеть, синтактико-семантический анализ предложений текста, неоднородная семантическая сеть

Анализ семантики видеосцен становится все более актуальным в связи с широким применением видеоаналитики в решении задач обеспечения безопасности. В настоящий момент эффективно решаются задачи нижнего уровня семантического анализа сцен (на примере работы видеоохранных систем). Это: детектирование оставленных предметов, детектирование движения, детектирование объектов, детектирование пересечения границ. Более сложные задачи семантического анализа сцены чаще всего не выходят за рамки статистического анализа потоков с выявлением нештатных треков. Все эти алгоритмы, будучи эмпирическими по своей природе, плохо масштабируются, и еще хуже интегрируются в цельное представление семантики сцены.

Основной задачей видеоаналитики является анализ видеопотока с использованием алгоритмов компьютерного зрения с целью автоматического получения той или иной информации без прямого участия человека.

Анализируемое видеоизображение можно условно разделить на две составляющие: фон (задний план) и объекты (передний план). При этом фон, как правило, является квазистатическим (медленно меняющимся), в то время как объекты переднего плана меняют свое положение во времени. В связи с этим, в решении большинства задач видеоаналитики можно выделить несколько основных этапов. (1) Выделение фона. Алгоритм выделения фона должен быть адаптивным. (2) Выделение объектов переднего плана. Основная цель заключается в обнаружении движущихся объектов на каждом кадре видеопоследовательности. (3) Трекинг движущихся объектов. Выделение на каждом кадре объектов и оценка их смещения от кадра к кадру позволяют построить траектории движения и получить оценки различных параметров (скорость, направление движения и т.д.). (4) Классификация. Каждый объект переднего плана может быть отнесен к определенному классу (человек, транспортное средство и т.д.) в соответствии с некоторым набором признаков.

Располагая информацией об объектах переднего плана, можно осуществлять анализ их поведения. В результате возможно, например, обнаружение фактов пересечения линии, прохода в запрещенную зону, резкого ускорения и т.д.

Анализ полученной информации позволяет принять решение о наличии или об отсутствии той или иной тревожной ситуации.

Типовой набор характеристик объекта включает: (1) уникальный идентификатор (ID); (2) траекторию объекта (набор координат положения объекта в координатах изображения); (3) линейные размеры объекта; (4) среднюю и мгновенную скорости; (5) среднее и мгновенное направления движения; (6) принадлежность к классу (человек, машина, неодушевленный предмет небольшого размера, и т.д.); (7) результаты работы тех или иных логических (эмпирических) алгоритмов анализа поведения (проход в запрещенную зону, пересечение линии контроля, резкое ускорение и т.д.).

Использование для анализа сцен подмножества естественного языка, обладающего по своей природе иерархической структурой, позволяет снять ограничения на масштабирование представлений по степени сложности, и, кроме того, позволяет реализовать автоматическое формирование визуализации семантики сцены в виде семантической сети. Для этого требуется осуществить переход от динамики видеорядов в терминах представленных выше характеристик к статике семантических представлений, включающий:

- анализ сцен по предметным областям (классификация типов видеокадров);
- соотнесение типов видеокадров с шаблонами подмножества естественного языка;
- интерпретация видеоряда (также в терминах упомянутых характеристик) как квазитекста: формирование на основе этого квазитекста (возможно, с использованием других квазитекстов, описывающих заданную предметную область) однородной семантической сети, где вершины соответствуют объектам сцены, а связи однотипны (только ассоциативные);
- переход к семантическому представлению в виде неоднородной семантической сети с применением лингвистических правил выявления расширенных предикатных структур предложений – шаблонов – в которых отношения между элементами сцены поименованы.

При формировании шаблонов описаний кадров видеоряда необходимо учитывать два условия: одно – относящееся к зрительной модальности, другое – к текстовой. Выполнение первого условия возможно за счет принятия во внимание вариативности видеокадров видеорядов, относящихся к заданной предметной области. Выполнение второго условия обеспечивается учетом всех вариантов расширенных предикатных структур, включающих те или иные конкретные предикаты, описывающие видеокадр.

I. Классификация кадров видеоряда визуальной сцены в заданной предметной области

На множестве видеорядов (скорее треков), описывающих стандартные и нестандартные ситуации, представляющие реальные видеосцены, осуществляется выявление типов видеокадров (а, точнее, треков с их начальными и конечными состояниями), участвующих в видеорядах выбранного множества. Эти видеокадры относятся как к базовым элементам динамики сцены: начало движения, перемещение в заданном направлении, остановка, объединение треков объектов, разделение треков, и подобное; так и к нештатным (или тревожным) элементам: появление оставленных предметов, пересечение запрещенных границ, и подобное. Разные типы поведения объектов на сцене могут включаться как в штатные, так и в нештатные ситуации, а отнесение их к тем, или другим возможно лишь их соотнесением с более широким контекстом всей динамики сцены, которое в настоящий момент невозможно из-за использования для выявления отдельных типов поведения эмпирических алгоритмов, которые плохо интегрируются в комплексную сцену. Плохая интеграция может быть объяснена использованием в разных алгоритмах разных систем параметров объектов и разных систем правил для их анализа. С целью преодоления противоречия необходимо использование единого языка представления видеосцены на всех этапах анализа, каковым, например, является естественный язык. Дополнительный бонус использования естественного языка – легкость понимания человеком-оператором описаний сцены, представленных на этом языке.

Для представления видеорядов динамичной видеосцены с этой целью разумно использовать некие стандартные предложения естественного языка (шаблоны), характеризующие отдельные кадры видеоряда. Тогда весь видеоряд (вся динамичная видеосцена) может быть описан последовательностью таких шаблонов – текстом естественного языка. Такое описание не ново: это стандартный способ комментирования отдельных сцен видеофильмов. Нова сама постановка вопроса: заменить комментатора автоматическим устройством. Тогда нахождение нужного видеокадра в массиве видеорядов большого объема оказывается достаточно просто выполнимой задачей.

Для того чтобы сформировать систему шаблонов, необходимо предварительно сформировать систему классов кадров видеоряда, описывающих все возможные ситуации в заданной предметной области. Часть классов хорошо и давно известна. Это: переход из динамического состояния в статическое (оставление предмета), перемещение (движение) в некотором направлении, наличие объекта, переход преграды – условной, или физической (пересечение), появление, исчезновение. Наверное, есть и другие подобные классы. Им всем соответствуют определенные естественно-языковые шаблоны (предложения из некоторого подмножества естественного языка).

II. Формирование естественно-языковых шаблонов классов кадров видеоряда

Для формирования перечня шаблонов необходимо проанализировать классы слов естественного языка (в первую очередь - предикатов), которые участвуют в описании видеокадров, как с точки зрения номенклатуры валентностей соответствующих слов, так и с точки зрения влияния синонимии на эту номенклатуру. Учет номенклатуры валентностей позволит максимально точно и подробно описывать видеокадры. Учет влияния синонимии позволит выявить различия в подробности описания одного и того же видеокадра различными вариантами шаблонов. В идеале необходим выбор перечня шаблонов, описывающих видеокадры максимально инвариантно. Такой перечень будет открытым, но постепенно процесс его заполнения должен сходиться.

Формирование перечня шаблонов будет идти параллельно с формированием перечня классов видеокадров. Эти два процесса будут влиять друг на друга: выявление новых типов шаблонов будет порождать новые классы видеокадров; появление новых классов видеокадров приведет к формированию новых типов шаблонов. И еще: отсутствие соответствия видеокадров, интерпретируемых с точки зрения имеющейся видеосенсорики, наличествующим шаблонам будет понуждать видеоаналитиков формировать новые механизмы видеосенсорики для интерпретации недостающих элементов видеокадра.

III. Сопоставление лингвистических шаблонов отдельным кадрам видеоряда визуальной сцены. Формирование квазитекста из шаблонов, соответствующих последовательным кадрам видеоряда визуальной сцены

Два параллельных процесса формирования перечня классов видеокадров и формирования перечня классов описывающих их шаблонов приводят к взаимнооднозначному и на (изоморфному) сопоставлению двух перечней. Такое сопоставление будет возможно в том случае, если видеосенсорика будет давать все необходимые данные для формирования естественно-языкового описания видеокадра, соответствующего его шаблону.

Сопоставление перечня шаблонов с перечнем описываемых шаблонами видеокадров позволяет осуществить автоматический переход от описываемого с помощью шаблонов видеоряда к тексту, описывающему динамичную сцену. Степень подробности описания может варьироваться во времени от учета наиболее крупных изменений событий на видеокадрах до протокольной покадровой записи. Степень подробности описания может варьироваться в пространстве признаков в зависимости от наличия тех или иных элементов видеосенсорики, дающих более или менее подробное представление видеокадра в соответствие с принятым шаблоном.

IV. Однородная семантическая сеть, описывающая динамичную видеосцену

Однородная семантическая сеть представляет собой циклический граф, вершины которого соответствуют ключевым объектам видеосцены, а дуги соответствуют отношениям совместной встречаемости ключевых объектов на видеокадрах видеосцены [4, 5].

Благодаря наличию специфических механизмов видеосенсорики, которые учитывают не только статику видеокадра, но и динамику сцены (объекты перемещаются, из-за чего возникает эта динамика), удается объединить видеокадры в видеоряд - квазитекст. То есть последовательное объединение соответствующих видеокадрам естественно-языковых шаблонов позволяет сформировать естественно-языковой текст, описывающий видеосцену – последовательность видеокадров.

Полученная в результате анализа такого текста однородная (ассоциативная) семантическая сеть, таким образом, позволяет показать взаимосвязи ключевых объектов на видеосцене. Цепочки вершин на ассоциативной сети позволяют увидеть зависимости между объектами.

V. Формирование однородной семантической сети из квазитекста, описывающего видеосцену

Как только мы получили естественно-языковой текст – последовательность шаблонов, описывающий видеоряд, соответствующий динамичной видеосцене, мы в состоянии построить однородную семантическую сеть, характеризующую эту видеосцену. Построение однородной семантической сети осуществляется стандартными механизмами технологии TextAnalyst [2] для автоматической смысловой обработки текстов [1].

Построение однородной семантической сети включает несколько этапов: первичную обработку, формирование частотной сети, и переранжирование частотных характеристик вершин сети в их смысловые веса. Первичная обработка включает: сегментацию предложения, удаление стоп-слов, рабочих и общеупотребимых слов, морфологическую обработку (точнее стемминг) с целью устранения информационного шума. Формирование частотного портрета текста включает вычисление частоты встречаемости оставшихся корневых основ $< c_i >$ в тексте (соответствующих вершинам сети), полученных в результате стемминга, вычисление частоты попарной встречаемости корневых основ $< c_i c_j >$ в тексте, формирование первичной ассоциативной сети, а также выявление устойчивых словосочетений (которые также ставятся в соответствие вершинам сети). И наконец – этап перерењжирования – перевычисления частотных характеристик вершин сети в смысловые характеристики ключевых понятий.

В результате получается однородная семантическая сеть как множество несимметричных пар понятий.

Определение. Под ассоциативной (однородной) семантической сетью понимается двойка $< c_i c_j >$, где c_i и c_j - несимметричная пара понятий, связанных между собой отношением ассоциативности (совместной встречаемости в предложении текста). Или, что то же самое, семантическую сеть можно представить в виде множества звездочек $< c_i < c_j >>$, где c_j – множество ближайших ассоциантов ключевого понятия c_i:

$$N \cong < c_i < c_j >> \qquad (1)$$

VI. Формирование неоднородной семантической сети из однородной семантической сети

Сформированная ранее однородная семантическая сеть может быть преобразована в неоднородную путем добавления в нее информации о типах отношений между парами понятий, которая (информация) может быть получена из исходного текста (корпуса текстов) привлечением лингвистических методов анализа – методов выявления расширенной предикатной структуры отдельного предложения [3].

Расширенная предикатная структура предложения представляет собой ту же звездочку (1), только строится она не на основе пар понятий, а на основе пар понятий, отношения между которыми поименованы их типами.

Под расширенной предикатной структурой будем понимать тройку $P \cong < c_i < r_{ij} c_j >$, где c_i - субъект, $r_{ij} \cong r_p$, где $j = 1$, - предикативное отношение между субъектом и главным объектом, а r_{ij} , где $j > 1$– связи субъекта с другими актантами предиката.

После выявления расширенной предикатной структуры отношения, выявленные в процессе формирования расширенной предикатной структуры, могут быть использованы для разметки связей между вершинами однородной семантической сети. И тогда семантическая сеть превращается в неоднородную семантическую сеть:

$$N \cong < c_i < r_{ij} c_j > \qquad (2)$$

VII. Пример формирования однородной семантической сети на основе анализа квазитекста

В качестве примера формирования однородной семантической сети можно взять произвольный видеоряд, описывающий конкретную видеосцену. Для простоты восприятия текста в данной работе формальные термины «Объект A», «Объект B», «Неподвижный объект» заменены на «Вася», «Петя», «Кейс» и подобное.

«Вася появляется в проеме **Входной двери**. **Вася** движется от **Входной двери** в **Направлении Киоска**. **Вася** движется от **Входной двери** в **Направление Киоска**. **Вася** движется от **Входной двери** в **Направление Киоска**. **Вася** движется от **Входной двери** в **Направление Киоска**. **Вася** прекращает движение в **Направление Киоска**. У **Киоска Вася** оставляет **Кейс**. **Вася** начинает движение в **Направление Внутренней двери**. **Петя** появляется в проеме **Внутренней двери**. **Петя** движется от **Внутренней двери** в **Направление Киоска. Петя** движется от **Внутренней двери** в **Направление Киоска. Петя** движется от **Внутренней двери** в **Направление Киоска. Петя** движется от **Внутренней двери** в **Направление Киоска. Петя** проходит мимо неподвижного **Кейса».**

В результате автоматического анализа текста формируется ассоциативная сеть. Ее фрагмент представлен в Таблице I.

TABLE I. Ассоциативная звездочка – фрагмент однородной семантической сети

Родитель	**Частота**	**Вес**	**Дочерняя вершина**
…			
Вася	10	84	Входной двери
Вася	12	90	Направление
Вася	12	90	Киоска
…			

В фрагменте сети представлена только одна звездочка. Здесь главное слово звездочки – один из основных объектов, участвующих в описании видеосцены – «Вася» . А второстепенные – другие объекты – «Входная дверь», «Направление», «Киоск», описывающие видеосцену. Эта звездочка соответствует предложению текста «Вася движется от Входной двери в Направление Киоска».

Неоднородная сеть, полученная после разметки отношений с помощью лингвистического анализа [6], очень точно описывает видеосцену (см. Таблицу II), связность же ключевых понятий обеспечивается за счет статистического подхода к анализу всего текста.

TABLE II. Звездочка с типами отношений – фрагмент неоднородной семантической сети

Родитель	**Тип отношения**	**Дочерняя вершина**
…		
Вася	«откуда»	Входной двери
Вася	«движется»	Направление
Вася	«куда»	Киоска
…		

Conclusion

Переход от графического представления видеосцены как последовательности видеокадров через типовые характеристики объектов к квази-тексту как последовательности лингвистических шаблонов, соответствующих отдельным видеокадрам позволяет анализировать сцену, очищенную от информационного шума вариативности изображений. Статистическая, а далее, лингвистическая обработка последовательности шаблонов как текста естественного языка дает в руки эксперта мощный инструмент семантического анализа видеоматериала, а также удобный и компактный способ представления информации аналитику. Такое представление информации позволяет перейти к логическому и эмпирическому анализу информации верхних уровней абстракции.

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SEMANTIC ANALYSIS OF VISUAL SCENE

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Transition from pictures of video to its nature language description is a natural step in the procedure of semantic analysis of video. The transition eliminates the pictures variability from one side and to use instruments of the semantic text analysis from the other one. A nonhomogeneous semantic network is builded during such an analysis. The scene pictures in the process are translated from graphical format into set of specific attributes, which are the result of scene censoring. Some natural language templates are put into accordance to these scene representations. The template is a scenarios of the scene pictures. Then the sequence of templates is analyzed as a quasytext by statistical methods to build a homogenous semantic network. And at last the relationships of nodes pares of homogenous semantic network are named of their types by linguistic mechanisms of syntactical-semantic sentence analysis. Such a quasytext and its nonhomogenous semantic network could then be used for semantic analysis of more complex level.

Anthropomorphic Control System for Robotic Complexes

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***Abstract*—The paper considers the problems of formation, expansion and control of motor actions in the human body in terms of Anokhin's theory of functional systems and Bernstein's multi-level system of construction of movements. Based on the structure chart of functional control system of motor actions in the human body, an anthropomorphic control system intended for robotics complexes has been proposed. The system includes 5 control levels and features a number of advantages compared to conventional control systems of technical objects.**

Keywords*—*anthropomorphic , control system , robotic complexes, nervous system.

I. Introduction

Nowadays, one of the mainstreams in the evolution of technical systems is the development of robots and robotics complexes [1-2]. The areas of their applications are constantly expanding: space technologies [3], military and industrial applications [4–8], medicine [9-10], social activities, security systems [11], smart house, etc. At the same time modern robotic systems increasingly become more complex, for instance, implementation of the standard of industrial internet of things [12-13] results in a tendency of integration of individual robots into intelligent robotic production lines. All these factors cause significantly increasing complexity of hardware and software modules intended for the control of robots or robotic complexes. A number of papers are dedicated to the development of hardware and software modules of control systems for robots [14 – 18]. This paper considers the model of control system built by analogy with the activities of human central nervous system.

II. Control System of Motor Actions in the Human Body

The process of formation, expansion and control of motor actions in the human body can be considered in the context of Anokhin's theory of functional systems [19–21] and Bernstein's multi-level system of construction of movements [22–24]. Different structures of nervous system organized hierarchically participate in planning, conversion, and performing motoric program, i.e. control system of motoric actions presents a multi-level system [25]. The more complicated (to be specific: more intelligent, more objective) is motoric problem, the higher levels of nervous system are involved in solving the problem and the realization of appropriate movements.

Hierarchy of the levels of construction of movements is as follows [22-26]:

1) Level A presents the level of paleokinetic regulations. Level A regulates muscular tonus and is also responsible for muscular irritability, therefore this level participates, together with other levels, in the organization of any movement. Signals from muscle proprioceptors (information on muscle stretch and tension) as well as from the organs of equilibrium (information on acceleration, deceleration, changes in body position) are transferred to this level [25, 26].
2) Level B presents the level of synergies and patterns. The level ensures the following functions: extensive muscle synergies, i.e. the ability to perform highly coordinated movements of entire body with many tens of muscles involved; the ability to perform movements proportionally and consistently in time; correct alternation of muscle contractions and extremity movements; the ability to perform patterns and high repeatability of movements. This level is also responsible for various motoric skills [25]. The level of synergies and patterns plays the most important part in the automation of motoric skills. This level processes the afferent signals from musculo-articular receptors (information on the values of articular angles, velocities of movements in the joints, forces and directions of pressures on muscles and deep tissues of extremities and trunk) as well as from the organs of equilibrium [26].
3) Level C presents the level of spatial field. Level C ensures target movements in space: locomotions, sportive movements, accurate purposeful movements, overcoming resistance, throwing and shock movements, imitative movements [25]. Signals from visual, auditory, and tactile receptors as well as from the organs of equilibrium are transferred to this level. Therefore, the movements adapted to spatial properties of objects such as shapes, positions, lengths or weight are constructed using this level.
4) Level D presents the level of object-related actions. The level ensures the execution of successive movements which all work together to solve this or that motoric task. Level D is characterized by objectivity, chain structure, and adaptive variability of the actions. Such actions as tool using, handling objects, all common and everyday movements, etc. fall into this level. Specific character of the movements of this level is that they match the object logic. They represent actions rather than movements; moving components are not fixed for such movements while final object-related result is only determined. The way the action

performed or the set of motoric actions is indifferent towards this level [22].
5) Level E presents the sense level. The level ensures symbolic actions (speech and writing); movement chains united not by an object but by an abstract task; movements which depict object-related action; object-related actions for which the object does not represent direct target but serves as means to reproduce abstract not subject-related relations within it or using it [24, 25].

As a rule, several levels are simultaneously involved in the management of complex movements: the one the movement under consideration is based (called master) and all underlying levels. Formally, the same movement can be organized on different master levels. At that, master level of movement organization is determined by the sense, or by the task, of the movement.

Understanding of multi-level system of regulation of movements makes it possible not only to form motoric skills but to correct them as well as to identify brain disorders and diseases [24].

Thus, after having summarized theoretical information on natural physiological mechanisms of the formation of motoric acts [21–23], concepts of velocity corrections based on the analysis of sensory data as well as multi-level organization of the control system of motoric actions [24, 25] we can propose structural chart of the functional system which organizes the process of planning, execution, control, and correction of motoric program as well as integrates various systems of the organism into a single structure (see Figure 1).

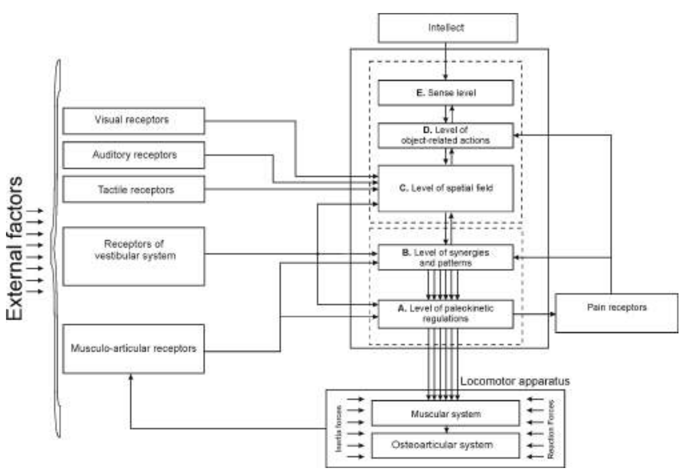

Figure 1. Structure Chart of Functional Control System of Motor Actions in the Human Body

III. CONTROL SYSTEM OF ROBOTICS COMPLEX

Further, based on the developed structure chart the multi-level block diagram of the control system of robotic complex has been developed using anthropomorphic concept of construction of hierarchical technical system [27, 28] (see Figure 2).

The chart includes the following control levels:

1) Level A: drivers of actuators. The level ensures the control of an actuator, for instance, stepping or asynchronous motor, servo-motor, pneumatic or hydraulic circuit, etc. The drivers can be equipped with various control inputs: analog current or voltage signals, digital codes, or complex digital protocol. Generally, driver receives diagnostics information from the actuator: consumed current, encoder signal, movement in progress, etc. In order to ensure high accuracy of the movements the drivers can also take into consideration the spatial data: signals from position sensors, accelerometers, gyroscopes. The driver also forms the information signal containing diagnostic data on current status of the actuators.
2) Level B: controller of instruction formation. This controller presents a control unit with a group of actuators connected by means of the drivers; control signals for the drivers are generated by the controller. Furthermore, elementary motoric patterns already stored in the controller memory are ready for the group of actuator.
Input data of the control unit are as follows 1) information on the movement which is necessary at the current point in time (level C); 2) data from position sensors, accelerometers, gyroscopes, etc. which makes it possible to control complex movements performed by a group of actuators; 3) information on the status of terminal actuators; this information generated by the diagnostics unit is taken into consideration when forming control actions.
Technically, this control level can be realized using high-performance microcontrollers (for instance, STM32 ARM Cortex) or programmable logic controllers.
3) Level C: Subsystem of environment analysis and formation of the algorithm for accomplishing current task. This system is intended for building algorithm of functioning of all actuators when accomplishing the current task. Information generated by the subsystem of task analysis (level D) presents input data of this subsystem. The subsystem processes the data on positions and movements of the actuators and their statuses (information received from level B), current position of the system in space relative to other objects (data from optical and ultrasonic sensors as well as limit switches) to form general algorithm of the movement and further outputs the information on the movement which is necessary at the current point in time to level B.
4) Level D: subsystem of task analysis (semantic system). General, in some cases unformalized task transferred from an operator or from another technical system through man-machine interface or machine-machine interface presents input data of this subsystem. This subsystem is intended for general analysis of the task, its decomposition and formation of the general plan of actions to accomplish the task. At that, technical conditions of actuator systems (data outputted by the diagnostics units of technical systems) as well as current position and state of the environment (information from level c) shall be taken into consideration.

5) Level E: man-machine interface/machine-machine interface. This level is used to convert the instructions from an operator or any other technical system into the format ”understandable” for semantic system.

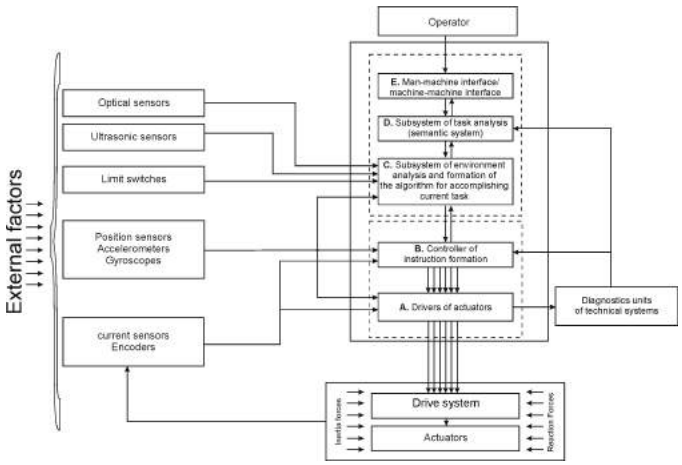

Figure 2. Block Diagram of Control System of Robotics Complex

As a rule, levels C, D, and E are realized by means of hardware. In the simplest case, they can be realized using single-board computers (Raspberry Pi, Red Pitaya, ZedBoard) while high-performance professional computers can be used for more advanced systems.

IV. Conclusion

Proposed control structure features a number of advantages:

1) Hierarchical levels of control systems differentiate the control functions appreciably. Thus, the development of such systems can be parallelized;
2) Later on, it is quite easy to upgrade the entire system through simple modifications of each level separately;
3) The system under consideration can be used not only to control one robotic complex but can be scaled as well to control a group of robotic complexes or an entire robot-controlled factory (within 6th techno-economic paradigm).

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АНТРОПОМОРФНАЯ СИСТЕМА УПРАВЛЕНИЯ РОБОТЕХНИЧЕСКИМ КОМПЛЕКСОМ

Давыдов М.В., Давыдова Н.С., Осипов А.Н.

В статье рассмотрены вопросы формирования, распространения и контроля двигательного действия в организме человека с позиции теории функциональных систем Анохина и теории уровневой организации движений Бернштейна. Иерархия уровней построения движений

1) Уровень «А»– уровень палеокинетических регуляций. Уровень «А» регулирует мышечный тонус, а также отвечает за возбудимость мышц, поэтому данный уровень участвует в организации любого движения совместно с другими уровнями.
2) Уровень «В» – уровень синергий и штампов. Данный уровень обеспечивает следующие функции: обширные мышечные синергии, т.е. способность вести высокослаженные движения всего тела, вовлекающие в согласованную работу многие десятки мышц; способность стройно и налажено вести движение во времени, обеспечение правильного чередования сокращения мышц и движения конечностей; способность к штампам, чеканной повторяемости движений. Этот уровень отвечает также за автоматизацию различных двигательных навыков.
3) Уровень «С» – уровень пространственного поля. Уровень «С» обеспечивает целевые перемещения в пространстве: локомоции, спортивные перемещения, точные, целенаправленные движения, преодоление сопротивлений, метательные и ударные движения, подражательные движения.
4) Уровень «D» – уровень предметных действий. Данный уровень обеспечивает выполнение последовательных движений, которые все вместе решают ту или другую двигательную задачу. Для уровня «D» характерна предметность, цепное строение и приспособительная изменчивость действий. К нему относятся все орудийные действия, манипуляции с предметами, все бытовые движения и т.п.
5) Уровень «Е» – смысловой уровень. Данный уровень обеспечивает символические действия (речь и письмо); двигательные цепи, объединенные не предметом, а отвлеченным заданием; движения, изображающие предметное действие; предметные действия, для которых предмет является не непосредственным объектом, а средством для воспроизведения в нем или с его помощью абстрагированных, непредметных соотношений.

На основе структурной схемы функциональной системы управления двигательной активностью в организме человека предложена антропоморфная система управления роботехническим комплексом. Данная система включает 5 уровней управления:

1) Уровень A – Драйверы исполнительных устройств. Данный уровень обеспечивает управление конечным исполнительным устройством, например шаговым или асинхронным двигателем, сервоприводом, пневмо- или гидроприводом и т.д. Драйверы могут иметь различные информационные входы управления – аналоговый сигнал тока или напряжения, цифровой код, сложный цифровой протокол. Как правило на драйвер поступает диагностическая информация от исполнительного устройства: потребление тока, сигнал энкодера, наличие перемещения и т.д.
2) Уровень B – Контроллер формирования команд. Данный контроллер представляет собой блок управления, к которому посредством драйверов подключена группа исполнительных устройств, для которых контроллер генерирует требуемые управляющие сигналы. Кроме того в памяти данного блока уже хранятся простейшие двигательные паттерны для групп исполнительных устройств.
3) Уровень C – Подсистема анализа окружающей обстановки и формирования алгоритма решения текущей задачи. Данная система предназначена для построения алгоритма работы всех исполнительных устройств при решении текущей задачи.
4) Уровень D – Подсистема анализа целей (семантическая система). Входными данными этой системы являются общая, в некоторых случаях неформализованная задача, поступающая от оператора либо другой технической системы посредством интерфейса человек-машина либо машина-машина.
5) Уровень E – Интерфейс человек-машина/машина-машина. Данный уровень служит для преобразования команд оператора либо другой технической системы в формат «понятный» семантической системе.

Предложенная структура управления обладает рядом достоинств:

1) Уровни иерархии системы управления хорошо разграничивают функции управления. Таким образом, разработку подобной системы легко распараллелить.
2) В последствии, достаточно просто выполнять модернизацию системы путем модернизации каждого уровня управления по-отдельности.
3) Данная система управления может применяться не только для управления одним роботехническим комплексом, она может масштабироваться с целью управления группой роботехнических комплексов или целым роботизированным предприятием (при введении шестого технологического уклада).

Analysis Order Book with a Card of Kohonen

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Abstract—**The properties of parameters order book of a financial instrument USD/RUB were studied. The paper studies some relationship between order book's parameters USD/RUB and the price movements on the graph on quarter timeframe. We have considered a series of standard and special indicators of order book.The investigation deals with the predicting the dollar price using parameters of order book prepared by Kohonen Self-Organizing Map. Several target prices were analyzed.**

Keywords—Order book, Kohonen map, the forecast price of a financial instrument

I. ITRODUCTION

Application of Neural Networks in stock trading is essential in the modern world. A thorough study of the phenomenon was made. As research shows, that the information of order book is wery important. A comprehensive study of the theoretical studies of various scientists on the forecast of stock prices was made. An extensive study was performed of thethe effect of the ratio of orders to buy and sell orders on the exchange price of the financial instrument USD/RUB on the chart.

A detailed analysis of the type clusters, the distances to the center of the caster, numbering cells, the distances to the centers of cells, using Kohonen self-organizing maps has been carried out. An analysis was made of the research of modern scientists about the impact of the price of the order book. Scientific hypothesis was examined and it was shown that it is possibly to prove that Kohonen self-organizing maps options of the impact of the price of the order book at the beginning of the opening of the candles on the 15 minute time frame, can allow to obtain predicted values prices USD/RUB at the close of the candle. It is concluded that the model provides a very good fit to the experimental data. The allocation purchase and sale of the bulk were described with particular attention to the structure of their various ranges of values.

It has been shown that the issues of portfolio management in the stock market with the help of artificial intelligence systems have dedicated their works, many scientists. The dollar exchange rate forecasthas with using astrological cyclical indices Gyushon and Gan had been studied by Maximova O.N. [8]. The using of the neural network of the exchange trading robot in portfolio management have been investigated by Noeva E.A. [10], the theoretical bases of perfection of brokering had been researched by Popovicheva N.S.[11], Nesterova A.O. studied the neural network model of money management [9].

The study was intended to establish dependence between the structure of applications for buying and selling in the stock and a glass on a chart the dynamics within a 15 minute period.

The aim of the study was to provide some information concerning the life and habits of these animals using Artificial Neural Networks in stock trading, but some issues require further theoretical study.

According to Bondarenko Y.A., it is necessary to continue research on profit prediction [1], the point of view Lomakin N.I. is that, fuzzy-algorithm is best suited for financial risk management in the stock transaction [6], and stock transactions are applicable to increase the investment activity of the enterprises of the real sector of the economy [4], large-scale using of the stock robots is rather useful in conditions of information society development [7].

II. TEXT OF THE ARTICLE

It was found that the order book is a table that contains information that is a digital display of the current market sentiment. Over the short-term analysis of the current market situation would have been done using information from the order book, for a specific financial instrument included in the portfolio.

Unlike graphs, which reproduce market information in a visual form, in exchange glass reflected application is only offered for Exchange close of the market price at a given distance from the market equilibrium. Applications, The applications was submitted to the order book, will be executed wery soon and thus affect the movement of prices on the market [3].

The orders of big players are visibled in the Quotes glass, and it can be used for trading decisions. The Quotation glass does not show a complete picture of the market. The Quotation glass didn't show a complete picture of the market, so, it is reflected not all the orders of the stock exchange. There are visibled only a small part of the limit orders. Only limit orders, that are close to the market price are reflecting there.

Order book is included several parts: the green part - is an application for purchase (bid), in the red zone - an application for sale (ask or offer). The market price is within the spread, ie Best price between buyer and seller is called better price.

The export off Quotation glass orders for the purchase and saleare was performed using trader terminal QUIK. The histogram of stock warrants for the purchase and saleare had been reflected in the Quotes glass top red candle in USD/RUS by 19.30. Diagrams are introduced to simplify the discussion (Fig. 1).

Figure 1. The histogram of stock warrants for the purchase and saleare had been reflected in the Quotes glass top red candle in USD/RUS by 19.30

It's possible to suggest that the volume of orders to buy and sell, as well as their location in the glass at the beginning of "birth" of a candle are influenced on the behavior of asset prices in future. So it can be the basis to forecast the closing price of the current candle. Nine candles of USD/RUB were successfully imported from trading terminal QUIK to Dedactor. The picture is includes three parts - frames. In the top frame is the price chart candle of the first observations at 19.30 time, thise candle has a red colour.

The index chart RSI (relative strength index) is placed on the middle frame. It is shown overbought market at values ? 70 and oversold when values ?30, thus predicting the imminent trend reversal.

In the lower frame MACD gistogram index (Moving Average Convergence/Divergence) is placed on. This index is reflected the birth and development of the fading trend. Dynamics of parameters candlestick is presented in Table 1.

Table I. DYNAMICS OF PARAMETERS OF USD/RUB

N	1	2	3	4	5
T	19.15	19.30	19.45	20.00	20.15
Po	60.05	60.06	60.1	60.14	60.14
Ph	60.07	60.1	60.15	60.15	60.15
Pl	60.02	60.04	60.1	60.12	60.12
Pc	60.07	60.1	60.14	60.15	60.13
RSI	54.2	57.88	57.88	62.27	59.2
MACD	0.010	0.012	0.016	0.022	0.028
N	6	7	8	9	
T	20.30	20.45	21.00	21.15	
Po	60.12	60.13	60.13	60.14	
Ph	60.14	60.14	60.15	60.15	
Pl	60.11	60.12	60.13	60.13	
Pc	60.14	60.13	60.15	60.15	
RSI	59.84	58.53	60.85	60.48	
MACD	0.026	0.02	0.18	0.01	

For the analysis of statistical parameters Deductor order book program have been used.

The input data were processed with the help of neural networks - Kohonen map. Kohonen self-organizing maps (SOM) is one of the varieties of neural network algorithms.[11].

Functioning of the self-learning algorithm maps (Self Organizing Maps - SOM) is one of the options for clustering multidimensional vectors. As an example of such an algorithm the algorithm can perform k-nearest medium (k-means).

The coordinates of the input vector are designated on cross marked. The map coordinates of nodes after the modification are marked in gray. Moreover, grid view after the modification is depicted by dashed lines. Diagram is introduced for the simplification of the discussion (Fig. 2).

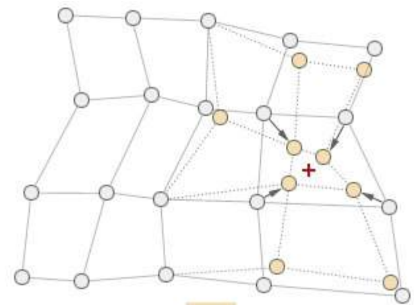

Figure 2. Tuning the weights of the winner neuron and its neighbors

Besides the parameters of candlesticks,it's very important to use technical analysis indicators RSI and MACD relative strength index. RSI is a technical analysis indicator that measures trend strength and the likelihood of change [5]. Indicator Moving Average Convergence / Divergence is a technical indicator used in technical analysis to assess and predict price fluctuations on the stock and currency exchanges [6]. The program Deductor is used in data processing applications. It is also employed when investigating Kohonen Maps for the analysis of the statistical parameters of order book. Neural networks of this type are commonly used for a wide range of tasks, from data analysis to find patterns, for example, financial problems [19].

Moreover, it should be noted that an important difference between SOM algorithm is that it all neurons (nodes classes centers ...) arranged in a certain structure (usually a two-dimensional grid). Then in the course of training is modified not only the neuron-winner, but also its neighbors, but to a lesser extent. The parameters Kohonen maps at the beginning of the first candle are represented on the screenshot. The diagram can be plotted (pic. 3).

The total aggregate of buy orders is divided into six ranges.

It should be noted that the ranges have a symmetrical distribution with respect to the market equilibrium in terms of supply and demand. The bulk of the orders 27 (67.5 percent) is located within the range of the size of orders from 0 to 216.833 and then leads to a range of sizes from 433.666 to 650.5 comprising 6 orders (15.0 percent).

Similarly, we can see the histogram of frequency allocations for other parameters and, if necessary, to use them in the "perceptron" - neural network model to predict the closing

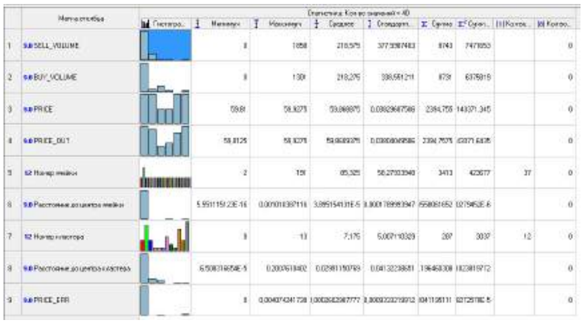

Figure 3. The settings order book the beginning of the first candle USD/RUB

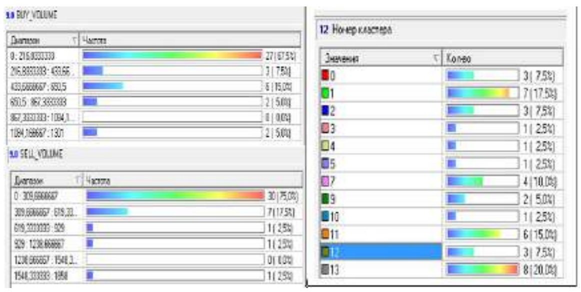

Figure 4. The frequency of the basic parameters

price of USD / RUB at the end of the candle. Diagrams are introduced to simplify the discussion (Fig. 4).

Numerous figures show that the spectrum contains a very broad frequency ranges for different. The rate calculated for all available software options are very important for research. The frequency for histogram "price" were distributed as follows. Diagram is introduced in order to simplifying (Fig. 5). The

Figure 5. Frequency histogram "price" were distributed

frequency allocation spectrum consists of two types of components - 8(20,0) and 4(10.0). As we see, Deductor program allows you to calculate the required parameters: the cell number, the distance to the center of the cell, cluster number, the distance to the cluster center, the amount of error in the price. The Deductor program which makes use statistics method of detecting is described. Statistics obtained are important for research. For the simplification of the discussion diagram is introduced (Fig. 6)

The necessary mathematical data were received after the training neural model. They characterize the feature of the composition and structure of the order book. We can plot a diagram (Fig. 7).

The formula is used to modify the weighting coefficients:

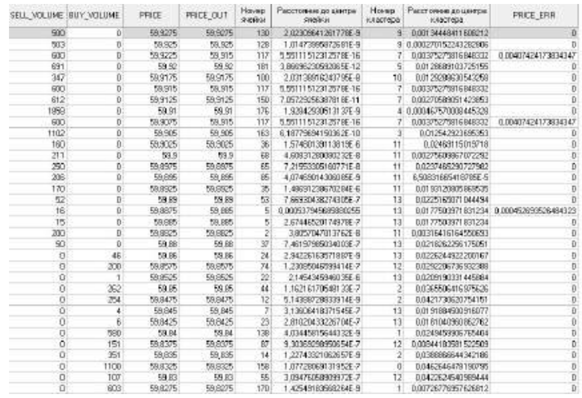

Figure 6. The parameters Kohonen maps at the beginning of the first candle

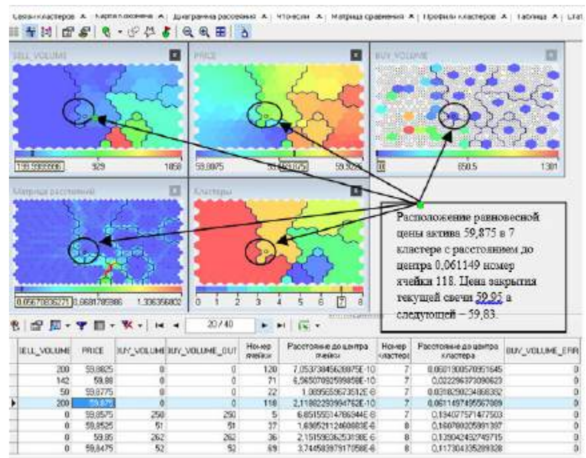

Figure 7. Kohonen map for glass candle at 19.30 times

$$wi(t+1) = wi(t) + hci(t)?[x(t) - w(t)]wi(t+1) = wi(t) + hci(t)?[x(t) - w(t)]$$

where t - denotes the epoch number (discrete time);
x (t) - vector selected randomly from the training sample at iteration t;
h (t) - function is called neurons neighborhood.

The meaning of the equilibrium price of the asset at 19.30 time is 59.875. The value of this parameter is located in 7-cluster distance to the center of 0.061149 cell number 118. The closing price of the current candle is 59.95 and the following candle - 59.83. Thus, such "image clusters" corresponds with "declining market".

The function "What-if" in the program Deductor makes it possible to calculate the predicted value of the closing of the next candle - 59.89. In order to simplify the discussion diagram is introduced (Fig. 8).

Kohonen map is provided a high accuracy of the forecast. The deviation of the actual value of the asset price 59.89 from the actual 59.89 is amounted to 0.06, so error value is not exceeded 0.001.

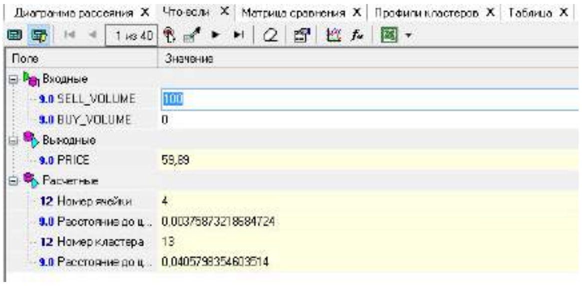

Figure 8. Predictive value of the closing price of the USD / RUB 59,89 at the actual value of 59.83

III. Conclusion

Investigation of the dynamics parameters order book is very important. It made it possible to get a forecast price for change of supply and demand of speculators in real time. This approach has the advantage in comparison with the results of a technical analysis, which is based on data from the past.

A new method has been developed to produce the forecasts financial instrument price USD/RUB.The scientific research supports assumption. Thus, on the basis of the above we can conclude that:

- firstly, some relationship between order book's parameters USD/RUB and the price movements on the graph on quarter timeframe was found;
- secondly, an extensive study was performed of thethe effect of the ratio of orders to buy and sell orders on the exchange price of the financial instrument USD/RUB on the chart;
- thirdly, the detailed analysis of the type clusters, the distances to the center of the caster, numbering cells, the distances to the centers of cells, using Kohonen self-organizing maps has been carried out;
- fourthly, the analysis was made of the research of modern scientists about the impact of the price of the order book;
- fifthly, scientific hypothesis was examined and it was shown that it is possibly to prove that Kohonen self-organizing maps options of the impact of the price of the order book at the beginning of the opening of the candles on the 15 minute time frame, can allow to obtain predicted values prices USD/RUB at the close of the candle.
- sixthly, it becomes possible to use the algorithm in the stock trading robot.

It will automate the process of deciding whether to buy / sell an asset at a scalping [5], developed method will have been to design more successful trading robots [12].

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АНАЛИЗ БИРЖЕВОГО СТАКАНА С ПОМОЩЬЮ КАРТЫ КОХОНЕНА

Ломакин Н.И., Орлова Е.Р., Нересов В.С.

В статье проведен анализ взаимосвязи параметров биржевого стакана финансового инструмента USD на пятнадцатиминутном таймфрейме и движения цены на графике. Для проведения исследования использовался алгоритм нейронной сети - Карта Кохонена. Учитывались такие параметры, как количество заявок на покупку и на продажу на различных ценовых уровнях финансового инструмента в биржевом стакане. Во внимание принимались рассчитываемые параметры стакана, как минимальные, максимальные и средние значения объемов продаж, объемов покупок и цены, их средние значения и стандартные отклонения. Кроме того, с помощью Карты Кохонена рассчитывались значения кластеров и распределение параметров по кластерам в абсолютном выражении и их веса. Анализ проводился с целью подтвердить или опровергнуть гипотезу о том, что динамика параметров биржевого стакана может выступить генератором факториальных признаков для прогнозирования направления и амплитуды движения USD в японских пятнадцатиминутных свечах. Исследования показали, что с помощью анализа выявленных факториальных признаком можно спрогнозировать движение цены актива. Результаты анализа представляют интерес по поводу оценки движения цены биржевого актива.

Some Aspects of Formation Knowledge Base Information on the Basis of Use Optical-Electronic Devices of TV and MM Paths

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***Abstract*—This paper considers algorithms of visual information in the application of multimedia and television problems. Looks at the application of data of visual information in their spectral composition. Attention is drawn to the fact that the color with particular characteristics may be represented by different spectral components. It presents one of the way to optimize the obtained spectral data and simplify the detection of the same color in different spectral distribution.**

***Keywords*—Base data, color appearance models, models of color vision, spectral distribution, TV, MM.**

I. Introduction

Task of correct perception and transformation of visual information is important in systems of machinery vision, in the television devices (TV), in multimedia devices (MM). Correct information about light transformation is reduced to quality of converting sensors, cameras matrix and elements of path and for forming and transmission optical energy. All mentioned above system nodes in bring their own errors and noise, special attention should be paid to the elements of conversion "light-signal". The latter work on the principle of averaging spectral energy in the visible range of the human eye. Analytical expressions describing the operation of the converter shown in the paper [1]. Expressions do not allow to take into account the spectral distribution which in result of energy computation give the same value. The latter may cause the system to identify one color, and in other conditions will give as a result a completely different color, which will lead to a false perception, in a self-learning systems to increase the knowledge base. These and other questions will be addressed in this paper.

II. Optical-electronic devices (OED) TV and MM paths as a means of obtaining knowledge

The main feature of the progress of television systems and other video applications is the trend of transition to new levels of image quality and creation of new system functionality. Thus the special place is occupied by the fidelity of the rendering, depending on the colorimetric characteristics of the systems as a whole and their components, defining the colorimetric image quality. When it comes to colorimetric quality, it should be based on evaluation of color fidelity in a through path "from light to light" [1-3], as the main color irregularity occurs on the transmitting and receiving sides, namely, they arise due to possible imperfections in the spectral the composition of the source of studio lighting and radiation due to possible imperfections in the spectral characteristics of the camera, as well as colorimetric errors introduced by the playback device, and errors which may make a digital image processing at the transmitting and receiving sides.

One of the most critical factors is the imperfection of the spectral characteristics of the sensitivity channel of camera primary colors. This means that when assessing true color reproduction one can not move away from the spectral reflection characteristics of objects in the scene and to operate only with their color coordinates. That is why paper [1] focuses on the spectral composition of objects and given a comparison of distortion of color reproduction of optimal colors and an example of real colors in the form of a combination of Gaussian functions from length of the radiation wave, and is shown that there may be some inconsistency with a metamerism.

In order to quantitatively judge the trueness of colortransmission of TV cameras, one must have the opportunity to compare the characteristics of real cameras with the characteristics of an ideal cameras, and spectral characteristics of the R, G, B channels. primary colors of which would provide an undistorted colortransmission regardless of the spectral composition of objects.

In the present study determined the spectral characteristics of the ideal in terms of colorimetry CIE 1931 standard camera television (SDTV) and high (HDTV) and ultrahigh (UHDTV) definition, as well as for UHDTV system in terms of colorimetry CIE 2006 and there are examples of error estimation of colortransmission due to views difference about undistorted colortransmission. Also examples of distortion assessment for a set of colors, Color Checker, that optimally configured to a "standard" SDTV camera in relation to the ideal.

The difference of these characteristics leads to the error of colortransmission, which makes the camera in which feature colorimetry of 1931, in relation to the camera, which has a more advanced colorimetry 2006 year. Where $\alpha_R(\lambda)$, $\alpha_G(\lambda)$, $\alpha_B(\lambda)$ the vectors of spectral characteristics of the sensitivity of the channels of the primary colors of the TV camera. Index F marked affiliation colorimetry 2006 year.

Colors different in brightness and respectively belong to different levels of lightness of the image. For the set of Color Checker the signals of primary colors do not go beyond the

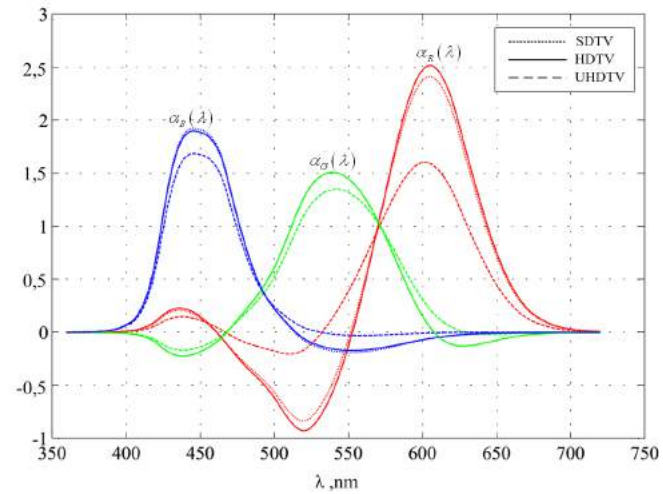

Figure 1. Comparison of the spectral characteristics of the sensitivity of the channels of the primary colors is ideal from the point of view of colorimetry, the CIE 1931 SDTV cameras, HDTV, UHDTV

boundaries of the interval $\overline{0,1}$, i.e. they can be transmitted by UHDTV system. For a set of optimal colors for some colors the basic colors exceeds a single level, so in their brightness was introduced normalization, in which signal levels were limited by interval $\overline{0,1}$. Points of colors of both sets are presented in Picture 3.

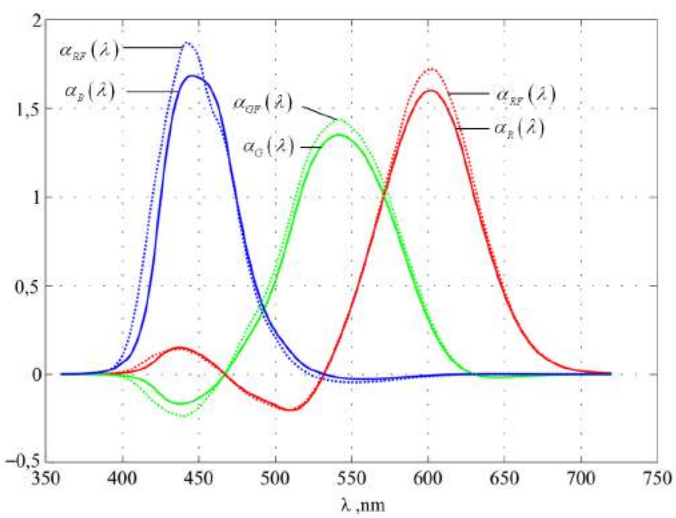

Figure 2. A comparison of the spectral characteristics of the sensitivity of the channels of the primary colors of the UHDTV camera, ideal from the point of view of colorimetry, the CIE 193 the CIE and 2006

Evaluation of distortion of color transmission of the "standard" camera when compared to the ideal. In TECH 3355 [4] introduced an assessment of true color transmission for "standard camera", the characteristics of which were obtained as a result of averaging modern cameras SDTV, picture 3. For the "standard camera" [4] were calculated the resulting spectral characteristics, taking into account the linear matrix that approximates the resulting spectral response, as far as possible to the ideal, and made evaluation of color shift with respect to the original colors for the two models-linear, i.e. excluding gamma transformation, and non-linear, i.e. taking into account the gamma transformation. However in [4] color shifts have its place due to the imperfection of the spectral characteristics of the camera, together with a non-linear transformation, and for compensation applied optimization of the matrix.

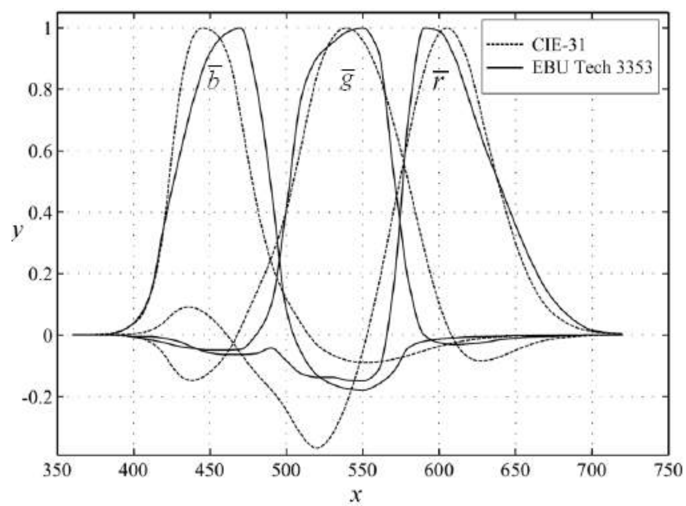

Figure 3. Spectral characteristics of reference and a real camera (EBU Tech 3353)

In the present work adopted for the baseline a different approach, consisting in the fact that the successive gamma conversion from $\gamma_1 = 0.45 = \frac{1}{2.2}$ on the transmitting side and $\gamma_2 = 2.4$ on the receiving side result in the reproduction of colors and brightness tones, perceived by observers as the best. Therefore, as a criteria of true color transmission is preferable to estimate the color shift in relation to colors specified in case of use of ideal camera and the use in series of both non-linear gamma transformation. Using the camera with the characteristics of a "standard" camera with a linear matrix [4, Pictures 11] provides a virtually undistorted color reproduction.

This conclusion can be extended to the HDTV system, given the proximity of colorimetric systems, standardized for SDTV and HDTV systems, and are consistent with the data of [4] for UHDTV system. The paper presents a study of the spectral characteristics of the camera standardized in ITU-R SDTV systems, HDTV and UHDTV in terms of their effect on the colorimetric image quality as one of the major factors.

III. One color and different light sources – different colors

The desire to improve the quality of the TV picture or MM causes engineers to integral actions-control and measurement parameters through television tracts. For this purpose there have been developed a technique of subjective and objective quality control, testing a variety of materials and measuring equipment. And if there more tools for assessing the quality, the greater the likelihood that the solution to enhance the image quality will be solved. A neglect of one of the factors affecting the quality, leads to imperfection video transmission system. Since there are many point in the path, in which there is a likelihood of distortion, lets pay attention to the distortions associated with the use in the D65 light studio but different spectral distribution and characteristics of cameras which differ

Table I. RESULTS OF THE EVALUATION OF THE INFLUENCE OF VARIOUS SOURCES OF LIGHTING ON COLOR REPRODUCTION OF THE SCENE

Y	Light source	*R*	*G*	*B*	*Ye*	*C*	*M*
0.25	FL3.15	2.3	1.8	0.6	3.2	0.5	0.8
	FL1	6.1	3.1	2.4	3.1	4.1	2.0
0.75	FL3.15	2.8	2.2	0.7	3.9	0.6	0.9
	FL1	7.3	3.7	2.9	3.8	4.9	2.4
1.00	FL3.15	3.0	2.3	0.7	4.1	0.7	1.0
	FL1	7.6	3.9	3.0	3.9	5.1	2.5

Table II. THE AMOUNT OF CHANGE OF VECTOR OF COLOR USING CAMERA EBU TECH 3353 [4] AND THE LIGHT SOURCES WITH RESPECT TO AN IDEAL CAMERA, ICE IS EXPRESSED IN UNIT

Y	Light source	*R*	*G*	*B*	*Ye*	*C*	*M*
0.25	D65	4.1	2.0	3.7	13.5	0.5	7.9
	FL3.15	3.8	1.8	4.6	13.6	0.2	7.6
	FL1	3.5	4.8	10.0	11.8	3.1	10.4
0.75	D65	4.9	2.4	4.5	16.3	0.7	9.5
	FL3.15	4.5	2.1	5.6	16.4	0.2	9.2
	FL1	4.1	5.8	12.4	14.1	3.8	12.4
1.00	D65	5.2	2.5	4.8	17.1	0.7	9.9
	FL3.15	4.7	2.2	5.9	17.2	0.2	9.6
	FL1	4.4	6.2	13.1	14.7	4.0	13.0

from the idealized characteristics of standardized CIE-31. As for the camera, then not having the spectral characteristics of the latter it is not possible to judge the colorimetric capabilities of cameras, since, at this stage, this information is hidden in nature were used standardized characteristics cameras EBU Tech 3353.

As for the metrics and thresholds used in the calculations was used analysis represented by authors in paper [5]. For evaluation of effect of mentioned factors was used equally contrasted system CAM02-UCS [6].

Table 1 shows the value of the color differences in lighting of scene at the transmitting side of an idealized (reference) light source D65, and on the receiving side fluorescent light source type F3.15 and F1, with different brightness of the playback scene and brightness adjustment equal to 50 cd/m^2. The shaded area shows the most critical values of color distortion that will be visible to ordinary viewers.

The table results are presented in terms of the CIE, which expressed a long vector in three-dimensional color space. Its length refers to the distance between the studied colors and can be used for quantitative assessments. The criterion of length of the vector estimation is presented in [5]. Since the assessment carried out in uniform color space chromaticity point which are placed evenly over the entire area of the color it gives the right to assert that the proposed criterion is valid for any of the chromaticity diagram.

As for the camera, the camera's spectral characteristics are shown in Fig. 3. Studies conducted using the real camera in the same scene brightnesses and brightness adjustment are shown in Table 2. Assume that the ideal camera is the one that standardized CIE-31.

These results were obtained using artificial spectral characteristics which closer to the idealized and produced by mathematical modeling, more detail can be found in the literature of [8]. These colors are made up of a set of basic and additional colors, all other colors are not quantify but some issues are reflected in [10].

Table III. EVALUATION OF COLOR RENDERING ON THE EXAMPLE OF USING THE STANDARDIZED SPECTRAL DISTRIBUTIONS IN [7]

Research options	Value	
1. Optical sample illuminated by natural light, 2. Optical pattern illuminated light source D65, the,camera [8]	1.69	2.90
1. Optical sample illuminated by natural light, 2. Optical pattern illuminated light source A, the,camera [8]	11.03	15.94
1. Optical sample illuminated by natural light, 2. Optical pattern illuminated light source D65, the camera [4]	5.69	10.10

According to the data presented in the Table. 2 it can be argued that there is a color for which distortion accept invalid values, and there are those for which the distortion in the normal range, or not visible. But because the studies have not been conducted on the full and artificially generated spectral distributions advisable to conduct research on the actual spectral distributions. Data spectral distributions has been taken to achieve the last of the ISO/IEC standard [7]. In this standard, a wide range of spectral distributions of actual colors. The results of three studies of the possible embodiments were chosen, namely:

- an option when the color is perceived by the system which is equivalent to the average human eye and there is no distortion of the optical the machine or inverter "light to signal" (OTF – optical transfer function) or the distortions insignificant are small;
- an option when using the same system, but the artificial lighting, namely light source type A and D65;
- An option when using a real camera [4] and artificial lighting.

As can be seen from the results shown in the table appear as distortions only artificial lighting has excellent spectral distribution from natural sunlight and when the actual camera used different from the spectral characteris-tics shown in Fig. 1 and 2.

These data indicate unacceptable distortion, distortion of this kind can be reduced or eliminated through the use of adaptive models [9], but even the simplest model of color correction will not work without the second pa-rameter vector direction. The direction can be varied, as shown in the example in Figure 4.

IV. METAMERISM IN THE APPLICATION OF MULTIMEDIA AND TV SYSTEMS

Understanding about the concept of metamerism in optics indicate the ability to create the same visual sensation of a stimulus by the person in different spectral distributions. The spectral distribution was noted in some earlier works, e.g. [1]. An example of metamerism is shown in pictures 4.

On the pictures shows two different spectral distribution (example 1 and example 2), which in the end give the same result the same values of color coordinates, namely $x = 0.2353$, $y = 0.1667$, $y = 0.5978$. The coordinates obtained using the spectral characteristics of the sensitivity of the camera shown

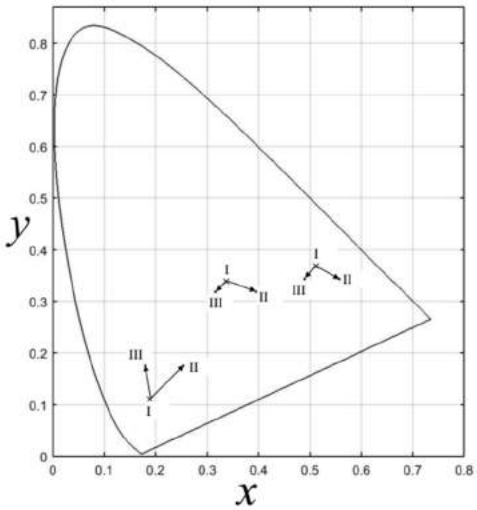

Figure 4. The character changes color point depending on the lighting and the different spectral characteristics of the cam-era's sensitivity to the example of the use of the spectral characteristics of a real object (I - the spectral distribution of the optical sample under natural light, II - for the variant using the camera with the characteristics [4], III - for option using the camera with the characteristics [8])

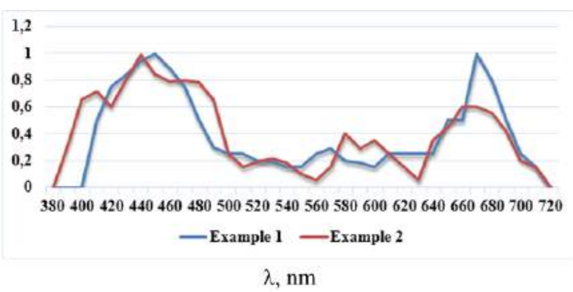

Figure 5. Is the spectral distribution of the color stimulus

in Fig.3, and the optical stimulus was illuminated by the light source type D65.

V. Conclusions

From the presented data we can draw the following conclusions. Given that the magnitude of change are presented in table. 1 and 2 in some cases reaches unacceptable values (more than 7 units) in the future, it is advisable to take into account the parameters of the light sources in the design of new TV and MM systems, in particular the adaptive television.

The spectral distribution of the sensitivity characteristics, standardized EBU camera brings distortions, and the use of other cameras in machine vision, and systems capable of accumulation of knowledge makes them not universal. That is, the use of the same conditions, different cameras leads to a duplication of the same the knowledge and most importantly, that the stored data is different, although the optical parameters of the observed object were original, and when they are compared in a common database leads to a lack identity between them which results in the desired increase in volume has not retained the knowledge. Similarly explained by the influence of other light sources.

One possible exception of this phenomenon may be the use of adaptive spectral sensor data obtained correction pattern. The use of the latter can be implemented in combination with the use of color patterns, such CAM02-UCS.

Questions metamerism require further research, since existing methods do not allow to eliminate this phenomenon is due to the design features of converters "light signal", as well as the absence of analytical methods for the determination and elimination of metamerism.

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Construction of polar coordinates grid in uniform color space, uniformly filling area of existing colors, particularly of color gamut transmitted and reproduced by television systems Gofaizen O.V., Pyliavskyi V.V.

НЕКОТОРЫЕ АСПЕКТЫ ФОРМИРОВАНИЯ БАЗ ДАННЫХ НА ОСНОВЕ ИСПОЛЬЗОВАНИЯ ОПТОЭЛЕКТРОННЫХ УСТРОЙСТВ ТЕЛЕВИЗИОННЫХ И МУЛЬТИМЕДИЙНЫХ ТРАКТОВ

О.В.Гофайзен, В.В.Пилявский, М.А.Форостенко

В работе рассматриваются алгоритмы обработки визуальной информации в прикладных мультимедийных и телевизионных задачах. Рассматривается вопрос различия визуальной информации на основании спектрального состава излучения. Акцентируется внимание на том, что цвет с одними спектральными характеристиками может быть представлен разными спектральными составляющими, что увеличивает. Представлены оценки метамеризма при воздействии источников освещения, спектральной чувствительности камеры и т д. Представлен возможный вариант оптимизации полученных данных и упрощение детектирования одного цвета по разным спектральным распределением.

Associative Relations in the Assessment of TV Images

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***Abstract*—With the creation and international standardization HDTV and UHDTV systems becomes an actual task of specification test signals to be used in the construction and maintenance video path and equipment of this systems. In this paper suggestions are made on the associative relations in the assessment of TV images. The semantic relation between the objects of the frame will be the most valuable information that requires transmission with the highest priority. The proposals can be considered as the initial to new step of progress of metrological provision technical implementation HDTV and UHDTV systems**

***Keywords*—3DTV, mesh, video path, image quality, quality assessment, semantic relation, date base.**

I. Introduction

The paper contains proposals on three-dimensional (3D) mesh that is currently used in many multimedia applications such as digital entertainment, medical imaging, and digital television system. In the process of visualization 3D-mesh, undergo some operations lossy compression, simplification, turns, putting watermarks. Since end-users, in most cases, people, it is important to obtain indicators that can accurately evaluate the perceptual distortions introduced by such operations [1]. Classic metrics simple geometric distances (eg, mean square error and the Hausdorff distance) [2, 3], are not consistent with human visual perception and, therefore, is unable to predict the visual difference between a pair of reference and deformed mesh object Material of this work is a continuation of previous studies in this area [5]. It should be noted that the parameters of color for HDTV systems have been proposed in [5]. However, sub-sequent analysis done by the authors has shown that to achieve compatibility with existing measurement equipment proposed set of parameters should be modified in terms of time characteristics, and this modification is made in this work.

II. Mesh object composition

TV mesh objects are combining several structures, in particular:

- polygonal mesh cage;
- a set of matching texture;
- a set of normals to landfills;
- the color information for each polygon;

Each of these sets in its own is coded and transmitted. Effectively given polygonal mesh model is suitable for television broadcast only if the object-oriented construction of the scene. Trips to mesh compression quality assessment, usually based on a comparison of the starting mesh with it image distorted copy. Graphical representation of the mesh image is represented in Fig. 1.

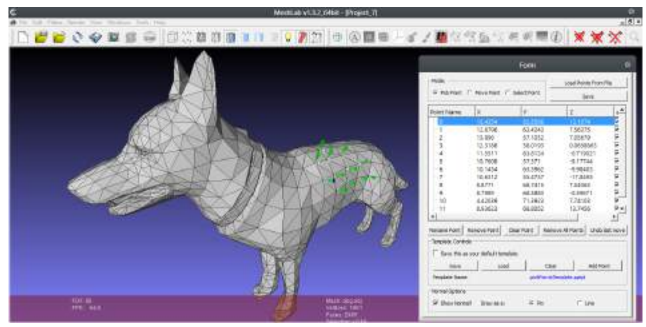

Figure 1. Mesh representation of the image

It can be assumed that by specifying the description of the object of the mesh set of semantic relations, with the subsequent search in the database corresponding to images of objects, allowing you to replace them distorted.

III. The semantic relations in the TV frame

P.A. Florensky had shown that human perception of three-dimensional images are always carried out in time, it is always discrete, and it has a certain rhythm. Then, any message must be configured or "stapled" of closed ones in the space-time events and objects. The audience watching the static frame for 3 - 4 seconds and then if nothing happens begin to lose interest in it, or closely begins to learn the details. A frame is a minimum unit of the television language. It is like words in a language, respectively, the frame carries meaning. The semantic relation between the objects of the frame will be the most valuable information that requires transmission with the highest priority.

Multimedia space can adequately replace the digital image signal or audio images of their "verbal" representation and vice versa. The associative memory search is carried out without the use of direct or indirect addressing but according to the content of information Search for data on the basis of their content is based on a limited comparison of some important parts of the words stored in the memory cells. The procedure is advantageously carried out by comparing the rules of fuzzy logic, which allows to find similar, but not exactly the word, wondering interval criterion relevant key information.

However, this understanding of the associative memory represents, in essence, only the fact of the relationship between the data and has nothing to do with the very mechanism of information storage. Therefore, to refer to such information storage mechanism uses the term "memory content addressed". In contrast, the unit you can store data integrity in a particular cell, having only information on direct connections a given cell with the other - so we come to understand the semantic networks. These principles are also applicated for indexing and searching the modern databases. The concept of linguistic variable and its application to accept approximate solutions capable of dynamically generate the object based on the association of a text description and audio or video image. [4] The search in the database can be organized on a linguistic change, to open access to the association by the file storing the image or sound. Sami linguistic variables is desirable to be formed by use of a multilingual interface. It can be argued that the associative sample in a narrow sense is equivalent to pattern recognition.

IV. The process of image verbalization

Image verbalization occurs in the following sequence: the image contours are monitored, after the corresponding differences of brightness; color segmentation performed. Then, the approximation obtained for contours and color boundaries.

For example, here, the image search procedure comprising similar dominant color ranges in the database. Comparison is made on the basis of the shortest distance from Manhattan found the dominant color in the selected color coordinate system of a predetermined set of basic colors classified by brightness, saturation and hue.

The resulting color is used as an identifier for the organization of the search procedure in the image database. Determine the association of colors from a core set of primary colors for the formation of the characteristics of the visual similarity of colors and visual contrast of colors. Generate index (metadata) of the image to the required basic color in RGB format, and / or name and / or the tag color. Searches for images in the information database.

In the search result list form index images coinciding with the presented index and / or indices in which the primary colors are present in the list of visual associations or similarities in color contrast to the list of primary color images in the search index.

V. Databases of images

Closest in technical essence is a method of extracting digital images from a database of images [5,6,7], wherein the presented image is calculated histogram and histograms of images stored in the database, then the image similarity measure is calculated using a method of assessing the similarity of two distributions probabilities. Then, the search results are ranked according to the degree of similarity of the input image. [8]

Currently several universities developed image database as the high and ultrahigh color definition, and three-dimensional. Base images of various objects created by members of Intelligent Systems Lab Amsterdam lab. The database contains images of 1,000 items (one-thousand small objects. Each object presented three series of images. The first series includes 24 frontal images of the object taken in different lighting direc and light color. Each object was recorded frontally, with five included bulbs. lighting colors changed from 2175K to 3075K. White balance in the cells was set to 3075K, whereby illuminated objects from reddish to white light. The third series includes 72 images taken at different positions of the camera on the subject. The database also includes a stereo pair for 750 objects. Each image in the database is represented in the color and grayscale form in three different resolutions: 768×576, 384×288 and 192×144 pixels. (Tabl.1)

Table I. ALOI Media database 1000 different objects

Amsterdam Library of Object Images	Processing method
24 frontal image of the object	different directions of illumination
12 Frontal image of the object	different light color
72 images relative to the object	at different positions of the camera
stereo pair for 750 objects	in color and grayscale form

Image database for testing three-dimensional object recognition algorithms developed at New York University. The base is designed for experiments with recognition of three-dimensional objects. It contains 50 images of toys belonging to 5 main categories: the four-legged animals, human figures, airplanes, trucks and cars. The images were taken by two cameras at 6 different lighting conditions, with 9 slopes and 18 azimuths.

Image database of persons trained at Yale University. The database contains frontal images of faces. The base consists of 165 images of 15 people. Each person is represented by a series of 11 images: with three different light; with glasses and without glasses; six different facial expressions. The base of natural texture images, created Massachusetts Institute of Technology. (Tab.2).

Table II. Media databases

Dataset	Type of images
The NORB Dataset, New York University	four-legged animals, human figures, airplanes, trucks and cars
Yale Face, Yale University	images of 15 people with six different face impressions
Massachusetts Institute of Technology	homogeneous texture. 15 texture scenes
Notre Dam datasets	iris recognition

VI. Conclusions

The paper proposes parameters for priority construction of 3D images as a task of searching for images according to the systems by form and a specific color. Image attributes that describe the location, color, texture, category image and other are called an index or image metadata. Image index is stored in the information database. In this picture index must include, along with the tag name of the color, which should be as accurate as possible to characterize the color of the object in the image. Semantic Coding images, audio, images and video moves us to a more general understanding of the world.

In the field of high-definition and ultra-high television pressing issue is to evaluate the image quality based on the properties of human vision. Researchers have proposed dozens of criteria correlated with the human visual system and allowing to predict the quality of the images. Due to the fact that holding subjective assessment appears long and expensive procedure in recent years are developed color image data bases, which contain typical reference image and distorted images. The image distortion uniquely identified objective metric of distorting factors and the result of the subjective evaluation of this particular type of distortion. An example of such a database is the database TID2013 of television images, developed jointly by Ukrainian and Finnish researchers [6]. The database contains information about the 24 types of distortions including distortion arising from the compression of digital images. Each of the distortions is represented on five levels. Few types of the distortions from the database TID2013.

- additive Gaussian noise;
- spatially correlated Noise;
- quantization noise;
- image denoising;
- JPEG transmission. Errors;
- contrast change;
- change of color saturation;
- chromatic aberrations.

Of course, a single database cannot foresee all possible distortions. Moreover, the feature of the television program is to have a combination of several distortions simultaneously. The manifestation of the aggregate of distortions in the subjective assessment is the subject of investigations, since deterioration stack with different impact on the final score. We should also take into account the effect of masking some other distortion. None of the existing image database did not include information on the spectral composition of the primary colors, and does not include features about color system and its coordinates.

From the point of view of the image search capabilities for associative connections in these bases are not provided until the appropriate descriptors, or other verbal descriptions. The other branch of image databases associated with the collection of color volume images in which the images are presented by the primary colors red, green and blue, as well as depth.

Michael Firman studied in [7] the area of creating a set of image data into eight categories:

- semantics;
- evaluation of the object pose;
- tracking camera positions;
- reconstructing of the scenes;
- tracking of the moving objects;
- human actions;
- identification of persons.

Recent research in the field of computer graphics and 3D TV has led to the creation of larger and more ambitious RGBD data sets, and the number of new databases of images every year shows no signs of. Semantic video tags were added, depth reconstruction was used to capture the entire surface of the object, and generating algorithms entire scene were used to create synthetic data plausible. Synthetic data have attracted relatively little attention to the problems associated with the transfer of the depth of the TV cameras. However, such artificial data may offer many advantages.

Table III. EXAMPLES OF ACTIONS

Examples of actions	Year
Get up, enter room, stand up, mop the floor	2011
Two people interacting	2012
Drink, eat, reading the book	2012
Typical gaming actions	2012
Arm gesture	2012
American Sign Language	2012
Older people performing actions	2013
Scratch head, cross arms	2013
Brushing teeth, drinking, talking on couch	2013
Jumping, bending, punching	2013
Mopping, sleeping, [U+FB01]nding objects	2014
Discussion, smoking	2014
Humans falling over	2014
Italian hand gestures	2014
Humans interacting with computer game	2014
Boxing, forward bend	2015
Sneezing, staggering, punching	2016

Early face datasets focused on the method of acquisition or tended to be quite small. The field has now expanded to include datasets for identity recognition, pose regression, and those where the expressions or emotions are to be inferred. As front-facing depth cameras become installed in laptops and tablets we expect this area of research to continue to gain further attention. Actions being performed include sign language, Italian hand gestures and common daily actions such as standing up, drinking and reading. Examples of actions [7] are given in tab. 3

Three datasets of humans falling over reflect an interest in use of RGBD sensors for monitoring vulnerable humans in their daily lives. The manipulation action is unique in providing semantic segmentation of objects as they are manipulated. Many of these datasets suffer from being filmed in the confines of an office or laboratory, with researchers performing the actions. Filming real people at work and home would help prevent dataset bias and provide a more believable baseline for activity and gesture recognition.

Tracking datasets feature videos of dynamic worlds, where the aim is to detect where an object is in each frame. Like datasets of actions, datasets designed for human recognition typically film people performing activities such as walking. However, the aim now is to recognize the identity, gender or other attributes about the subjects, rather than the activity they are performing.

Aside from a single sequence [6] it is know of no RGBD datasets captured from dynamic scenes with ground truth dense geometry. One option is to use deformable meshes provided for face datasets or fabrics, which can be synthetically re-rendered to give dense correspondences between frames re-render data. Datasets of humans with motion capture data also give a very sparse dense geometry with correspondences. The open challenge for the [U+FB01]eld of dense reconstruction is to directly capture an RGBD dataset of deforming objects with ground truth geometry and correspondences between frames.

In recent years, the number of range scanners and surface reconstruction algorithms has been growing rapidly. Many researchers, however, do not have access to scanning facilities or dense polygonal models. The purpose of this repository is to make some range data and detailed reconstructions available to the public. [9].

The models in this archive are fairly widely used in the graphics, visualization, and vision communities. Things people have done with these models include simplification, multi-resolution representation, curved surface fitting, compression, texture mapping, modeling, deformation, animation, physically-based simulation, texture synthesis, and rendering. The Stanford Bunny is particularly widely used, as surveyed by Greg Turk. This repository might use 3D models and range datasets, and remember that several of these artifacts have religious or cultural significance. Aside from the buddha, which is a religious symbol revered by hundreds of millions of people, the dragon is a symbol of Chinese culture, the Thai statue contains elements of religious significance to Hindus, and Lucy is a Christian angel; statues like her are commonly seen in Italian churches. Keep your renderings and other uses of these particular models in good taste.

To describe the complex volume of real objects meshes need to move in the direction of reducing the computing power, as in the classic form of each vertex of the object is subjected to a mathematical transformation, which increases on the order of the computational cost. To reduce the computational complexity of polygonal - grid model proposed shift in the spectral region by dividing the object in the field with further subband filtering by using wavelet transforms.

To increase the processing speed of a real object Daubechies 4, Wavelet Coiflets 2, Symlets 4, Discrete Meyer, Biorthogonal 2.4, Biorthogonal 4.4: - Wavelet conversion of these types were used. The test object for further processing are not subjected to additional distortions. To increase the rate of the algorithm is necessary to filter out non-significant factors (which are not actually affected, site restoration). We determine the threshold analytically to give a depth of wavelet – transformation.

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АССОЦИАТИВНЫЕ СВЯЗИ В ОЦЕНКЕ ТВ ИЗОБРАЖЕНИЙ

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С созданием и международной стандартизаций систем телевидения высокой и сверхвысокой четкости становится актуальной задача спецификации испытательных сигналов, которые будут использоваться при построении и техническом обслуживании видео трактов и оборудования таких системы. В области телевидения высокой и сверхвысокой четкости актуальным вопросом является оценка качества изображений с учетом свойств человеческого зрения. Исследователями были предложены десятки критериев, коррелированных со зрительной системой человека и позволяющих предсказывать качество изображений. В связи с тем, что проведение субъективной оценки представляется длительной и дорогостоящей процедурой, в последние годы разрабатываются базы данных цветных изображений, в которых собраны эталонные типичные изображения и искаженные изображения. В искаженных изображениях однозначна определена объективная метрика искажающего фактора и результат субъективного оценивания конкретно этого вида искажения. Примером такой базы является база телевизионных изображений TID2013, разработанная совместно украинскими и финскими учеными [6]. В этой базе собраны сведения о 24 типах искажений, в том числе и искажения, возникающие при сжатии цифровых изображений. Каждое из искажений представлено на четырех уровнях. Конечно, в одной базе данных невозможно предусмотреть все возможные искажения. Более того, особенностью телевизионной передачи является наличие совокупности нескольких искажений одновременно. Проявление совокупности искажений при субъективной оценке является темой исследований, так как ухудшения складываются с разным влиянием на конечную оценку. Следует учитывать также и маскирующее действие одних искажений на другие. С точки зрения возможностей поиска изображений по ассоциативным связям в таких базах пока не предусмотрены соответствующие дескрипторы или другие вербальные описания.

Другая ветка развития баз данных изображений связана с коллекцией объемных цветных изображений, в которых изображения представлены основными цветами красным, зеленым и синими, а также глубиной. В данной работе сделаны предложения об ассоциативных отношениях при оценке качества телевизионных изображений. Семантические отношения между объектами кадра и будет наиболее ценной информацией, которая требует передачи с наивысшим приоритетом. Можно предположить, что, указав описание объекта множествами смысловых отношений, с последующим поиском в базе данных соответствующих изображений объектов, позволит заменить их на приеме неискаженными. В статье предлагаются приоритетные параметры описания 2D и 3D-изображений для дальнейшего поиска изображений. Атрибуты изображения, описывающие местоположение, цвет, текстуру, категорию изображения и другие называют индексом или метаданными изображения. Индекс изображения хранится в информационной базе данных. Поиск данных на основе их содержания основано на ограниченном сравнении некоторых важных частей метаданных, хранящихся в ячейках памяти. Процедура поиска проводится путем сравнения по правилам нечеткой логики, что позволяет найти подобные, но не точно такие изображения, задаваясь преимущественно интервальными критериями соответствия. Эти предложения могут быть рассмотрены в качестве исходных для нового шага технической реализации метрологического обеспечения систем телевидения высокой и сверхвысокой четкости.

Methods for Searching Key Points in Images

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***Abstract*—The paper presents the interpretation of the concept - "key points", classification approaches to their definition. Described descriptors key points such as SIFT, SURF, BRIEF, ORB. Presents the comparative analysis of the data descriptors on such parameters as time and detection accuracy.**

***Keywords*—Computer vision, key point, descriptor, image, detection.**

I. Introduction

In recent time a lot of attention in the field of computer vision given to the task of visual tracking of objects. It consists in the consecutive determining the location target for each frame of the video stream. This task finds practical applications in many fields, anyway associated with video processing to obtain some information from them.

Examples of systems that use tracking technologies, are analysis of the system of sports matches that have appeared recently a system of augmented reality, security organizations, law enforcement agencies. It is also an object tracking system can be designed for use on quadrocopters, through which it will be possible to observe the object from a height.

Search and comparison of the key points in the images is an important task of computer vision. At first glance, the respective sets of points on the images give very little information about the images and the observed scene, but in fact it is not. If multiple images of the same scene, and a set of corresponding points in these images becomes possible to determine the camera position and settings for each image.

The relevance of this work is justified by the fact that, despite the huge progress in research, visual detection of objects remains a challenge.

II. The concept of key points

Of particular importance in the construction of feature image description is the selection (detection) specific to the parts of the image, as which it is possible to consider, for example, corners, edges, regions corresponding intensity extremums, etc.

The key point of the stage or point feature - it is the image point (pixel) with a characteristic neighborhood, that is, other than their neighborhood from all the neighboring points. Describes the feature vector is calculated based on the intensity / gradients, or other characteristics of the neighborhoods of the points. Using the key points may be analyzed as a whole picture and the objects to them. Good key points allow to cope with the change in scale, perspective and overlay a scene or object.

The key point of such properties as the repeatability (key point is in the same location of the scene or object image, in spite of the changes in viewpoint and illumination), focus (neighborhood points should be big differences from one another), locality (a key point should occupy a small area of the image to be to reduce the likelihood of sensitivity to the geometric and photometric distortion between two images taken at different points of the review), the number (the number of points should be large enough so that they have enough to detect even small objects), accuracy (in terms must be localized exactly as in the original image, and taken on a different scale), efficiency (time of detection points in the image should be admissible in a time-critical applications).

III. Classification of approaches to identify key points

Approaches to determining the key points can be divided into the following categories:

1) based on the intensity of the image: the key points are computed directly from the image pixel intensity values;
2) using the contours of the image: the methods extract contours and looking for a place with a maximum value of curvature or make a polygonal approximation of the contour and define the intersection. These methods are sensitive to the neighborhood of the intersection;
3) based on the use models: models are used with intensity as parameters that are adjusted to the images-patterns to sub-pixel accuracy, depending on the template.

In practice, for a broad application of the most common methods based on image intensity.

IV. Descriptors key points in the image

Descriptor key points is the numeric vector characterizing features of the image in the vicinity of this point.

There are a number of requirements to the descriptors [1]: they must be invariant (the description of the same point on the two different images should be identical), unique (descriptors two different features should be markedly different from each other), stable (for geometric transformations descriptor the same point does not vary greatly). In a real situation the descriptor do not have all of these properties simultaneously and have to choose the one descriptor that best fits the task.

The general scheme of the algorithm for calculating descriptors is shown in Figure 1

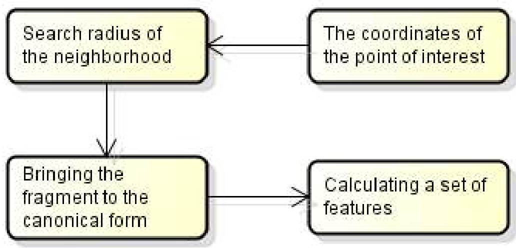

Figure 1. The algorithm for calculation descriptors

One of the most famous descriptors key points is a SIFT (Scale Invariant Feature Transform) [2], which is based on the idea of calculating the histogram of oriented gradients in the vicinity of the key points (figure 2). Neighborhood feature point divided into four square sectors. In every pixel inside each sector gradient image is calculated as well as its direction and module. Then the modulus of the gradient are multiplied by the weight decreases exponentially with distance from the point of interest. For each sector going histogram gradient direction, and each entry is weighted gradient module [3].

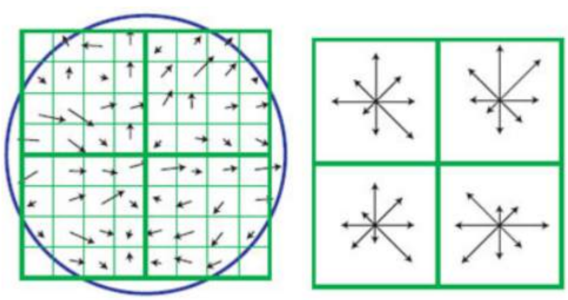

Figure 2. Building a SIFT descriptor

The closest competitor is the descriptor SIFT-SURF-descriptor (Speeded up Robust Features) [4]. SURF similar to its predecessor, but the procedure is to describe the key points of the neighborhood is somewhat different, because it does not use the histogram-weighted gradient, and the responses of the original image on Haar wavelets (figure 3).

The first step in getting descriptors around points of interest builds a square area that is oriented with respect to some preferred direction. Then, the square area is divided into sectors. In each of the sectors in the points belonging to a regular grid, calculated responses to the two types of wavelets - horizontal and vertical directions. The responses are weighted by a Gaussian, summed for each sector, and constitute the first part of the descriptor (figure 4).

The second part consists of sums feedback modules. This is done in order to take into account not only the fact that changes in brightness from one point to another, but also to

Figure 3. Haar wavelets

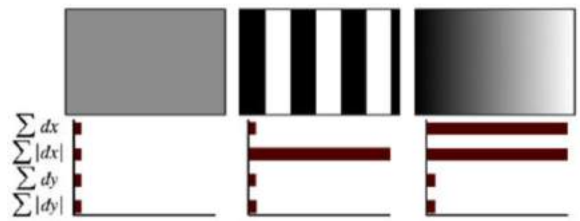

Figure 4. SURF-descriptor components point to the structure of the image. From left to right: a homogeneous region, strongly anisotropic texture, gradient texture

keep information about changes in direction. SURF-descriptor has a length of 64. As with SIFT, SURF-descriptor is invariant to changes in the brightness of the additive.

Among the key points of search engine algorithms there is a division on a math-based, but the relatively slow (Harris detector, the SIFT detector), and a heuristic, but rapid (SURF, FAST). The same division applies to the description of point features, but here as a separating sign stands compact and easy to handle computation. The smaller the descriptor length, the less memory is required to store it, less time and its comparison with others. This feature is very important when processing large numbers of images.

The most compact descriptor refers BRIEF (Binary Robust Independent Elementary Features) [5]. To calculate the descriptor at matching the brightness values of points located in its vicinity. This compares luminance values are not all the points with all but analyzed only a small subset of adjacent pairs of points, the coordinates of which are distributed randomly (but in the same way for each of the analyzed points).

Themselves BRIEF descriptors are not invariant to rotation. However, this invariance can be achieved if the pre-turn fragment around a point of interest on the angle corresponding to, for example, the dominant direction of the luminance gradient, as is done for SIFT and SURF descriptor.

The purpose of the descriptor BRIEF [6] was to provide recognition sites identical images, which were obtained from different viewing angles. The objective is to reduce the number of calculations performed. A more effective alternative is a binary descriptor BRIEF is descriptor ORB (Oriented FAST and Rotated BRIEF) [6] - an improved version of the detector and the combination of points and FAST BRIEF binary descriptors.

SIFT algorithm shows excellent results in problems of detection, identification and localization of objects in the image, but as is evident from the present disclosure requires significant computation on volumes. In this connection, efforts continue to create simpler algorithms points detection and calculation of descriptors, thus providing sufficient invariance of the distortion. One of them is considered in this paper, the above-mentioned ORB.

In the first step for the detection of large-scale construction of the singular points of the Gaussian image pyramid. Then extremes of brightness functions are defined at each scale level. To solve this problem, use the FAST algorithm, according to which each point of the image is formed by a circle of radius, and count the number of points lying on the circle and having a brightness value less than or greater than the luminance of its center.

The structure of the ORB algorithm shows that it is less demanding of computing resources in comparison with the algorithm described earlier SIFT. The gain in speed of calculation is determined, above all, a simpler procedure for constructing descriptors and the mechanism of calculating the norm.

V. Comparison key points

There is an approach associated with the search for the image of the marker on a picture on his key points. This process can be divided into four stages:

1) highlight key points using the detector;
2) description points found using a descriptor;
3) getting a set of relations (correspondence) between the key points using matcher;
4) analysis of the connections to determine whether location marker in the image.

The implementation of the first three points is not difficult because of the presence of a broad class of computer vision library. Among them stands out OpenCV library (which we will use in the future), is written in C ++ and has the most extensive feature set. First of all, it contains a module Feature Points Detection and Description, contains the implementation of the various detectors and descriptors matchers. In view of this, the first three points of the search marker in the image are resolved simply and without any serious difficulties.

The main difficulty is in the fourth step, as there is some special features, which could confidently say - is the desired object in the image or not.

Famous matching algorithm between the key points of the two images often show a high percentage of false links (figure 5). This leads to the fact that they can not correctly match the tested image even though they are actually the same, only removed from several different angles.

Sets the corresponding points in the images give very little information about the images and the observed scene. For example, if we have multiple images of the same scene and sets the corresponding points in these images we can determine the configuration and position of the camera for each image. This requires to match each image key point.

An important property of any features matching algorithm is a set of image distortion key point with which it is able to cope. Typically, the following types of distortion:

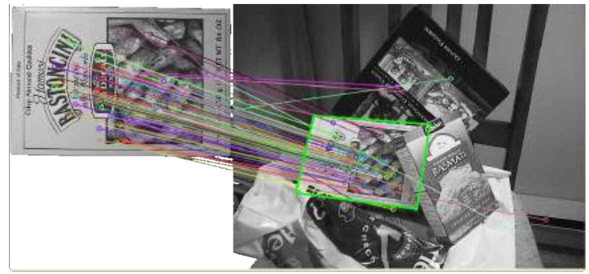

Figure 5. Comparison of key points on the two images

1) changes in the light key point;
2) zooming;
3) rotation of the key point;
4) projective image distortion characteristics associated with such rotation and movement of the camera in space.

VI. Description of research methodology

OpenCV library has a fairly wide range of detectors, descriptors and matchers. At the same time there are possibilities of different combinations with each other. They all differ in speed, the number of allocated points, as well as resistance to image transformations: rotations, shifts angles, changes of scale.

As a criteria comparison were selected: settling time key points in the image (in milliseconds), accuracy (percentage) defined as a percentage of the right set points to their total amount.

The research was conducted in a Microsoft Visual Studio 2012 Ultimate with the help of OpenCV 3.0 library.

To determine the accuracy of the establishment of the key points of the two images were selected with a slightly shifted scene.

To start searches for the key points and the calculation of descriptors (SIFT / SURF / BRISK / ORB) on both images, producing a description of found points, evaluating their position through the description of the neighborhoods.

Then the comparison of them, in other words, the construction of correspondences between two sets of image points.

To improve accuracy, the screening was carried out points that were obviously wrong compared. This is done as follows: were calculated minimum and maximum distance between the points, after comparing them. Then select only those points, the distance between them was less than half the sum of the maximum and minimum distance between them.

The result of the image will be built with matching lines between key points of two images.

VII. The research results

A result of research has been established settling time key points in the image and accuracy:

1) Descriptor SIFT load of 417 ms with an accuracy of 50 per cent (figure 6);

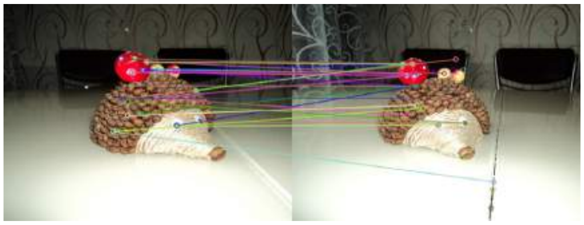

Figure 6. The result of the SIFT descriptor

2) Descriptor SURF load of 226 ms with an accuracy of 55 per cent (figure 7);

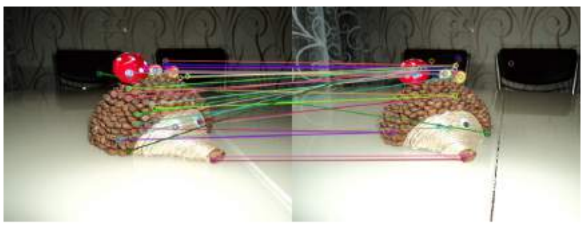

Figure 7. The result of the SURF descriptor

3) Descriptor BRISK load of 126 ms with an accuracy of 31 per cent (figure 8);

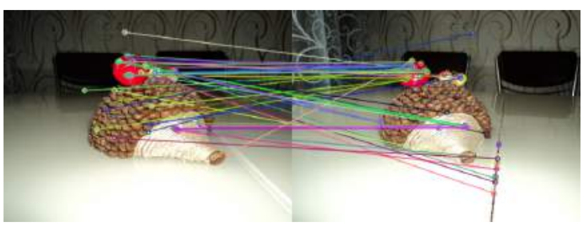

Figure 8. The result of the BRISK descriptor

4) Descriptor ORB load of 154 ms with an accuracy of 61 percent (figure 9).

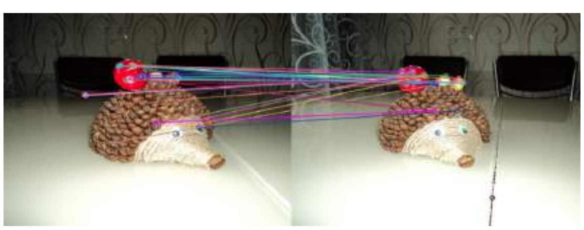

Figure 9. The result of the ORB descriptor

To establish the object in the image is best suited ORB descriptor, which showed low enough settling time points in the image (154 milliseconds) and high accuracy of establishing (61 percent) as compared with other descriptors. The lowest accuracy identify key points has a descriptor BRISK (31 percent). At the time of establishing the key points of the least expensive proved descriptor BRISK (126 milliseconds), and the longest - SIFT a result of 417 milliseconds.

VIII. Conclusion

Based on the analysis of literature related to the recognition scene in the video stream, it can be concluded that to effectively search for the object in the sequence of frames on a sample can be applied algorithms based on the calculation descriptors key points of the image.

The results of the work has been have explained to identify the key points on the image, a classification of approaches to their definition, are investigated descriptors key points as SIFT, SURF, BRIEF, ORB; identified and analyzed the statistics of their work.

Local features are a popular tool for image description nowadays. They are the standard representation for wide baseline matching and object recognition, both for specific objects as well as for category-level schemes. In this survey, we gave an overview of some of the most widely used detectors, with a qualitative evaluation of their respective strengths and weaknesses, which can be found at the end of the sections and chapters. Discussion and Conclusion that can inspire future research on local features and avoid a waste of resources by reinventing the wheel. The literature is huge, and we could only touch the different contributions without going into details. Yet, we hope to provide the right pointers so those who are interested have a starting point and can delve deeper if they want to.

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МЕТОДЫ ПОИСКА КЛЮЧЕВЫХ ТОЧЕК НА ИЗОБРАЖЕНИЯХ

Михайлов А.В., Коваленко П.О., Катаев А.В., Розалиев В.Л.

В работе рассматривается понятие «ключевые точки» и их применение для анализа видеоизображений. Приведена классификация подходов к их определению. Описаны дескрипторы ключевых точек, такие как SIFT, SURF, BRIEF, ORB. Описана методика проводимых исследований. Представлен сравнительный анализ работы данных дескрипторов по таким параметрам как время работы и точность детектирования.

Ontology-Based Risk Analysis System Concept

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***Abstract*—The work is dedicated to the development of an ontology concept for assessment risk of threats for information systems on the Microsoft approach – the model of identifying threats STRIDE and methodology DREAD for assessment risk of threats. The aim of the study is to describe the security implementation methodology of information systems offered by Microsoft. The basic concepts and techniques of this model are given and ontology concept of risk assessment is proposed, some of the classes and subclasses of the developed ontology are described.**

Keywords—information system, risk analysis, ontology, thread, DREAD, Protégé, STRIDE.

I. Introduction

The relevance of information security is not in doubt today is characterized by continuous and increasing threats to information systems (IS) and networks. The data, processed in IS, are important to users, as a weak and unreliable system can cause dramatic consequences: the loss of intellectual property, simple system, performance degradation, detriment to business reputation, loss of customer trust, financial risks. The contingent problems originated during the implementation of security systems, is presented in Fig. 1 [1].

Figure 1. Problems of implementation of protection IS

To manage the information security of IS the risk analysis is needed. Risk is a comprehensive evaluation of the effectiveness of confrontation threats [2], [3]. Mainly two approaches to defining security risks are described in literature [7], [11].

The degree of risk is evaluated on the basis of specific requirements for information security:

- variously regulations;
- recommendation of software producers;
- international standards.

The second approach involves determining the probability of potential threats and the extent of the damage. The degree of risk is calculated separately for each threat using various techniques. Expert evaluation of the probability of threats and the empirical value of possible damage is taken into account.

This article discusses Microsoft's approach of risk management for IS and the possibility of applying the method of ontology to describe threats to IS.

II. Method of risk management based on Microsoft

Announced in 2002 Microsoft initiative called "Trustworthy Computing" was not just another marketing campaign, but a significant step for the protection of the software at various levels. The essence of the initiative lies in the fact that developing IS, it is necessary to pay special attention to the security from the earliest stages.

"Trustworthy Computing" is a serious initiative within Microsoft to improve the security and reliability of computers. Security means a system is resilient to attack, and the confidentiality, integrity, and availability of both the system and its data are protected [16].

The first and most important criterion for the introduction of reliable protection is the confidence in the fact that protection of IS should be part of the development of the IS project. Microsoft has offered the security strategy SD3+C (Secure by Design, by Default, in Deployment, by Communication).

Structure SD3+C contains 4 principal components [1] (see. Tab. I). Stages of simulation IS threats are shown in Fig. 2 [1]. In the process of designing IS the threat modeling has great importance:

- an important part of IS design;
- reduces the costs on the developing IS security;
- helps the developers identify threats to the system.

It is necessary to generalize information about potential threats and identify the them. STRIDE model (Spoofing, Tampering, Repudiation, Information disclosure, Denial of service, Elevation of privilege) defines the types of potential threats (see. Tab. II) [17].

To evaluate the risk of threats to IS Microsoft offers methodology DREAD (Damage potential, Reproducibility, Exploitability, Affected users, Discoverability) [18]:

Table I. SD3+C SECURITY FRAMEWORK

Component	Characteristics
Secure by Design	Secure architecture and code
	Threat analysis
	Reduce vulnerabilities
Secure by Default	Reduce attack surface area
	Unused features off by default
Secure in Deployment	Protect, detect, defend, recover, manage
	Process: How to architecture guides
	People: Training
Secure by Communication	Clear security commitment
	Full member of the security community
	Microsoft Security Response Center

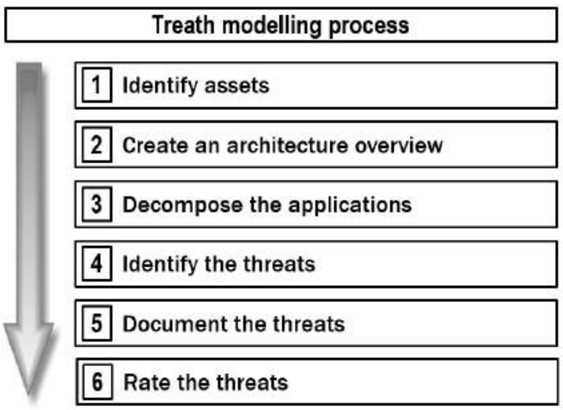

Figure 2. Treath modelling process

Table II. IDENTIFY SECURITY RISKS AND THREADS - STRIDE

Types of threats	Characteristics
Spoofing	Forge e-mail messages
	Replay authentication packets
Tampering	Alter data during transmission
	Change data in files
Repudiation	Delete a critical file and deny it
	Purchase a product and later deny it
Information disclosure	Expose information in error messages
	Expose code on Web sites
Denial of service	Flood a network with SYN packets
	Flood a network with forged ICMP packets
Elevation of privilegies	Exploit buffer overruns to gain system
	Obtain administrator privileges

- Damage potential (How much are the assets affected?)
- Reproducibility (How easily the attack can be reproduced?)
- Exploitability (How easily the attack can be launched?)
- Affected users (What's the number of affected users?)
- Discoverability (How easily the vulnerability can be found?)

For each of the identified vulnerabilities, for listed factors, the assessment from 0 to 10 is given and the total risk is calculated based on the formula (1):

$$Risk{-}DREAD = \frac{DMG + R + E + AU + D}{5} \qquad (1)$$

Where: DMG - Damage, R - Reproducibility, E - Exploitability, AU - Affected users and D - Discoverability.

The question is, what vulnerabilities must be considered primarily, i.e., to determine priorities. For a more detailed assessment the scale CVSS is used (Common Vulnerability Score System) [19].

Currently, IT management has to identify and evaluate vulnerabilities in various software and hardware platforms. They need some way to rank them according to the risk and choose those which must be closed first. However, there are a lot of vulnerabilities and the counting is carried out by their own rules on all platforms. CVSS - is an open platform that helps to solve this problem:

- Standardized range of vulnerabilities. When an organization introduces a common scale of vulnerabilities for all software and hardware platforms, it can develop a common management policy by closing vulnerabilities. This policy may be similar to an agreement on the level of service that sets how quickly a particular vulnerability must be identified and eliminated.
- Open platform. Using CVSS everyone can see the individual characteristics used in the obtaining of total value.
- Ranging from risk. When infrastructure component is designed, the vulnerability gets the particular case. Thus, the calculated vulnerability index is the actual risk for a particular company. This gives users a basis for comparison of vulnerabilities.

CVSS standard was developed by a group of security experts of National Infrastructure Advisory Council. This group included experts from various organizations such as CERT / CC, Cisco, DHS / MITRE, eBay, IBM Internet Security Systems, Microsoft, Symantec.

CVSS provides tools to calculate a numerical indicator on a ten-point scale that allows security professionals operatively make a decision about how to respond to a particular vulnerability. The higher the value of the metric, the more rapid response is required.

The standard includes three groups of metrics:

- Basic metrics describe the characteristics of vulnerabilities that do not change over time and do not depend on the runtime environment. These metrics describe the complexity of exploitation of vulnerability and potential damage to the confidentiality, integrity and availability of information.
- Temporary metrics, as the name implies, introduce in the overall assessment the amendment on the completeness of available information about vulnerabilities, the maturity of the exploiting code (if any) and the availability of correction.
- Using the contextual metrics, security experts can make amendments to the resulting score, taking into account the characteristics of the information environment.

Risk assessment is in fact the main objective in the IS management process: analyzing the information security risks and to take decisions to minimize the risk level. To minimize risks, the following steps are possible [16]:

- do nothing;
- warn the user;
- remove the problem;
- fix problem.

III. Possibilities of using ontologies

In recent years the development of ontologies is formal description of the terms in the domain and the relationships between them that moves from the world of artificial intelligence laboratories to desktops of domain experts [4]. In the World Wide Web ontologies have become common things. Ontologies on the net range from large taxonomies, categorizing Web sites, to categorizations of products sold and their characteristics. In many disciplines nowadays standardized ontologies are being developed that can be used by domain experts to share and annotate information in their fields.

The philosophical term "ontology" is known for a long time, but at the end of the last century, this concept was rethought with regard to knowledge engineering. The classic definition of an ontology in modern information technologies: "An ontology - a formal specification of a conceptualization that takes place in a context of the subject area" [13].

Informally, an ontology is a description of the view of the world in relation to a particular area of interest. This description consists of the terms and rules for the use of these terms, limiting their roles within a specific area. Formally, ontology is a system consisting of a set of concepts and a set of statements about the concepts on the base of which you can build up classes, objects, relations, functions, and theories.

Formally, an ontology is defined as $O =< X, R, F >$, where:

- X - a finite set of concepts of subject area;
- R - a finite set of relationships between concepts;
- F - a finite set of functions of the interpretation given on the concepts and / or relationships.

On a formal level, an ontology is a system consisting of a set of concepts and a set of statements about these concepts, on the base of which we can build classes, objects, relations, functions and theory. The main components of the ontology are classes or concepts, relations, functions, axioms, examples.

It is accepted that an ontology is a system of concepts of a subject area, which is represented as a set of concepts linked by different relations to determine the field of knowledge. The formal structure of the ontology is an advantage for the quality of the method of knowledge representation.

There are many ways to classify types of ontologies. One of the popular ways in the ontology classifies the ontologies according to the level of dependence on the specific task or the viewpoint of the problem [8]:

- Top-level ontologies - describe the most general concepts that do not depend on the subject areas;
- Domain-ontologies - formal description of the subject area, used to clarify the concepts defined in the meta-ontology and defines a common terminology base of subject area;
- Task ontologies - an ontology that defines a common terminology base, related to a specific task;
- Application ontologies - are often used to describe the outcome of actions performed by the objects of subject area or the problem.

The simplest model of ontology with relations is usually based on a class-subclass relationships. Such models are often called taxonomies - hierarchies of concepts towards investments.

Thus, the aim of building an ontology is a representation of knowledge in a particular subject area. A conditional concept of structure based on the use of ontologies can be represented for systems of risk analysis [5], [6], [9], [10], [12], [14], [15] (see. Fig. 3).

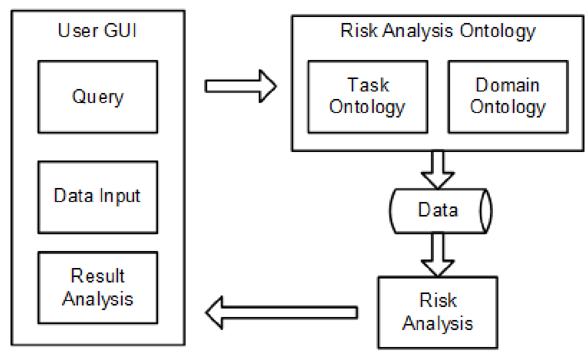

Figure 3. Conditional structure of risk analysis system based on ontologies

IV. The ontology concept of risk assessment

To create the ontology we use the Protégé program [20]. Protégé is a special tool for creating and editing the ontology. Protégé is an ontology and knowledge base editor. Protégé is a tool that enables the construction of domain ontologies, customized data entry forms to enter data. Protégé allows the definition of classes, class hierarchies, variables and the relationships between classes and the properties of these relationships.

Protégé is an initial, free - open source of the platform, which includes a special set of tools and allows to build knowledge-based models of a subject area and applications. Protégé is an extensible knowledge model. Development of ontologies using Protégé begins with identifying and describing of class hierarchy, and then copies of these classes and different types of relationships (properties).

The OWL Web Ontology Language is designed for use by applications that need to process the content of information instead of just presenting information to humans. OWL facilitates greater machine interpretability of Web content than that supported by XML, RDF. OWL ontology may include descriptions of classes, their characteristics and relationships.

The ontology concept for assessment risk of threats for information systems based on the concepts of STRIDE and DREAD methodology is proposed (see. Fig. 4).

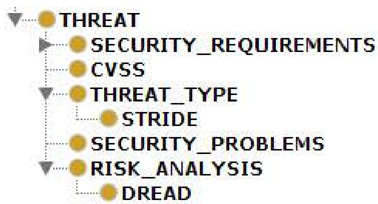

Figure 4. Hierarchy of classes in risk assessment

The upper level of ontology is the class Threat. This is an abstract class, which includes all the main classes of the subject area and risk analysis tasks (see Fig. 5). Class Security requirements is a list of security requirements to IS. It is understood that this class will contain the attributes of the confidentiality, integrity and availability, as well as the priorities of these attributes.

Status of class Security problems has not been determined.

Class Threat type is a list of subclasses of identify threats model STRIDE from Table II. STRIDE example is shown in Fig. 6 and their number can be complemented.

Class Risk analysis represents a list of subclasses of DREAD method. DREAD example is shown in Fig. 7.

Class Scale CVSS is used for the problem to calculate the risk with the method DREAD using the accumulated knowledge of the STRIDE.

It should be noted that this concept is under development and will be complemented.

V. Conclusions

Creating ontologies is a perspective direction of modern research on the processing of information, including risk analysis topics in a variety of applications. This article discussed the Microsoft approach to the identification of IS threats and a method of risk assessment. The ontology concept was proposed to assess the risks of IS threats, some of the classes and subclasses of the developed ontology were described. Thus, ontology becomes the storage and knowledge management system.

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КОНЦЕПЦИЯ ИСПОЛЬЗОВАНИЯ ОНТОЛОГИЙ В СИСТЕМАХ АНАЛИЗА РИСКОВ

Грабуст П.С., Ужга-Ребров О.И.

Работа посвящена разработке концепции онтологии для оценки рисков угроз информационным системам по подходу Microsoft - модели идентификации угроз STRIDE и методики DREAD для оценки рисков угроз. Даны основные понятия и методики этой модели и предложена концепция онтологии по оценке рисков, описаны некоторые классы и подклассы разрабатываемой онтологии.

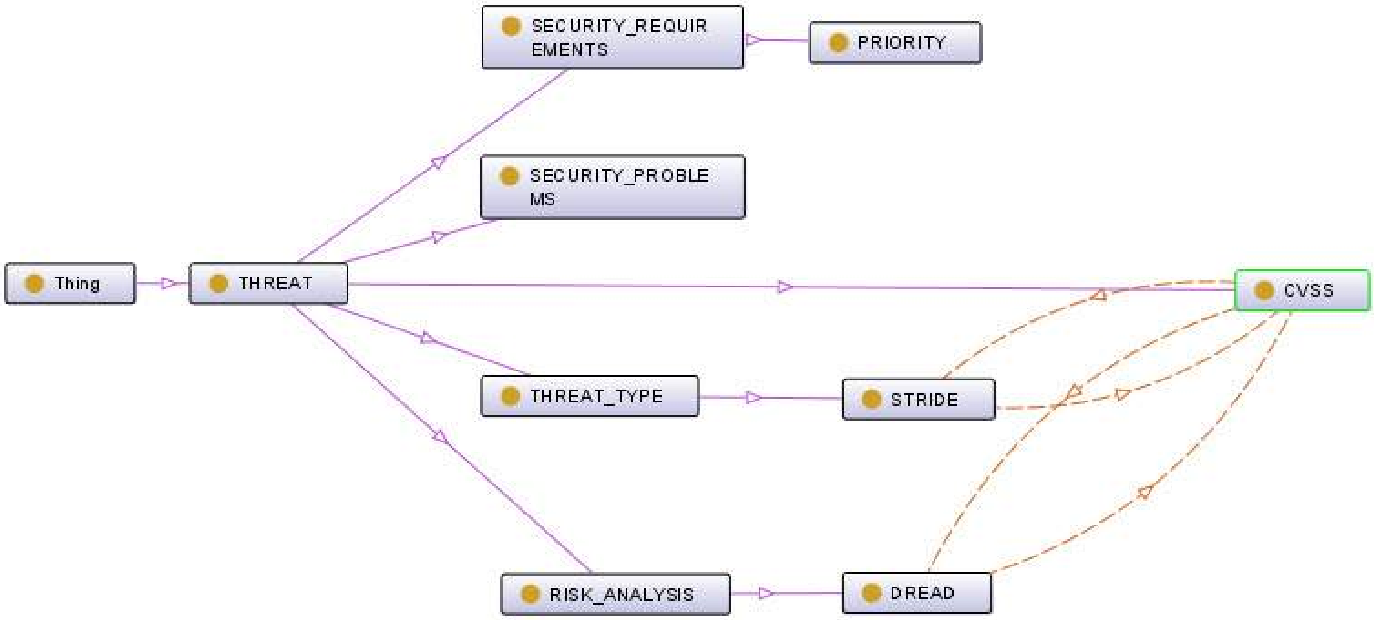

Figure 5. Ontology of IS risk assessment system

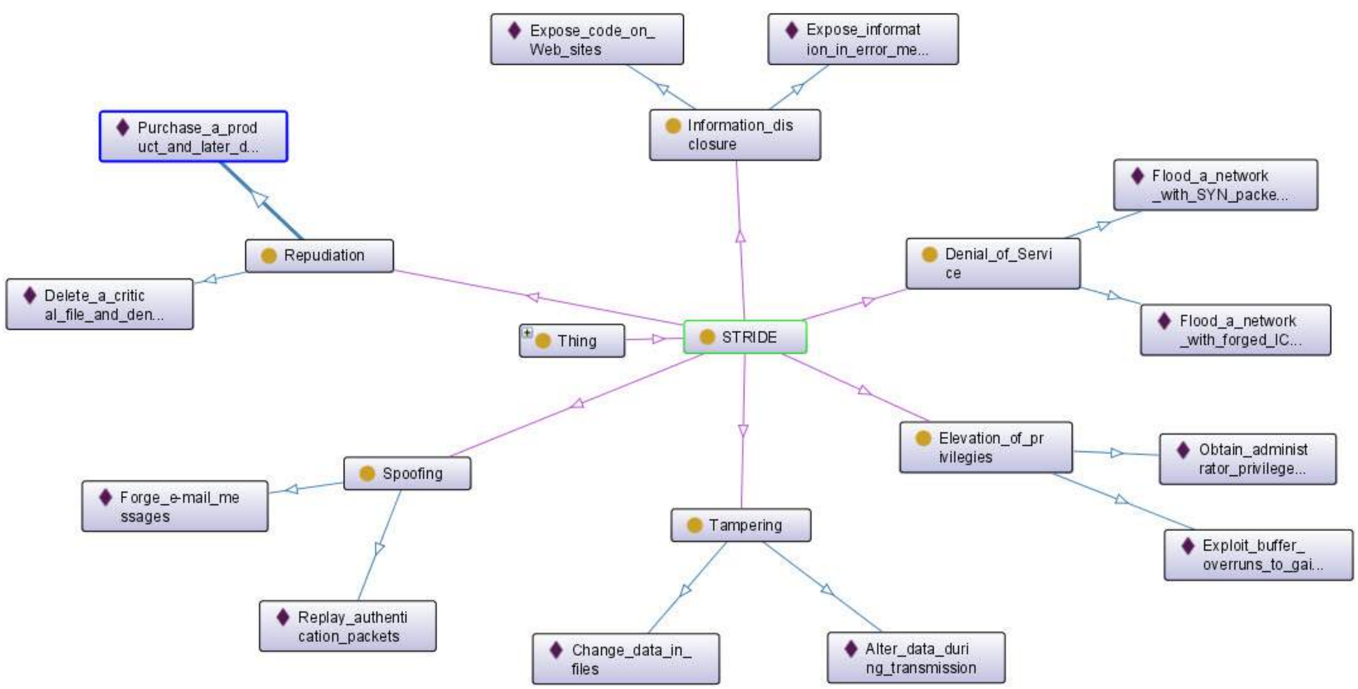

Figure 6. An ontology fragment of threat identification model STRIDE

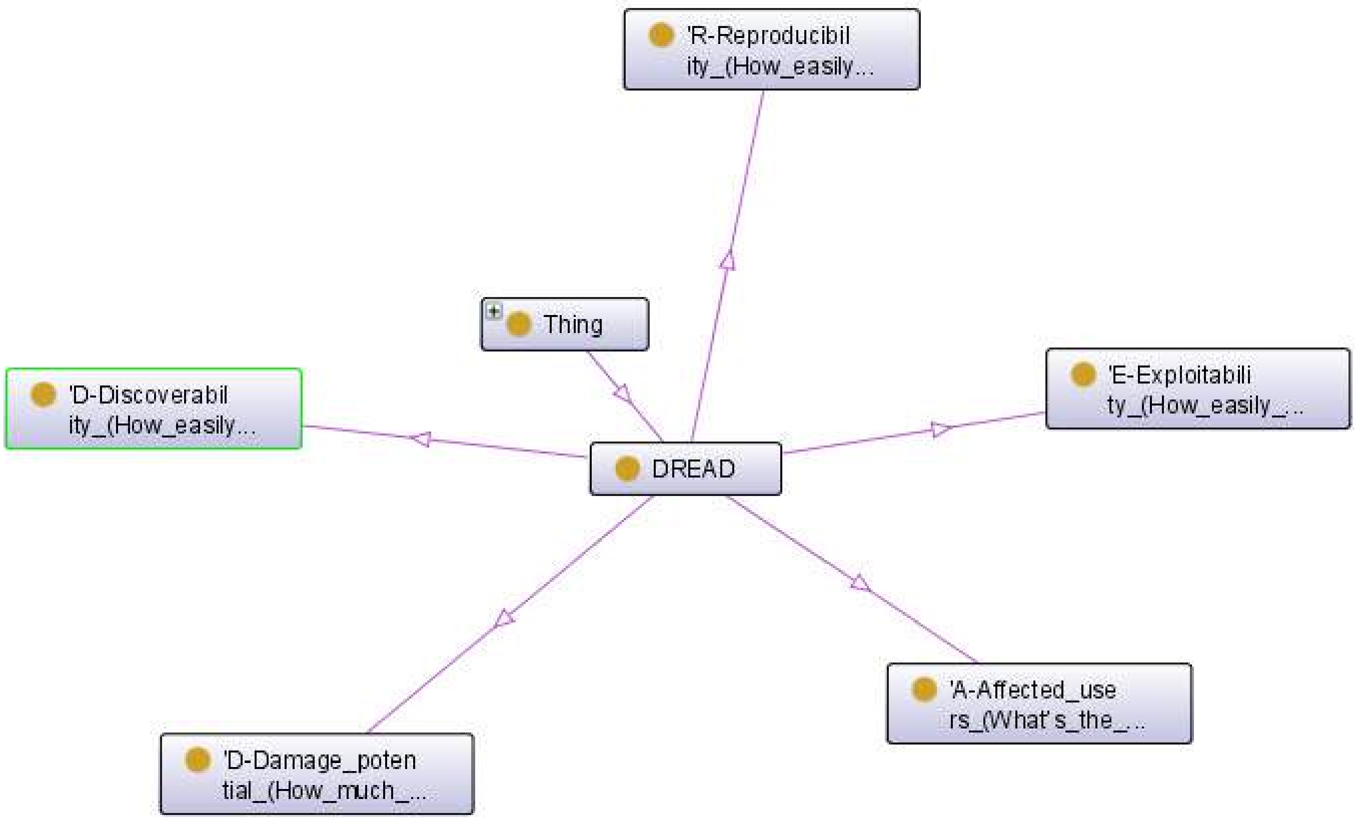

Figure 7. An ontology fragment of risk assessment method DREAD

Decision-Making Support for Strategic Planning

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***Abstract*—New methods of decision-making support based on the most complete usage of knowledge (both formal and expert) in a certain subject domain are proposed for long-term planning. An innovative approach to construction of a strategic plan is proposed. It is based on hierarchical decomposition of the problem by remotely working group of experts under the supervision of a knowledge engineer, provides an opportunity to use estimation scales with different number of grades, and allows increasing the reliability of the results of group examinations. The proposed approach features such methods as target dynamic evaluation of alternatives, as well as an original method of optimal allocation of resources. Application of the approach is illustrated by an example, related to planning of information operation counteraction.**

Keywords—Decision-Making Support, Weakly-Structured Domain, Strategic Planning, Resource Allocation, Expert Estimating.

I. INTRODUCTION

It is known that in a general sense a strategy is a non-detailed action plan, designed for a long-term period and aimed at achievement of a certain main goal. At the same time, the plan should be flexible, constructive, resistant to uncertainties of environmental conditions; is should also provide an opportunity for concretization through decomposition of the main goal.

In weakly structured subject domains, which include management, environmental protection, production, social sphere and others, the problem of building long-term non-detailed plans of action extremely relevant. There is no doubt that creation of such strategic plans should be based on all available knowledge in a given subject domain. Since knowledge in any such area is not completely formalized and, therefore, mostly, “stored” within in the minds of professionals, it would be unreasonable not to use the information obtained from experts in the planning process. Moreover, one cannot take into account only quantitative (e.g., financial) indicators. In order for long-term plans to be realistic, they need to adapt to imminent changes in the current situation and take into account the availability of resources, required for their implementation at any particular moment. Therefore, strategic plans can be rational only at a certain time interval.

The purpose of this research is to create a technology that would include formal mechanisms of building strategic plans in weakly structured subject domains, involving groups of experts and knowledge engineers.

With the above-mentioned requirements to strategies in mind (namely the need for realistic and dynamic plans), we suggest using decision-making support (DM) tools, capable of performing distribution of limited resources among specific activities, for strategic plan construction. Resources are allocated at a given moment in time, depending on potential contribution of certain activities to achievement of strategic goal. In essence, the approach should provide an answer to the question: "Which activities should be implemented under current conditions for the most effective achievement of the strategic goal?".

II. STRATEGY-BUILDING TECHNOLOGY

Considering the above, the developed strategy-building technology involves several stages:

A. Stage: "Building of a Knowledge Base"

This stage is implemented using a web-based software system that allows the decision-maker, knowledge engineers and experts to work remotely to create a Knowledge Base (KB), without the need to come together.

This stage includes a number of sub-stages:

1) Selection of expert group for the examination. The problem of expert selection is, generally, the responsibility of decision-makers and knowledge engineers. Moreover, under the examination intended for resolving of different issues different groups of experts (most competent specialists in each specific area) are formed.
2) Construction (through dialogue with the experts) of goal hierarchy, which describes the subject domain. At this sub-stage the decision-maker formulates strategic goal, which is subject to decomposition into local goals (factors) that significantly influence its achievement (through examinations conducted by knowledge engineers). In the process of decomposition, the experts (working remotely in a web-centric system "Consensus" [1]) coordinate their judgments on the composition of the set of influence factors for a particular goal, and gradually reach agreement on every issue. For decomposition of each local goal knowledge engineers, working as examination organizers, form a separate group of experts. The software system allows different expert groups to work simultaneously, while every expert can be included into different groups. The advantage of the remote approach is that experts in the group can collaborate and provide their knowledge (while they might be incompatible at the direct personal contact,

remote work ensures anonymity of the experts and this, in turn, eliminates the influence of any "dictator's" judgment). The range of specialists involved to the expertise can be significantly expanded with the ability for each user to choose (in the system) the most suitable language for communication, i.e., the examination may involve specialists, who have not even been able to work and communicate with each other without an interpreter.

The examination organizers determine the sufficient level of detail, and, therefore, the moment of termination of the strategic goal decomposition process in the case when the lower level of the hierarchy features only the goals (factors), which are "ready" for implementation, i.e. specific activities (projects).

The result of this stage of strategy construction process is a hierarchical structure, which, in accordance to the aggregate opinion of this expert group, fully describes the subject domain.

General view of a goal hierarchy in the decision support system (DSS) "Solon" [2] is shown on Fig. 1. The DSS demo version is available at the website of DSS lab ($http://dss-lab.org.ua/$).

3) Expert estimation of relative influences of goals in the hierarchy. The relative influence of each goal in the goal hierarchy graph is determined by the knowledge engineer (in the case of availability of reliable knowledge about the level of influence of some sub-goal upon a specific goal), or (otherwise) by the expert group by means of paired comparisons of the goal (factor) influences.

To improve the reliability of the examination results, a special software tool is developed, that provides an expert with the ability to perform each individual pair-wise comparison in the verbal scale, which most adequately reflects the knowledge of the expert about the issue under consideration and the level of his / her confidence in this own knowledge [3], [4]. This software tool allows to gradually increase the level of detail of the scale, and then to perform a final estimation in the most appropriate scale (Fig. 2).

The results of this sub-stage are: the relative values of mutual influences of goals, resulting from aggregation of individual expert estimates, performed in different detail scales, and presented in the form of incomplete group pair-wise comparisons matrices (PCM) of influences. For aggregation we propose using the combinatorial method [5], which is more efficient in comparison to other methods (efficiency advantage is confirmed by the relevant experimental study [6]).

This aggregation method has several advantages over existing approaches to processing of PCMs:

- In the combinatorial method the informational redundancy is used as fully as possible.
- The method allows for determining of alternative weights in cases when some elements of the PCM are missing (not specified). That is, the presence of all paired comparisons in the matrices is not a mandatory requirement for determining the weights of alternatives. The only necessary condition is the connectivity of the graph corresponding to the generalized PCM.
- The method has only one stage (in contrast to well-known approaches, used for calculation of weights in the group methods of estimation [7]). Aggregation of paired comparisons in such group DM methods is a two-stage procedure: either (1) initially the individual PCMs element-wise are aggregated, and then – on the basis of the generalized matrix the weight vector of alternatives is calculated , or (2) at first for each PCM the weight vector is calculated, and then all the vectors are aggregated. In case (1) consistency of all corresponding elements from the individual PCMs does not guarantee the consistency of the resulting PCM. In case (2) consistency of each individual PCM does not guarantee the consistency of the weight vectors calculated for each PCM. The two-stage procedure makes it impossible to organize feedback with experts for improvement of consistency, if its level is insufficient for aggregation and for the weight calculation. When using of combinatorial method, there is no need for gradual achievement of the desired level of consistency and, therefore, a conflict between the two successive processes of consistency and mutual compatibility improvement is not occurring. If you want to increase consistency of paired comparisons, certain elements of individual PCM are adjusted (under consent of the experts who built the respective PCM).

We should note that aggregation is acceptable only under sufficient consistency of expert judgments. To evaluate consistency level of paired comparisons we suggest using the Double-entropy consistency index [8], which determines consistency degree based on the spectrum of the expert estimates of weights for each of the influences. In comparison to other known indices, it reflects (more accurately and correctly) the properties of the consistent set of expert estimates. In the case of insufficient consistency, the method provides an opportunity to improve its level by feedback with experts.

At this point the KB construction is finished. The next stage of building of optimal strategy, based on the knowledge, incorporated in the KB, starts.

B. Stage: "Determination of the optimal strategy"

Obviously, the greater the weight of a specific project or activity, the more considerably it influences the achievement of strategic goal. Therefore, allocation of resources to the project will bring more tangible and measurable results. At the same time, there is no sense to allocate lesser resources to the project, than it requires for launching and implementation. Consequently, we define optimal strategy as the optimal variant of resource distribution between projects (i.e. the one that provides the most effective achievement of the strategic goal).

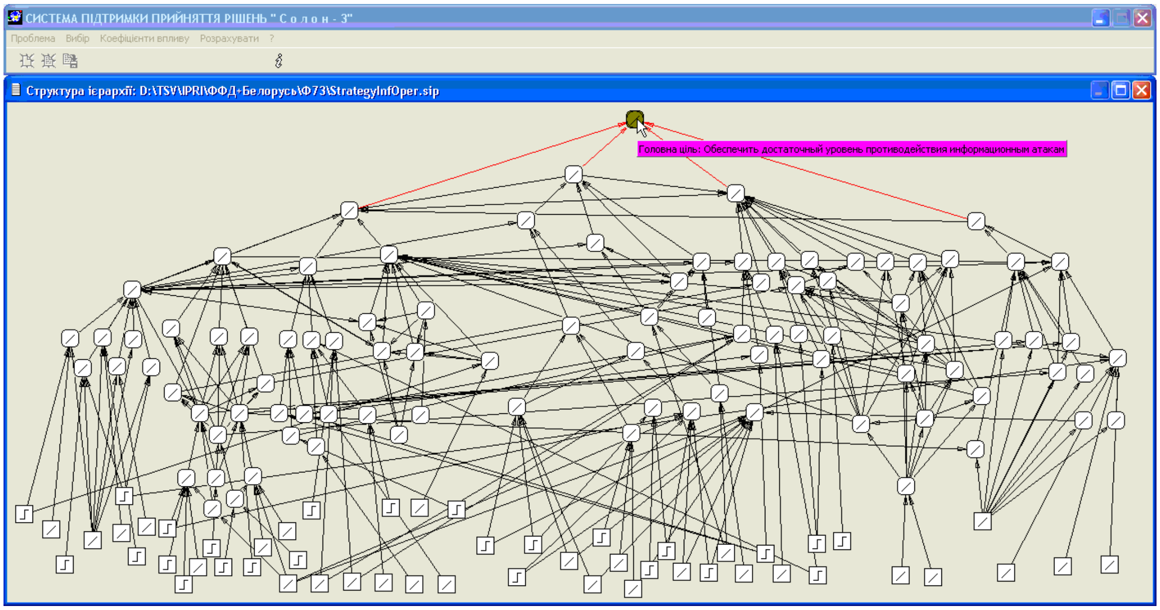

Figure 1. The DSS "Solon" interface and the view of the goal hierarchy

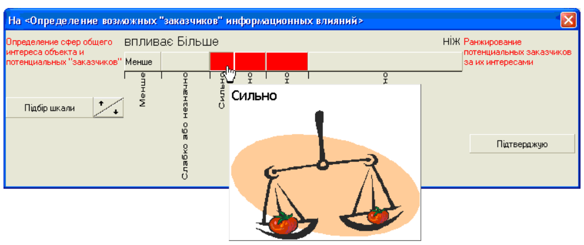

Figure 2. Expert choice of a detail level of the paired comparison scale

The task of choosing the optimal allocation of resources to projects is the subject of a separate study. It should be noted that (since the projects can be characterized by different terms of realization and, in addition, goals can have different delays of influence upon the main goal) optimal resource allocation is relevant only for a given point in time. Through the use of the method of targeted dynamic of estimation of alternatives [9], [10] within a given strategic plan, it is possible to evaluate and compare quite diverse projects / activities: those that provide the immediate effect and those, whose effect may be witnessed in the distant strategic perspective. Another important parameter that characterizes the projects is the range of necessary resource volumes. For example, if the minimum required amount of funding for the project is 1 million UAH, and requested – 2 millions UAH, it makes no sense to allocate amount, which does not belong to this range, to the project.

Given these features, the most efficient way to solve the problem of resource allocation to projects during a given time period can be considered as targeted search of an optimal allocation among all possible resource allocations with a given accuracy (say, up to 10 thousands UAH), for example, using genetic algorithm [11].

Depending on the complexity of the subject domain and the formulated goal to be achieved, strategic plan construction process can be easier or more difficult. However, the proposed mathematical apparatus and the developed DM software tools allow to create rather extensive, meaningful, and most importantly, realistic long-term plans (based on all available knowledge about the domain). In subsequent sections of this paper some of the stages of technology implementation are illustrated by an example: formation of a confrontation strategy in the information war.

The term "information operations" (IO) in the modern-world environment gained considerable popularity in the beginning of this century, when the information has become an important strategic resource, lack of which leads to significant losses in all spheres of life. It is probable that the term became popular after the declassification of a number of the US Department of Defense documents, where IO is defined as "actions aimed at influencing the enemy’s information and information systems, protection of one’s own information and information systems." Then, in the "road map of information operations" [12] the term was clarified: "The integrated implementation of the core capabilities of Electronic Warfare, Computer Network Operations, Psychological Operations, Military Masking and Security Operations, within the concept of supporting and associated capacities, in order to influence, disrupt, corrupt or usurp adversarial human and automated decision-making, while protecting one’s own facilities". The meaning of the term IO covers and explains informational influence on public consciousness (both adversarial and friendly), the impact on the information available to the enemy and necessary for him to make decisions, as well as on information and analytical system of the enemy [13]. In the modern conditions IO, being an inseparable part of the information war, is viewed as a new kind of combat action, active counteraction in the information space, and the information in this case is viewed as a potential weapon and as a target for attack.

The two main types of IO (according to general convention) are offensive and defensive operations. However, in practice most IO are mixed, and the majority of their constituent procedures are simultaneously offensive and defensive. A distinguishing feature of an offensive IO (information attacks) is that the objects of influence of such operations are identified and the planning is based on fairly accurate information about these objects. The information attack often calls for detection or creation of an informational occasion (for defensive IOs the occasion may be the information attack of the enemy itself), the “promotion” of the occasion i.e. propaganda (in contrast to the counter-propaganda activities during a defensive IO), as well as for measures to counteract the information exposure. Thus, IO, regardless of its type, can be divided into the following phases: assessment, planning, implementation, and final phase. Now, following the purpose of this research, let us consider in greater detail a defensive IO, corresponding to doctrines of the majority of progressively developing countries.

Typical defensive IO covers the following basic phases:

- Estimation:
  - Analysis of possible vulnerabilities (goals);
  - Collection of information about possible operations;
  - Identification of possible requesters / "customers" of the information influences:
    - definition of areas of common interest of the object and the potential "customers";
    - ranking of potential customers by their interest;
- Planning:
  - Strategic planning of defensive operations (explicit or implicit):
    - Defining the criteria of information influences;
    - Information Modeling effects, taking into account:
      - object relations;
      - dynamics of the influence;
      - «special» (critical) points of the influence;
    - Forecasting of the next steps;
    - Calculation of the consequences;
  - Tactical planning of counter-operations;
- Execution - implementation of informational influence:
  - Identification and "smoothing" of information occasion;
  - Counter-propaganda;
  - Operational intelligence;
  - Evaluation of the information environment;
  - Adjustments to the information counteraction;
- The final phase:
  - Analysis of effectiveness;
  - The use of positive results of the information influence;
  - Counteraction to negative results.

As we can see from the proposed detailed plan of a defensive IO, strategic planning is a fundamental component of IO. Obviously, there is no uniform "standard" plan for IO. We can only consider an exemplary sequence of actions on IO implementation, obtained by generalization of some already realized IO. Moreover, the choice of an optimal set of such actions depends, primarily, on the availability of resources to perform them at a given time, as well as on the results of execution of previously selected activities. Optimality should be considered here in terms of effectiveness of achievement of goals of one or another defensive IO.

A separate objective of this study is improvement of the existing DM apparatus, taking into account the peculiar features of strategic planning process in weakly structured domains. The following example demonstrates the formal IO strategy construction, involving a group of competent specialists in this area.

III. Numerical example

A hypothetical example, presented here, shows the final stages of the process of optimal strategic plan construction for counteraction to the information operations within a 5-year term, under condition of availability of financial resources in the amount of 200 million UAH. Within the example we assume that the hierarchy with the main objective "Ensure sufficient level of counteraction to information attacks" has already been built and presently we are at sub-stage 3 of strategic plan construction – estimation of relative influences of the projects upon a certain goal from the goal hierarchy graph.

Let us assume that estimation at this stage is performed by a group of three equally-competent experts. Each expert is formally given the opportunity to determine the domination degree in each pair of 4 projects – to perform an ordinal comparison (">" - more; "<" - less), decide on verbal estimation scale, select the number of points (grades) of the scale and, finally, select the number of a particular point (grade).

Table I shows the data of the expert estimation of the importance of activities that are part of the goal of "Implementation of information influence": C_1 – Revealing and "smoothing" of information occasion; C_2 – Counter-propaganda; C_3 – Operational Intelligence; and C_4 – Evaluation of the information environment. The asterisk symbol "*" in the matrices denotes the elements (pair comparisons) on which the experts (due to one reason or another) have not provided information.

Based on the pair-wise comparisons of unified values (bottom row of matrices in Table I) we calculate the relative weights of project influences (Table II).

To construct the optimal strategy for the 5-year term, we use the resource allocation tools of the DSS "Solon" (see. Fig. 3).

On the screen form we can see that the following expert estimates are entered for each project, which claims to be funded: the minimum necessary number of resources for the project (R min), the percentage of completion of the project under minimal funding (% min), the amount of resources that is requested (R max) and the planned percentage of the project completion (% max, usually, 100%). After calculations (<Distribute> button), the amounts of allocated resources are displayed in the "allocated" column.

A list of recommended actions for decision-makers in the form of a set of projects with the calculated funding volumes

Table I. EXAMPLE OF EXPERT ESTIMATION OF PROJECTS' RELATIVE INFLUENCES

		Expert 1				Expert 2				Expert 3			
		C_1	C_2	C_3	C_4	C_1	C_2	C_3	C_4	C_1	C_2	C_3	C_4
Ordinal Comparison	C_1	1	>	>	>	1	>	<	>	1	*	>	>
	C_2		1	<	>		1	<	>		1	<	<
	C_3			1	>			1	*			1	>
	C_4				1				1				1
The number of scale points	C_1	1	5	9	9	1	5	5	9	1	*	8	9
	C_2		1	5	9		1	7	9		1	9	3
	C_3			1	7			1	*			1	9
	C_4				1				1				1
Point number	C_1	1	2	3	5	1	3	2	5	1	*	4	8
	C_2		1	2	2		1	4	5		1	2	2
	C_3			1	5			1	*			1	3
	C_4				1				1				1
Scale number	C_1	1	1	3	1	1	3	4	1	1	*	2	3
	C_2		1	2	1		1	4	2		1	3	5
	C_3			1	2			1	*			1	1
	C_4				1				1				1
Unified values of pair-wise comparisons	C_1	1	2.500	1.732	5.000	1	2.615	0.833	5.000	1	*	2.011	6.839
	C_2		1	0.739	2.000		1	0.574	2.333		1	0.760	0.726
	C_3			1	3.138			1	*			1	3.000
	C_4				1				1				1

Table II. THE CALCULATED RELATIVE WEIGHTS OF PROJECTS' INFLUENCES

Marking a project	Normalized value of the weight
C_1	0.4455
C_2	0.1743
C_3	0.2919
C_4	0.0883

will provide the basis for an optimal strategic plan for ensuring a sufficient level of information attack counteraction in a 5-year prospect, under the limitations on the amount of financial resources supplied.

IV. CONCLUSIONS

A strategic planning technology in weakly structured subject domains, based on the use of decision-making support apparatus, is proposed. The advantages of the technology are: the ability to use all available knowledge about the subject domain (including knowledge of experts), opportunity to consider both quantitative and qualitative factors influencing the achievement of strategic goal, high reliability of group expert examinations (resulting from availability of a mechanism to ensure sufficient consistency of expert data, including incomplete data and estimated, provided in different scales), as well as opportunity to consider time frames of project execution and the limitations on available resource volumes.

This technology allows to define the rational (for a given moment in time) allocation of resources among the initial set of activities, which ensures the most effective achievement of the strategic goal. Subject domain is described by an expert-built knowledge base, and targeted resource allocation variant search is performed by Genetic algorithm.

Above-mentioned features make the technology a universal, convenient and flexible tool for strategic planning. As an example of technology application we have considered the estimation of specific activities aimed at counteraction to potential information operations.

Further research in this area can be dedicated to development of new algorithms for determination of optimal resource allocation variant in the context of a given strategic goal.

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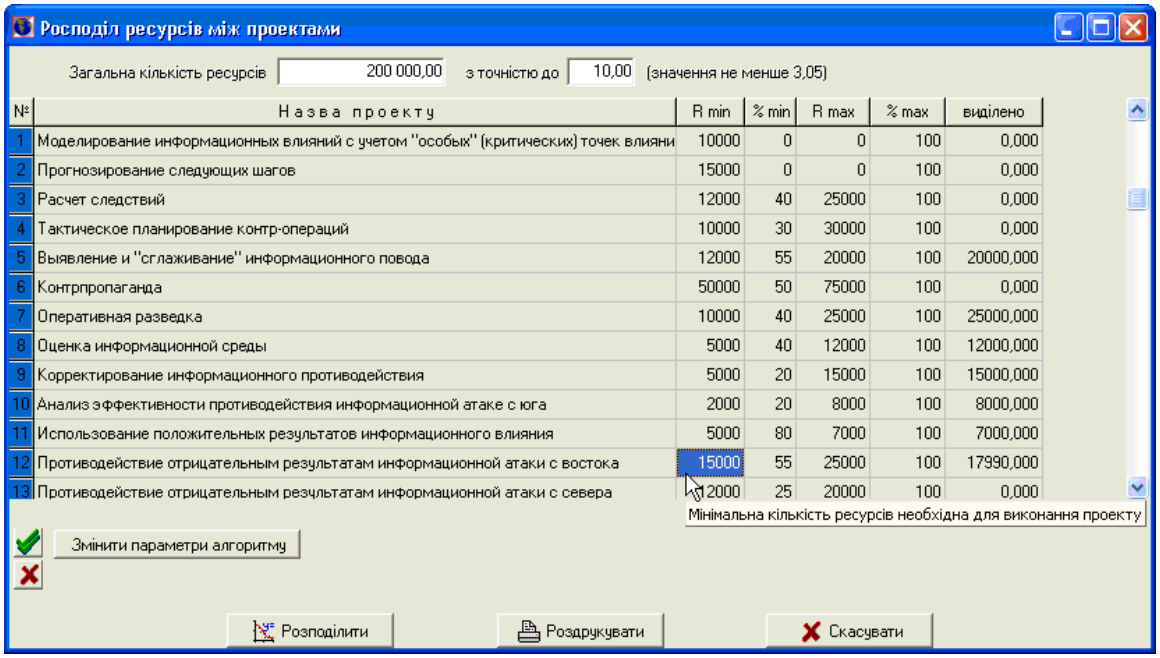

№	Назва проекту	R min	% min	R max	% max	виділено
1	Моделирование информационных влияний с учетом "особых" (критических) точек влияни	10000	0	0	100	0,000
2	Прогнозирование следующих шагов	15000	0	0	100	0,000
3	Расчет следствий	12000	40	25000	100	0,000
4	Тактическое планирование контр-операций	10000	30	30000	100	0,000
5	Выявление и "сглаживание" информационного повода	12000	55	20000	100	20000,000
6	Контрпропаганда	50000	50	75000	100	0,000
7	Оперативная разведка	10000	40	25000	100	25000,000
8	Оценка информационной среды	5000	40	12000	100	12000,000
9	Корректирование информационного противодействия	5000	20	15000	100	15000,000
10	Анализ эффективности противодействия информационной атаке с юга	2000	20	8000	100	8000,000
11	Использование положительных результатов информационного влияния	5000	80	7000	100	7000,000
12	Противодействие отрицательным результатам информационной атаки с востока	15000	55	25000	100	17990,000
13	Противодействие отрицательным результатам информационной атаки с севера	12000	25	20000	100	0,000

Figure 3. The calculated allocation of resources among the projects

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ПОДДЕРЖКА ПРИНЯТИЯ РЕШЕНИЙ ПРИ СТРАТЕГИЧЕСКОМ ПЛАНИРОВАНИИ

Цыганок В.В.

Современные методы поддержки принятия решений, основанные на наиболее полном использовании знаний в определенной предметной области (как формализованных, так и экспертных) предлагаются к применению при долгосрочном планировании. Предложен подход к построению стратегических планов в слабо-структурированных предметных областях. Подход включает иерархическую декомпозицию проблемы группой удаленно работающих экспертов под руководством инженера по знаниям. Предлагается возможность использования разных шкал оценивания, позволяющая повысить достоверность результатов групповых экспертиз, целевое динамическое оценивание альтернатив, а также, метод оптимального распределения ресурсов. Применение подхода описывается на примере планирования противодействия информационным операциям.

Usage of Decision Support Technologies in Information Security Domain: Opportunities and Prospects

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***Abstract*—Information security is an important national security sphere, characterized by multiple tangible and intangible factors of both quantitative and qualitative nature. In order to be able to set priorities and plan actions in the area of information security one needs to have a clear analytical, formal description of this subject domain. However, not all the data about informational security in general and informational operations in particular is deterministic or even quantifiable. Many authors list certain features of information operations, which allow us to conclude that they represent a weakly structured domain. One of the most effective (and sometimes the only) way to get a formal description of a weakly structured domain is to turn to experts for information. Multi-criteria decision support technologies allow decision-makers to get recommendations concerning selection of best options when it comes to strategic planning, resource allocation, prioritization, project selection etc. This paper explains why expert data-based decision support technologies provide a powerful tool for analytical description and formalization of informational operations and information security strategies, and describes the main stages of implementation of decision support arsenal in information security domain.**

Keywords*—*information security, informational operation, decision-making, expert estimate, decision support system, strategic planning, hierarchic problem decomposition.

I. Introduction

During the last few decades the relevance of information security as a sub-domain of national security was growing rapidly. We can recall that informational impact was a powerful propaganda tool even in ancient times. However, in the modern world information security is more relevant than ever. Success in the information war is a necessary condition of the war success in general. That is why information security, particularly prevention of informational operations, should be a necessary activity component and an important strategic priority of any large organization (including national and local governments).

In this report it is suggested to use the definition of informational operation, provided in [1]. According to the authors, an informational operation is, usually, meant to

- introduce certain ideas and notions into the minds of the public in general and of specific individuals in particular
- disorientate and mislead the recipients of information
- weaken the conventions of citizens and the society in general
- intimidate the masses (sometimes).

Planning of activities, meant to strengthen the information security, prevent negative/alien information impacts and informational operations (as well as successful planning of actions in the process of informational combat) calls for in-depth knowledge of the subject domain. However, information security domain is a weakly-structured one, which is problematic to describe, particularly, in formal quantitative terms. Expert data-based decision-making support technologies provide the means for problem-solving in weakly-structured domains [2]. That is why we feel that usage of expert data-based decision support technologies in the area of informational security and specific context of implementation of certain methods deserve to be considered in a separate paper.

II. Information Security as a Weakly Structured Domain

The author of [3] lists the following features of weakly structured domains (Fig. 1): lack of functioning goal, which could be formalized, lack of optimality criterion, uniqueness, dynamics, incompleteness of description, inability to build an analytical model, lack of benchmarks, large dimensionality.

In [1] it is stated that informational operations are influenced by numerous solely qualitative criteria, factors, and parameters (including socio-psychological ones). It is problematic to provide a formal mathematical (analytic) description of these factors.

Gorbulin et al also point out the impossibility of development and practical application of some universal methodology for modeling of informational operations, first and foremost, due to weak formalization of concepts and factors. These authors stress, that in each particular case one should consult the analysts (i. e. information operation experts) and rely on their competency. The analysts are sometimes able to build accurate forecasts of certain dependencies, which are later confirmed by practice. Analysts (experts) should be consulted to provide description of subjective factors. When it comes to objective factors, their description and analysis can be performed using well-known methods, which operate determined data, including mathematical statistics and analysis

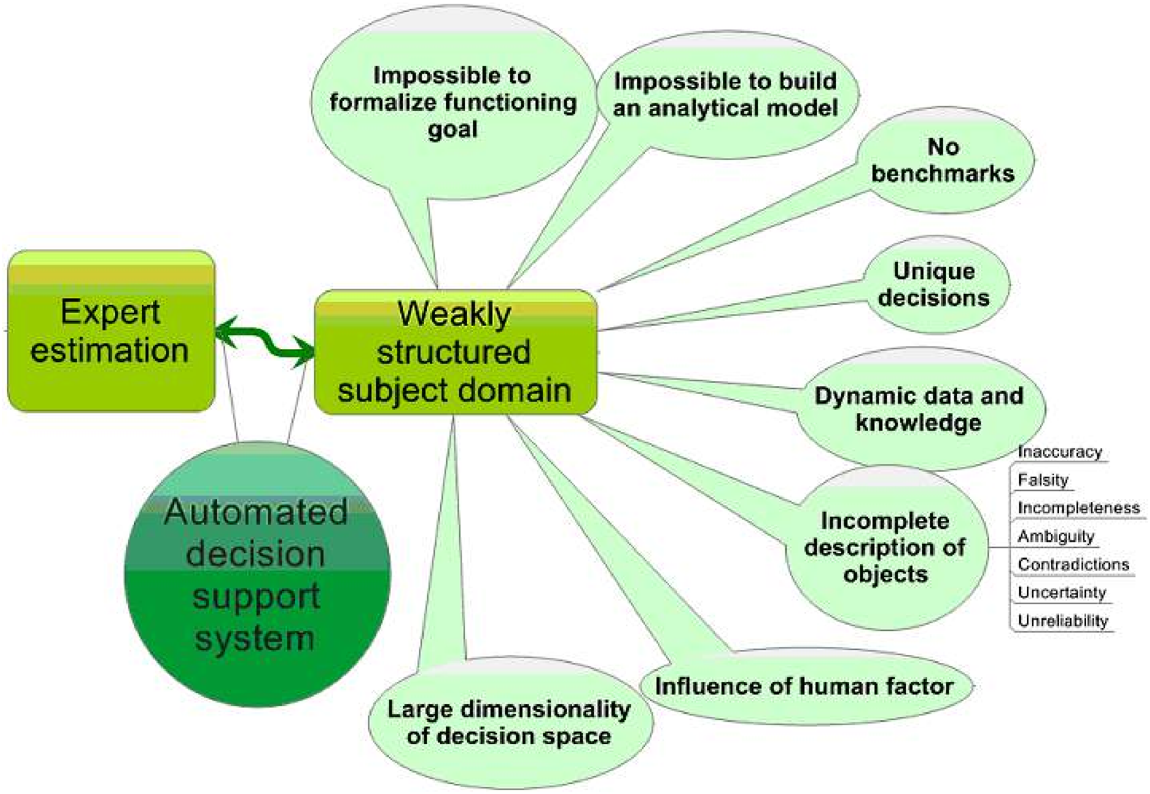

Figure 1. Features of weakly structured domains

of time series. However, these methods are targeted only at description of formal aspects, and do not touch upon content-related aspects. As a result, Gorbulin et al stress the necessity of extension of technological arsenal, which can be used for analysis and modeling of informational operations.

As we can see, informational operations (like all other operations, requiring human participation) represent a vivid example of a weakly-structured subject domain. We feel that expert data-based decision support technologies should become one of the technical tools for analysis and modeling of informational operations. The relevance of expert data usage in weakly structured subject domains is also corroborated by the research, conducted by Delphi Group, listing the sources of knowledge, possessed by organizations [4] (Fig. 2).

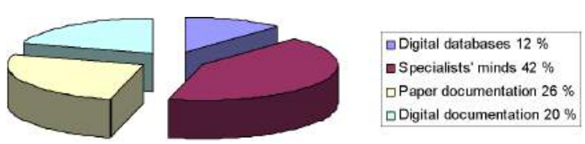

Figure 2. Sources of knowledge about an organization, according to Delphi Group research

The research indicated that a considerable share of knowledge is stored not in the databases, or on paper and digital mediums, but rather in the minds of experts (analysts, specialists). Consequently, in the context of description and analysis of informational operations, expert knowledge should, definitely, be involved, especially when it comes to subjective qualitative factors.

III. Hierarchic Decomposition and Complex Target-Oriented Dynamic Evaluation of Alternatives

As it is stated in [1], an informational operation is an inter-disciplinary set of methods and technologies that encompasses multiple spheres, from military science to sociology. At the same time, there is no universal standard information operation technology (which could serve both the military and the management of large governmental or business agencies). So, according to Gorbulin et al, development of a scientific basis of informational operations remains an extremely relevant issue.

With the inter-disciplinary nature of informational operations in mind, we feel that expert knowledge-based hierarchic decomposition should become a handy informational operation description tool. Particularly, a hierarchic approach provides the basis for the method of complex target-oriented dynamic evaluation of alternatives (MCTDEA), suggested by V.Totsenko [2] and further improved by V.Tsyganok [5]. The method allows to aggregate a large quantity of criteria of different nature (i.e. belonging to different spheres) (Fig. 3), that influence a specified main goal, into a unified hierarchy.

Depending on the type of a specific informational operation (offensive or defensive [1]), the analyst (expert) or the decision-maker (DM) himself can formulate the main goal. Any informational operation is decomposed into certain stages (or steps), which are listed in [1]. The contents of these steps can vary, depending, again, on the type and context of the operation. For example, during modeling and decomposition of an informational attack against the Academy of sciences (using MCTDEA), a goal formulated as “Discredit an aca-

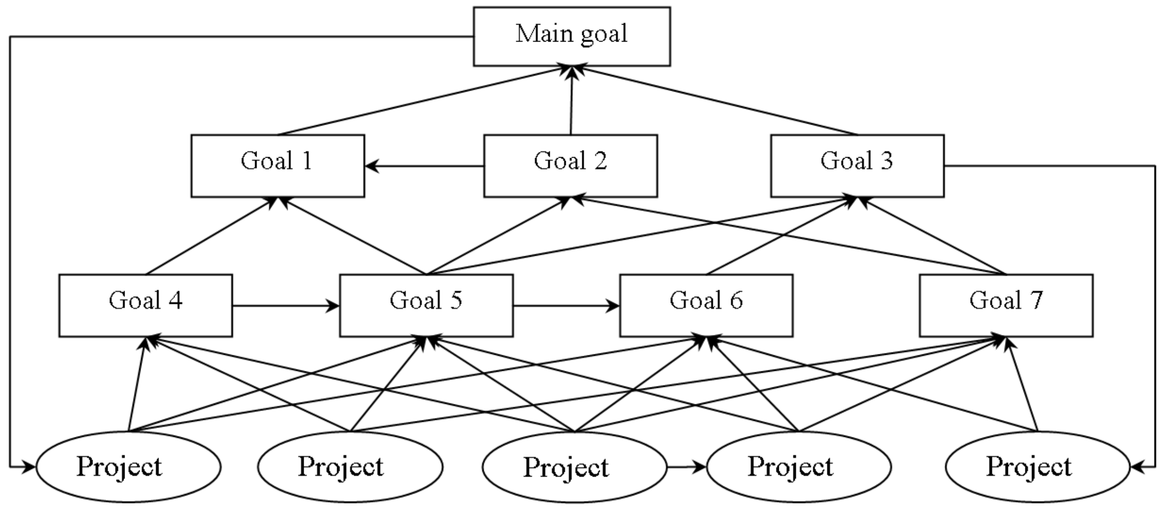

Figure 3. An example of goal hierarchy

demic institution in the media" can be decomposed into the following lower-level sub-goals: "Discredit academic papers and achievements" and "Discredit academic researchers".

In MCTDEA decomposition is performed down to the level of "atomic", elementary sub-goals (factors, criteria) that can be directly influenced by the DM. These goals are called projects (see Fig. 3), and, generally, can be characterized by a certain value (absolute/relative numeric, Boolean, or threshold-type).

The general conceptual task of decision support methods, involving hierarchic decomposition of a problem, particularly, MCTDEA and analytic hierarchy/network process (AHP/ANP) [6], is to build a rating or ranking of objects (alternatives, projects). Based on such rating, a DM can make an informed choice of the best alternative (decision variant) from a given set, or set priorities in his/her activity (i.e., determine, which factors or actions are most important for achievement of a given main goal). In order to build such a rating, one should define the relative importance of all goals in the hierarchy graph, built by experts (or by knowledge engineers through dialogues with experts). In order to define the relative importance of sub-goals of a given goal (its "descendants" in the hierarchy graph), experts should compare them pair-wise (unless they are able to provide direct estimates). Evaluation of impacts (weights) can be conducted by experts in different pair-wise comparison scales. Recent research of V.Tsyganok [7],[8] has shown that the expert should be given an opportunity to input every single pair-wise comparison value in the scale, which is most convenient for him or her (i.e. which reflects his/her knowledge of the subject domain most accurately). When the experts have evaluated all relative weights (priorities) in the hierarchy graph, relative impacts of all the projects upon the main goal (their relative efficiencies) can be calculated as shown in [2].

If evaluation is done by several experts, then a few important aspects should be taken into consideration. The first aspect is expert competence. If it is known that the experts, who evaluate criteria, projects, or alternatives, have different competencies, their relative competence levels should be calculated based on three components: self-assessment, mutual assessment, and objective data (as shown in [2]). Differences in relative competence levels of the experts can be neglected only when the size of the expert group is large enough [9]. The second important aspect is consistency of estimates, provided by different expert group members. Expert estimates' consistency should be checked (as recommendations to the DM, based on inconsistent or incompatible expert data will provoke distrust). In order to evaluate consistency level of expert estimates, in our view, it is appropriate to use so-called spectral methods, described, for instance, in [10] and [11]. The advantage of spectral methods over other approaches to consistency evaluation (for example, those suggested by Saaty and colleagues [12]) is as follows. If necessary (i.e., if consistency level of expert estimates in the group is low), spectral methods allow the knowledge engineer to organize step-by-step feedback with experts. Experts are requested to change the respective outlying estimates so as to make overall consistency level reach the required threshold (as shown on Fig. 4).

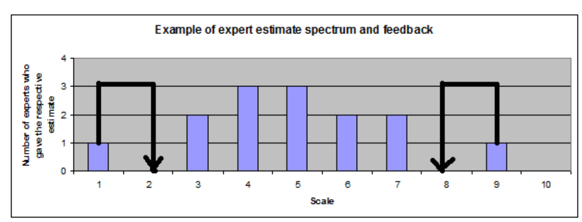

Figure 4. Example of consistency improvement during group expert estimation

When estimates, provided by different members of the expert group, achieve the level of consistency, that is high enough, they can be aggregated (used for calculation of generalized group estimates). For aggregation of expert estimates, we suggest using the combinatory aggregation method [13]. The most important of the method's advantages over other aggregation methods are as follows. First, it can be used for aggregation of incomplete pair-wise comparison matrices. Second, it utilizes the redundancy of information most thoroughly.

In the context of MCTDEA the "weighted" hierarchy of criteria (goals) is called the knowledge base (KB) of the subject domain. This paper is focused on subject domains, related to information security, particularly, information operations. In terms of content, such KB represents one of the types of subject domain models. The KB is built by experts (or by knowledge engineers through dialogues with experts) using special software tools – automated decision support systems (DSS) (see Fig. 1).

We should note that MCTDEA does not require all the data, input into DSS KB, to be represented by expert estimates only. For instance, when it comes to comparison of several alternatives according to some criterion, estimate values should not necessarily be expressed by grades of pair-wise comparison scales. Sometimes, the values can be absolute ones, available from open information sources. For example, in order to analyze the information policy or campaign of some organization absolute values are often used, such as "number of publications with negative flavor per month". An indicator like this "has all the rights" to be included into a hierarchy of criteria, describing the information policy of an organization.

IV. Issues concerning dialogues with experts

An expert (analyst), usually, comes from a narrow-focused subject domain and, in the general case, is not familiar with decision support methods and technologies. Consequently, it is extremely important to make the process of expert data input into the DSS as comfortable for experts as possible. Formal side of the process (expert data formalization) should be delegated to the knowledge engineer, and mathematical calculations – to the automated DSS. In order to achieve this objective during expert examination it is appropriate to keep several important issues in mind.

First, if an expert is completely new to decision support technologies, it makes sense to familiarize him/her at least with the general agenda of the examination. In the ideal case examination participants should be given a thorough explanation of the whole technology, used to process their estimates and to form recommendations for the DM as to decision variant selection. Such an explanation will increase the level of trust the experts have towards the process and allow them to input data into the DSS in the most convenient format. So, before starting to collect information from the experts, it is reasonable to hold coaching sessions with them.

Second, criteria (goal) hierarchy (See Fig. 3) should be well-balanced. It is preferable to locate all the projects on one level (because, as it is shown in [6], their weights should belong to one order of magnitude). With human psycho-physiological constraints taken into consideration, any goal in the hierarchy graph should not have more than 72 descendants [14]. In the process of hierarchy building, it is preferable not to "bother" the expert with multiple similar questions (particularly, concerning positive or negative character of impact of goals upon their common "ancestor" in the graph, or pair-wise compatibility of "descendant" goals).

Third, when evaluating the impacts, verbal values should be used rather than their numeric equivalents (for instance "1" – equality, "2" – weak preference, … , "5" – extremely strong preference). See Fig. 5, illustrating one of pair-wise comparison scale examples, suggested by Saaty [6].

Numerical values	Verbal term	Explanation
1	Equally important	Two elements have equal importance
3	Moderately more important	Experience or judgment slightly favors one element
5	Strongly more important	Experience or judgment strongly favors one element
7	Very strongly more important	Dominance of one element proved in practice
9	Extremely more important	The highest order dominance of one element over another
2,4,6,8	Important intermediate values	Compromise is needed

Figure 5. Fundamental pair-wise comparison scale with 9 grades

Another scale type, which is used for interviewing of respondents from most diverse subject domains is Likert's agreement/disagreement scale. Interviewees are offered to agree or disagree with some positively formulated statements (like, for instance, "Posts in social networks with positive flavor substantially improve the image of the business"). Afterwards their answers are assigned numerical values (one of the correspondence rules is shown on Fig. 6 and aggregated.

Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
1	2	3	4	5

Figure 6. Likert's agreement scale example

On the whole, interface of an automated DSS should be user-friendly, intuitively understandable, and easy to master.

More detailed analysis of peculiar features of working with experts is provided in [15].

V. Elicitation of patterns and parameters of informational impact dissemination based on available data and experience

In the context of information operations research authors of [1] stress, that it is important to be able to evaluate parameters of the model based on real behavior patterns and dependencies. Detected patterns and dependencies will provide the basis for forecasts of information operation impacts even if clear picture is still missing. Moreover, such a forecast may be more accurate than the results of regular expert examinations (where experts make forecasts in the form of estimates).

In this regard (returning to decision support perspective) we should mention the relevance of factor analysis and neural network algorithms, which allow to determine model parameters based on given sets of "input" and "output" values.

This opportunity was noted by V.Totsenko in [2], who listed specific factor analysis methods in his book: group method of data handling (GMDH), least squares method (LSM), multi-dimensional linear extrapolation, and minimum discrepancy method.

We should stress, that input data for factor analysis can be represented by both determined data of actual system behavior (particularly, input and output parameters, characterizing an informational operation) and expert data. Above-listed factor analysis methods (as well as neural networks) are relevant if input data is cardinal (numeric). If only ordinal-type data (that contains information about the order of alternatives in the ranking, but not about quantitative relation between them) is available, then ordinal factor analysis methods, set forth in [16], [17], [18], should be used. For example, if after parliamentary election ratings and final ranks of parties are already known, relative weights of certain strategic points in their election programs can be calculated based on available ratings.

Cardinal and ordinal factor analysis methods also allow us to define, which parameters influence the centrality of an element in some network-type structure (Gorbulin et al dedicate a separate section of their book to network methods and structures in the context of information operations). Such a calculation was attempted, for example, in [20].

Beside that, when it comes to information network structure, we should remember, that its elements often reflect certain social relationships among network agents (or nodes) [1]. For instance, members of a community in a social (or terrorist) network can be associated through common ideas, slogans, references, links, etc. Elicitation of such relationships can be performed based on semantic similarity of content, attributed to members of this or that network structure. Even if there are no explicit connections, semantic analysis of respective online content can allow to detect latent, hidden connections. Content similarity methods are set forth (from decision support perspective) in the recent works of O.Andriichuk, such as [21].

VI. Strategic planning

A separate informational operation can have powerful impact. However, it represents, so to say, tactic level. Moving to strategic level, we should note that information security strategy is a necessary component of the general national security strategy [1].

In [22] Tsyganok et al show, that the strategy can be represented as an optimum (for a given moment in time) distribution of limited resources among top-priority projects in a specific domain. In [23] the subject domain, where the strategy is built, is represented by space activity and production of space equipment. In [22] the subject domain is the defense industry. A similar strategy can be built in the area of informational security as well.

The process of strategic planning, based on multi-criteria decision support technologies using both expert and objective data, incorporates all the procedures, listed in the previous sections of this paper. It includes the following phases:

- Formulation of the main goal, which characterizes the subject domain, by the DM.
- Selection of a group of experts (specialists, analysts) to participate in the examination.
- Building of a hierarchy of criteria (factors), influencing the achievement of the main goal (through dialogues with experts).
- Expert evaluation of relative impacts of criteria (projects) in the hierarchy.
- Calculation of relative efficiencies of the projects, i.e. their contributions to the achievement of the main goal.
- Determination of the optimal development strategy.

In this case we are talking about information security development. As noted above, a strategy is a distribution of limited resources among separate projects, which guarantees the most effective achievement of the main goal. According to Tsyganok et al., as of now, the best way to find such a distribution is to select it from the set of all possible resource distributions using genetic algorithm. Particular algorithm of resource distribution selection is the subject of separate studies.

VII. Conclusion

Due to inter-disciplinary nature, impossibility of formalization, presence of human factor, and other reasons, strict analytical and mathematical description of informational operations represents a serious problem. However, such description is absolutely necessary in the context of active informational combat. Alongside other approaches, such as multi-agent modeling (using cellular automation and other means), expert data-based decision support technologies allow us to get a clearer and more formal understanding of informational operations and their effects. While multi-agent approaches provide a reliable tool for modeling of the process of dissemination of informational impact or effect of informational operations, multi-criteria decision aids using expert and objective data should provide means of formal description and analysis of planning and implementation of informational operations.

Particular areas of decision support technology implementation in the information security domain include:

- formalization and analytical description of informational operations;
- decomposition of offensive and defensive informational operations into elementary steps/phases;
- setting of priorities in informational combat;
- informational policy making;
- elicitation and analysis of informational impact dissemination parameters;
- detection of relations between agents in information networks through content analysis;
- development of information security strategies.

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ПРИМЕНЕНИЕ ТЕХНОЛОГИЙ ПОДДЕРЖКИ ПРИНЯТИЯ РЕШЕНИЙ В ОБЛАСТИ ИНФОРМАЦИОННОЙ БЕЗОПАСНОСТИ: ВОЗМОЖНОСТИ И ПЕРСПЕКТИВЫ

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В докладе проанализированы особенности сферы информационной безопасности как слабо структурированной предметной области. Показано, что информационная безопасность в целом и информационные операции в частности представляют собой яркий пример слабо структурированной предметной области, которая плохо поддается формальному описанию. Тем не менее, необходимость в формальном описании и анализе информационных операций остается актуальной. Вследствие слабой структурированности предметной области, для решения задач ранжирования, построения рейтинга мероприятий, расстановки приоритетов и стратегического планирования в сфере информационных операций целесообразно применять методы экспертной поддержки принятия решений. В тексте доклада описаны принципы использования экспертных технологий поддержки принятия решений на различных этапах анализа и планирования информационных операций, а также – противодействия вражеским информационным операциям.

Usage of Expert Decision-Making Support Systems in Information Operations Detection

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***Abstract*—In this paper a methodology for application of expert data-based decision support tools while identifying informational operations is suggested. The methodology utilizes expert data, obtained through group expert examinations using the respective tools, enabling experts to work remotely in a global network. Based on information, obtained from experts, the knowledge engineer builds the knowledge base of subject domain, using the respective decision support tools. The knowledge base, in its turn, provides the basis for specification of queries for analysis of dynamics of respective informational scenarios using text analytics means. Based on results of the analysis and the knowledge base structure, decision support tools calculate the achievement degree of the main goal of the informational operation as a complex system, consisting of specific informational activities. After that, using the results of these calculations, decision-makers can develop strategic and tactical steps to counter-act the informational operation, evaluate the operation's efficiency, as well as efficiencies of its separate components.**

Keywords*—*information security, informational operation, decision-making support system, expert estimate, content-monitoring system.

I. Introduction

Given the present level of development of information technologies it is hard to overestimate their impact to human life. Information media, into which every man, any social group, population are involved, forms the respective world-view, affects their behavior and decision making. Therefore, the problems, related to formation and modification of this information media, are extremely actual nowadays.

By information operation (IO) [1], [2], [3] we assume the complex of information activities (news articles in Internet and papers, news on TV, comments in social networks, forums, etc.) aimed to change the public opinion about a definite object (person, organization, institute, country, etc.). For example, spreading the rumors about problems in a bank can provoke its depositors to take back their deposits, which in turn can cause its bankruptcy. Mainly, this activity has a disinformation character. The information operation belongs to so called weakly structured subject areas [4], [5], because it possesses several characteristic for these areas features: uniqueness, inability to formalize the objective of its function and, as a consequence, inability to construct the analytical model, dynamicity, incompleteness of description, presence of human factor, absence of standards. These subject areas are treated using expert decision-making support systems (DMSS) [6].

In [1], [2], [3] the techniques are presented of IO identification based on the analysis of time series built on the basis of thematic information stream monitoring. The following problematic situations which can appear in IO identification due to drawbacks of current methods and techniques can be noted:

1) Given a sufficiently large number of publications about the IO object, the number of publications (information stove-piping) about its definite component can be very small and, as a consequence, the respective system distortions of the typical dynamics of information plots (such as, for example, discovered "Mexican hat" and Morlet wavelets on the respective wavelet scalogram) will not be revealed. Some IO may be complex and respective information stove-pipings may be staged, related to different components of the IO object in different time periods. If their number will be blurred at the background of the total number of publications about the IO object ("information noise") and the respective information attacks will not be identified, then the beginning of the information campaign on the object discredit can be missed, and some information damage to its image will not be taken into account.
2) Content-monitoring tools control the queries consisting of keywords to search the respective publications. Keywords are formed based on the IO object title. But the complex IO object can have a great number of components with the respective titles which are not accounted in queries and, as a consequence, not all publication on the issue will be found.
3) The queries related to IO object have different degrees of importance according to IO components to which they are related. The absence of information about values of these importance degrees (i.e. their equivalence) leads to the reduction of the IO model relevance.

To overcome the above-mentioned drawbacks we suggest using the following technique for application of decision making support tools in IO revealing.

II. The core of the methodology for application of expert decision-making support tools in identification of information operations

The core of the suggested methodology for application of expert decision making support tools in identification of information operations consists in:

1) Preliminary investigation of the IO object is carried out; its target parameters (indexes) are being selected. Then it is suggested that formerly, in retrospective, IOs against the object were taking place, and, thus, its condition (respective target indices) has been deteriorated.
2) The group expertise is done to determine and decompose the information operation purposes and to estimate its degree of influence. Thus, the IO object is being decomposed as a complex weakly structured system. For this purpose the tools of distributed acquisition and expert information processing system (DAEIPS) are used. For obtaining the expert information in a full range and without distortions the expert estimation system is used.
3) The respective knowledge base (KB) is constructed using the DMSS tools, based on the results of the group expertise performed by means of DAEIPS and using available objective information.
4) The analysis of the dynamics of the thematic information stream by means of content-monitoring system (CMS) is carried out. KB of DMSS is complemented.
5) The recommendations are calculated by means of DMSS based on the constructed KB. For this the IO target achievement degrees are calculated in retrospective and are compared with the respective changes of the IO object condition. The mean value of IO target achievement degrees is calculated, at which degrees the deterioration of the IO object target indices occurs. Thus, monitoring of the IO object condition for the current period of time allows one to predict the deterioration of the IO object target values based on the comparison of the calculated for the current period of time value of IO target achievement degree with the above-mentioned mean value. In the case of availability of statistically sufficient sample size, and given sufficient correlation between values of IO target achievement degrees and deterioration of IO object target index values, one can even predict the quantitative value of the IO object target index for the current period of time.

Let's consider the advantages of the suggested methodology. The great specification of the model – at the background of a large number of publications about IO object in general, the change in publication number dynamics due to the stovepiping about one of IO components will be insignificant and, therefore, will not be revealed. The number of found thematic publications will increase, because of a larger number of queries and keywords. Weighing of the IO components allows one to avoid the situation when all components are of equal importance. The IO model constructed in such a way will be more relevant. The constructed KB can be used again later during a long period of time without the necessity to carry out a new expertise. The use of DAEIPS tools makes it possible for experts to work through the global network saving time and resources.

Let's consider the drawbacks of the suggested methodology. Application of expert techniques requires time and financial efforts for implementation of the group expertise. Besides, the timely actualization of KB should be done for its second use in the future. Complexity and sometimes ambiguity of the presentation of some sufficiently complex statements of IO components in the form of queries in the content-monitoring system.

III. Example of the use of the methodology for application of expert decision-making support tools in identification of information operations

Let us show in detail the suggested methodology at the example of information operation against National academy of Sciences (NAS) of Ukraine. It is known that presently NAS of Ukraine is going through hard times. In recent years the funding of NAS is getting worse: the total funding of NAS of Ukraine decreases and also decreases the share of the budget of NAS of Ukraine in the total budget of Ukraine. This is well seen from the information about distribution of expenses for the State Budget of Ukraine for 2014 – 2016 [7], [8], [9]. Suppose that this cut of funding is the result of information operation against NAS of Ukraine.

A. Group expert decomposition in "Consensus-2" system

As DAEIPS for group expert decomposition we use "Consensus-2" system aimed to perform estimations by territorially distributed expert groups. This system is an upgraded version of "Consensus" system [10]. In DAEIPS "Consensus-2" the technique of KB construction is implemented for weakly structured non-formalized subject areas in the form of hierarchies of targets. "Consensus-2" system consists of two computer-aided working places: for an expertise organizer (knowledge engineer) and for an expert.

The group expertise consists of a set of stages, each being monitored by the knowledge engineer. He also initiates the transition from one stage to another. First, the expert is asked the following question: form the list of essential factors affecting the achievement of the target "Information operation against National academy of sciences of Ukraine". Now the expert introduces new statements or chooses the factors from the list of objects already present in KB. Then, when the expert group introduces a sufficient number of statements, the knowledge engineer selects the groups of the statements with the same meaning from all the statements introduced during the current decomposition. At the next stage in each semantic group the experts choose the best (by their opinion) statements and the respective voting is carried out. Then the knowledge engineer determines the types of influence of the factors. If the factor facilitates the achievement of the target, then the influence is considered as positive, if it prevents, then it is negative. At the final stage the respective graph of the hierarchy of targets is drawn (Fig. 1).

Next, the knowledge engineer chooses the target in the graph which will be expanded by the expert group at the

Figure 1. Decomposition of the main target in "Consensus-2" system

following decomposition step. Several targets can be expanded in parallel.

In the same manner the decomposition of other targets in the hierarchy is performed. As a result, the respective knowledge base tables are generated. Then DMSS forms the KB based on the interpretation of these intermediate data.

B. Knowledge base construction in DMSS "Solon-3"

DMSS "Solon-3" [11] is developed for the decision support in planning the large-scale complex long-term programs, including those for making strategic plans in different fields of activity. The system makes it possible to estimate and select various political, social, economic and other measures (solution variants) depending on their influence on the achievement of the main and intermediate targets of the program. "Solon-3" system allows one also to optimally distribute the available resources and to plan implementation of measures. During the estimation numerous complex interconnections of the factors affecting the achievement of the program's target are being taken into account. DMSS "Solon-3" is the multi-user system, the knowledge base of which is formed by many experts and specialists of highest rank in different areas of knowledge.

In DMSS "Solon-3" the original method is used based on decomposition of the main objective of the program, construction of the knowledge base (hierarchy of targets) and dynamic target estimation of alternatives [6].

Based on the interpretation of the knowledge base generated after operation of DAEIPS "Consensus-2" in previous chapter, DMSS "Solon-3" generates the respective KB. The knowledge engineer has an option to edit KB by system tools, namely: to introduce new targets/projects/connections, to edit/delete present targets/projects/connections, to introduce partial coefficients of influence according to the results of the group expertise, and also to introduce "objective (non-expert)" information and other functions.

C. Expert estimation in "Level" system

The software for an expert estimation using pair comparisons "Level" ("Riven") [12] is developed for execution of the expertise in decision making support systems and allows one to obtain knowledge from experts by offering them a possibility to compare the objects pairwise. It allows an expert to specify the existence of preference between the objects with an option to increase gradually the degree of this preference to the level corresponding to the actual knowledge of the expert about the object. In every distinct pair comparison the expert has an option to choose his own convenient scale with the respective number of divisions. That means that information from an expert is obtained in full volume and without pressure, which could distort it in respect to the expert's own impression.

Fig. 2 shows how the expert pair comparison is performed in "Level" system, namely: specification of the degree of influence superiority in the integral verbal scale with 9 divisions.

D. Analysis of thematic information stream by means of content-monitoring system InfoStream

In the result of described in previous chapters group expertise 15 expert statements were obtained presenting the components of IO against NAS of Ukraine, namely:

1) Bureaucracy in NAS of Ukraine;
2) Inefficient personnel policy of NASU;
3) Corruption in NAS of Ukraine;
4) Underestimation of the level of scientific results of NAS of Ukraine;
5) Lack of introduction of scientific developments into manufacture;
6) Underestimation of the level of international collaboration;
7) Misuse and inefficient use of the realty of NASU;
8) Misuse and inefficient use of land resources of NASU;
9) Discredit of President of NAS of Ukraine;
10) Discredit of Executive secretary of NAS of Ukraine;
11) Discredit of other well-known persons of NAS of Ukraine;
12) Juxtaposition of scientific results of Ministry of Education and Science (MES) and NAS;
13) Juxtaposition of scientific results of other academic organizations to NAS;
14) Juxtaposition of developments of Ukrainian companies to NAS of Ukraine;
15) Juxtaposition of scientific results of foreign organizations to NAS.

By means of CMS InfoStream [13] the analysis of thematic information stream dynamics is made. For this, in accordance with every of above-listed IO component, in the special

Figure 2. Expert pair comparison in the "Level" system

language the queries are formulated, using which the above-mentioned process – the analysis of publication dynamics on target issues – will take place.

Below the results are presented of the express-analysis [2] of thematic information stream corresponding to the IO object – NAS of Ukraine. In the result of the analysis by means of CMS InfoStream the respective information stream from the Ukrainian segment of web-space was obtained. To reveal an information stove-piping, the publication dynamics was analyzed on the target issue using available analytical tools. In Fig. 3 one characteristic fragment of the dynamics is shown (for the period from 01.07.2015 to 31.12.2015).

To reveal the degree of similarity of fragments of respective time series to IO diagram in different scales one can use the "wavelet analysis". Wavelet coefficients show to which extent the behavior of the process in a definite point is similar to the wavelet in a definite scale. In the respective wavelet spectrogram (Fig. 4) all the characteristic features of the initial series can be seen: scale and intensity of periodic variations, direction and value of trends, presence, position and duration of local features.

The IO dynamics most exactly is represented by "Mexican hat" and Morlet wavelets [14]. Therefore, the time series according to each of 15 IO components are analyzed during four periods (01.01.2013-31.12.2013, 01.01.2014-31.12.2014, 01.01.2015-31.12.2015 and 01.01.2016-15.12.2016), and the presence of the above-mentioned wavelets is identified.

E. Calculation of recommendation using DMSS 'Solon-3"

Based on revealed in the previous chapter information stove-pipings and their parameters (position and duration) the knowledge engineer complements KB of DMSS "Solon-3". In particular, the stove-piping was identified on the IO component "Underestimation of the scientific results of NAS of Ukraine" situated at 30.11.2015 with the duration of 14 days. Correspondingly, as a characteristic of the project "Underestimation of the scientific results of NAS of Ukraine" the parameter of duration of the project execution of 14 days is introduced, and as a characteristic of the project "Underestimation of the scientific results of NAS of Ukraine" influence on the objective "Discredit of scientific results of NAS of Ukraine" the parameter of delay in influence distribution for 10 months term is introduced. For other revealed information stove-pipings the characteristics of projects and influences are introduced in the similar manner.

Thus, for the time period 01.01.2015–31.12.2015, KB is complemented and has the structure shown in Fig. 5. Correspondingly, Table I contains the list of statements of all targets and projects of KB.

It should be noted that for some IO components, namely: "Corruption in NAS of Ukraine", "Bureaucracy in NAS of Ukraine", "Inefficient personnel policy of NASU", "Misuse and inefficient use of land resources of NASU" and "Misuse and inefficient use of the realty of NASU" stove-pipings were revealed twice during 2015, therefore, respective projects were entered into KB twice each. For example, for the IO component "Bureaucracy in NAS of Ukraine" – projects "Bureaucracy in NAS of Ukraine 1" and "Bureaucracy in NAS of Ukraine 2", but each of them has different characteristics of the execution duration (9 and 15 days) and respective influences have different characteristics of delay in distribution (9 and 11 months).

Then in DMSS "Solon-3" degrees of project implementation are introduced. If for some IO components no stove-piping was found, as in particular, for "Juxtaposition of developments of Ukrainian companies to NAS of Ukraine" and "Discredit of the actions of the Case Management department of NASU", then for respective projects the implementation degrees equal to 0% are set. For all other projects they equal to 100%.

Next, the results are obtained of the calculation of recommendations, namely: the degree of achievement of the main IO target and of project efficiency (relative contribution into achievement of the main target). For the periods 01.01.2013-31.12.2013, 01.01.2014-31.12.2014, 01.01.2015-31.12.2015 and 01.01.2016-15.12.2016 the degrees of achievements of the main target have values: 0.380492, 0.404188, 0.570779 and 0.438703, respectively.

In the retrospective, the mean value of the degree of achievements of the main target is equal: (0.380492 0.404188 0.570779) / 3.0 $\approx$ 0.45182.

Thus, since the mean retrospective and current value of the degree of achievements of the IO main target are sufficiently close (differ less than by 3%), then the conclusion can be drawn that IO during the current period with high probability

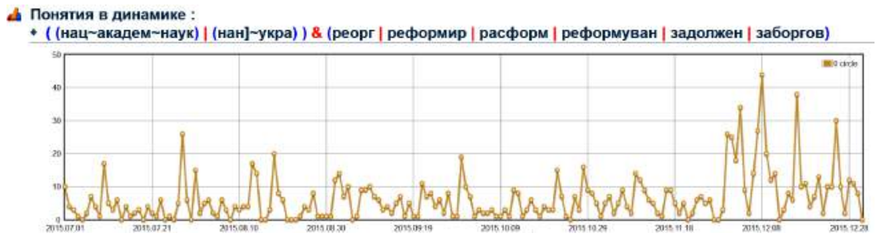

Figure 3. Publication dynamics on target issue

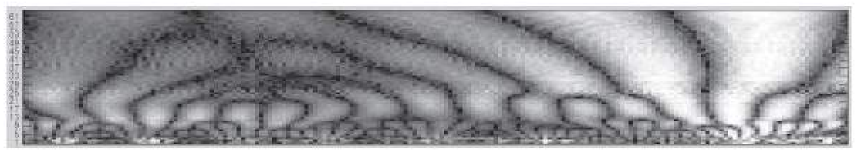

Figure 4. Wavelet spectrogram (wavelet Morlet) of the information stream

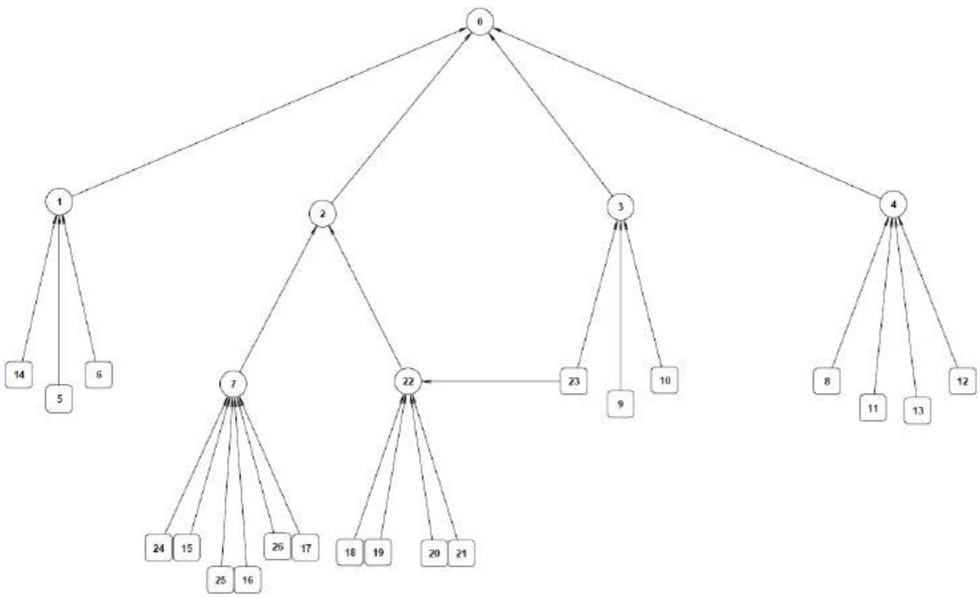

Figure 5. Structure of knowledge base

can provoke the deterioration of the target indexes of the object.

IV. Conclusions

1) The feasibility of application of expert decision making support tools is demonstrated in the process of identification of information operations.
2) The methodology is suggested for application of expert decision making support tools in revealing of information operations which allows one to predict the change of the values of target indices of the object for the current period based on the analysis of the retrospective data.
3) The suggested methodology is illustrated at the example of the information operation against National academy of sciences of Ukraine.

The study was carried out in the framework of the project F73/23558 “Development of methods and means for decision making support in revealing the information operations”. The project is the winner of the F73 competition on grant support of research and design projects of the State Fund of Fundamental Research of Ukraine and of Fund of Fundamental Research of Belorussian republic.

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Table I. LIST OF STATEMENTS OF TARGETS

#	Statement of objective
0	Information operation against National academy of sciences of Ukraine
1	Discredit of scientific results of NAS of Ukraine
2	Discredit of the structure of NAS of Ukraine
3	Discredit of well-known persons of NAS of Ukraine
4	Overestimation of scientific results of competing with NASU organizations
5	Lack of introductions of scientific developments into production
6	Underestimation of the level of international collaboration
7	Discredit of the organization structure of NASU
8	Juxtaposition of scientific results of MES and NAS
9	Discredit of President of NAS of Ukraine
10	Discredit of other well-known persons of NAS of Ukraine
11	Juxtaposition of scientific results of other academic organizations to NAS of Ukraine
12	Juxtaposition of scientific results of foreign organizations to NAS of Ukraine
13	Juxtaposition of developments of Ukrainian companies to NAS of Ukraine
14	Underestimation of the level of scientific results of NAS of Ukraine
15	Corruption in NAS of Ukraine 2
16	Bureaucracy in NAS of Ukraine 2
17	Inefficient personnel policy of NASU 2
18	Misuse and inefficient use of the realty of NASU 1
19	Misuse and inefficient use of the realty of NASU 2
20	Misuse and inefficient use of land resources of NASU 1
21	Misuse and inefficient use of land resources of NASU 2
22	Discredit of the actions of the Case Management department of NASU
23	Discredit of Executive secretary of NAS of Ukraine
24	Corruption in NAS of Ukraine 1
25	Bureaucracy in NAS of Ukraine 1
26	Inefficient personnel policy of NASU 1

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ПРИМЕНЕНИЕ ЭКСПЕРТНЫХ СИСТЕМ ПОДДЕРЖКИ ПРИНЯТИЯ РЕШЕНИЙ ПРИ ВЫЯВЛЕНИИ ИНФОРМАЦИОННЫХ ОПЕРАЦИЙ

Андрейчук О.В., Качанов П.Т.

В статье предложена методика применения инструментария экспертной поддержки принятия решений при идентификации информационных операций. Данная методика базируется на использовании экспертной информации, полученной путём проведения групповых экспертиз с помощью соответствующего инструментария для работы специалистов-экспертов через глобальную сеть. На основании полученной экспертной информации, инженер по знаниям строит базу знаний предметной области, путём применения соответствующего инструментария поддержки принятия решений. Согласно построенной базы знаний, уточняются запросы для анализа динамики соответствующих информационных сюжетов путём применения средств текстовой аналитики. Используя результаты анализа и построенную базу знаний, средствами поддержки принятия решений вычисляется степень достижения цели информационной операции, как сложной системы, компонентами которой являются конкретные информационные мероприятия. Далее, базируясь на проведённых расчётах, лица принимающие решения могут разрабатывать стратегические и тактические меры по противодействию информационной операции, оценивать её эффективность, а также и эффективности отдельных её компонентов.

Cognitive Ontology of Information Security Priorities in Social Networks

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***Abstract*—This article considers the importance of the field of knowledge used to describe the information security ontology, and the structure and the basic principles of a technology to create a competent SPARQL-based identification profile for a user of the Social Internet Network.**

***Keywords*—Social network, Internet, linguistics, semantics, SPARQL, ontology, identification.**

I. Introduction

The information security process should be comprehensive and based on a thorough analysis of possible negative consequences. This analysis implies the obligatory identification of possible threat sources, and those factors, which contribute to their vulnerabilities, and, as a consequence, the identification of the relevant threats to the information security. Based upon this principle, it is advisable to model and classify sources of threats and their manifestations relying on the analysis of such logical chain interaction as given below (Figure 1).

Figure 1. The logical chain analysis of the interaction

In this regard, the term "threat" means a potential threat or a factual threat of committing any action against an information resource protection object, which causes damage to the owner or user, and makes itself evident in a risk of distortion and/or loss of information.

The information relations subjects determine a great deal of information resources that must be protected from attacks of any kind whatsoever. They are the result of threat implementation and made through various protection vulnerabilities and are probable (risk - attacks).

From the analysis of the protection vulnerabilities, the threat source properties and the probabilities of a possible implementation of the said threats in a particular environment, risks should be identified for a given set of information resources. This, in turn, enables the protection policy to be specified, which is set by the security policy. The security policy determines a consistent totality of security mechanisms and services adequate to the values to be protected and the environment where they are used.

II. System information security - ontology

The knowledge representation using ontologies in information retrieval systems for information security makes it possible to execute multi-aspect structured queries that can be represented as a graph. Based on the ontology technology, the information security system may offer to concretize, or vice versa, to expand a query if it is satisfactory too much (too little) to objects. Furthermore, the ontology allows us to propose the user himself to overview the field of knowledge using the concept navigation, moving from one concept to another due to the links between them.

Language classes based on different mathematical models to define the object domain ontology are shown in Figure 2.

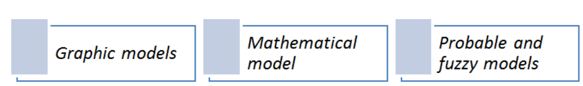

Figure 2. Language Classes of Mathematical Models

In the systems based on the ontologies, the methods used to extract information are shown in Figure 3.

The major advantages of using ontologies for knowledge representation may be noted as follows:

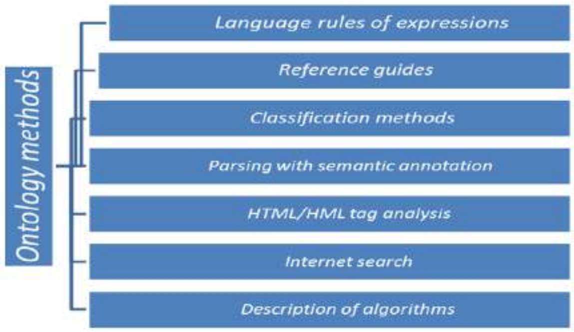

Figure 3. Available Information Extraction Methods

- Flexibility of a data model, which enables the model to be modified and extended with relative ease.
- Possibility to re-apply the existing ontologies.

The ontology is a method of representing knowledge by using a finite aggregate of concepts and relationships between them (Figure 4).

Figure 4. General Ontology Conceptualization

III. THE METHODOLOGY OF USING ONTOLOGY

If the ontology is a formal object domain model expressed, for example, as a graph of concepts and relations, then it generalizes a hierarchical data structure usually used for the filling in the extraction task. The information extraction is traditionally to find data, which describes some domain knowledge specified by the data structure.

To extract information, a prepared source selection-based training and / or heuristic models may be used that may be based, for example, on the usage of predetermined lexical and syntactic patterns, or ontologies.

The information extraction direction by using ontologies has stood out from the general information extraction problem relatively recently but has been already marked as a perspective trend towards the development of information extraction systems.

In many systems, the information extraction includes the following steps:

- Information search;
- Extraction of terms;
- Extraction of name groups such as names of people, organizations, and geographic positions;
- Extraction of words and word-combinations, which designate one and the same object (coreference resolution);
- Normalization of terms, which makes it possible to connect them with a formal description of the object domain;
- Extraction of semantic relationship between the terms;
- Duplicate record search;
- Normalization of records, i.e., reduction thereof to the standard form (see Figure 5). Possibility to re-apply the existing ontologies.

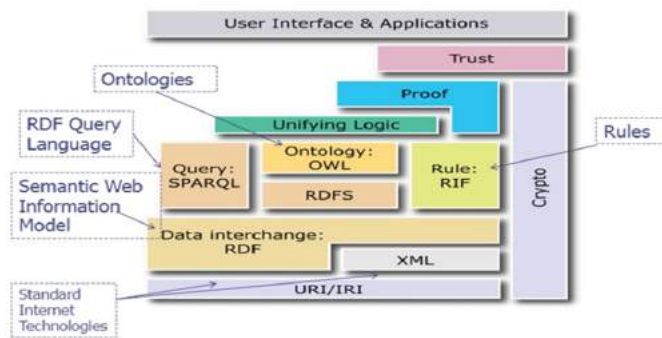

Figure 5. W3C Semantic Web Stack

The building and population of ontologies are closely related to the information extraction by using ontologies. The building of ontologies includes extraction of sets of concepts and names of relations as well as instances of the said concepts and relations between them, and the population of ontologies implies concepts, relations, and is aimed at the search of instances of concepts and relations between them.

It should be noted that the problems of building and populating ontologies are currently very pressing for the following reasons:

1. The construction and population of ontologies require the development of algorithms for an automatic highlighting of information from texts in a natural language. The most part of information in the Internet is contained just in this form. The manual processing of such data requires a good deal of permanently increasing human resources due to the huge volumes of stored information. This is precisely why the intelligent algorithms that automate the said process, acquire great importance;

2. The populated ontology is a stock information resource for a semantic web. To realize vision of the said semantic web, automatic metadata generation means are required. The semantic annotation makes it possible in future to process the said information by machines embodying the concept of the Semantic Web;

3. The population of ontology may be used to improve its quality. The basic idea is that if the ontology helps to

effectively extract the necessary information from texts, one can conclude that the ontology adequately describes the field of knowledge.

The major issue related to the information extraction is that the existing systems either need the learning under such documents as marked manually by experts, or only enable the data to be extracted from structured texts. The notion or the essence is a class of individual objects or instances, and types of relationship between the concepts are shown in Figure 6 [4].

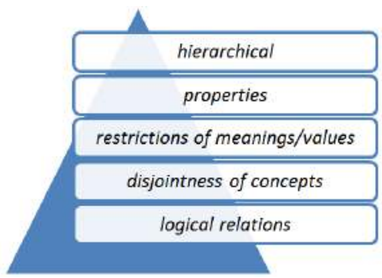

Figure 6. Types of relationship between the concepts in the ontology

IV. Modern problems of information security systems: ontology

Recently, the researchers have been paying more and more attention to the problem of extracting information from the World Wide Web. The Web HTML-pages have the advantage over straight texts that they contain markup elements such as lists, headings and tables.

Another feature of Web-documents is the fact that information therein is usually generated automatically from some databases that changes the process of extracting information from such texts to the process of “decoding”. Finally, we should mention a great deal of data available in the Internet and their heterogeneity.

The above-listed features determine a number of methods usually applied when extracting data from the World Wide Web. If in the traditional systems of extracting information from unstructured texts the natural language processing methods are usually applied such as dictionaries and grammars, algorithms for the machine learning and extraction of templates are used more often in the systems of extracting information from the Internet, which are based on the syntactic properties and visual structure of Web-pages (Figure 7).

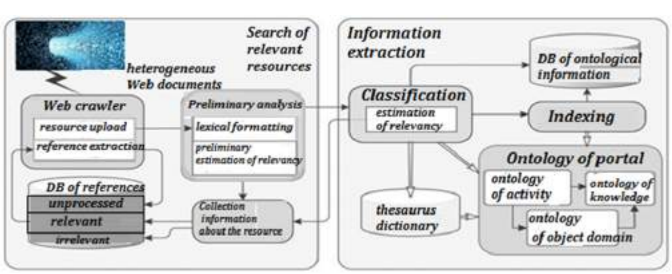

Figure 7. Operational diagram for information object when working with users

Information on the Internet Web-pages is divided into two classes:

1. Information generated automatically from the structured databases;

2. Information published manually.

The information search is to select the relevant documents from a large collection. In this task, the document is nothing more than mere words, whose meanings and relations are not considered. The search engine does not generally enable the complex analytical queries to be executed that require the analysis of the content of documents. The data extraction direction, which is less developed, just assigns a task to single out a structure, i.e. a value of information from unstructured texts.

The task to extract information from an unstructured text is important in the data analysis and processing direction. The relevance of the task is caused by the rapidly growing volume of unstructured information, for example, in the Internet. In general, the information extraction implies a certain data structure or template to be filled with such information as contained in the text data in the natural language, or, in other words, instances of certain classes of objects or events, and relations between them to be identified. According to the study of Russell and Norvig, the information extraction is “in the middle” between the information retrieval, which consists in the selection of those documents that meet the user’s query, and the understanding of the meaning of a text implying a deep analysis of the said text with a view to identify its semantics [1, 3, 4, 10, 11, 13].

The information security ontology based on a case approach is shown in Figure 8.

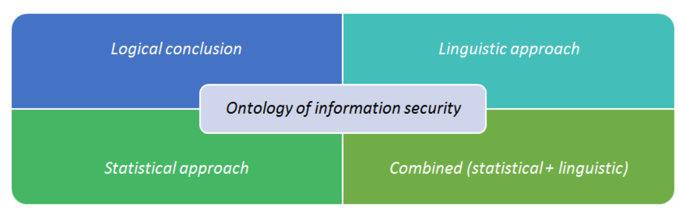

Figure 8. Ontology-based information security methods

On the one hand, it allows the use of a powerful mathematical tool and the obtainment of a theoretical proof of the efficiency of the algorithms. On the other hand, the most of these approaches have one significant drawback. Its essence is that they are based on the assumption of independence of the occurrence of words in a sentence. For the natural language, such a hypothesis is an excessively strong [7].

Unlike the linguistic approach, the major issue in the implementation of the statistical approach is a “silence” - a situation where the terms consisting of one word remain unnoticed by the system. In the studies of the recent years, statistical and linguistic methods are often combined. Here the ACABIT System and TRUCKS can be noted [7].

Thus, the use of ontologies ensures the compliance with the requirements for the developed system, which consists in the need for the inference of a new knowledge.

V. The classification of knowledge manipulation

The technological elements of the information modification system are a manipulative impact on the users of social networks. For this purpose, a complex criterion is used based on the accounting of combination of the following parameters:

1. Frequency of the use of technologies;

2. Range of application thereof;

3. Level of impact.

Subject to the complex criterion, those groups of manipulative methods may be singled out, which are the most multipurpose, with a high frequency of occurrence in different information war technologies having an area of application some information and communication situations such as public debates and group discussions, speeches at public rallies and demonstrations, in mass media, in intergroup and interpersonal conflicts characterized by a sufficiently high efficacy and impact on the human mind. These methods are characterized by a high degree of expressiveness in all three parameters of the manipulative impact on the users of social networks.

The application of text message processing methods to protect against information modification is critically important in cases where the unambiguous identification uses characteristics of information and communication facilities by calculating network data, such identification methods.

A lot of online resources and services such as forums, portals, online stores are faced with various aspects of the problem of manipulation and an artificial formation of public opinion by "organizing" purposeful thematic dialogues where a number of users have several accounting records.

The methods of the information and psychological impact on the mass consciousness are divided into the following seven basic groups of the information and psychological impact:

1. "Name calling";

2. "Glittering generality";

3. "Transfer";

4. "Reference to influencers", "on recommendation", "testimonial";

5. "Plainfolks"; "Card stacking"; "Dealing a card from the bottom of the deck";

6. "Common platform" or "bandwagon" [2,15].

The possibility to use portals and sites for dissemination of information and insufficient functionality of user identification and authentication mechanisms, those users who leave messages, determines a number of ways to improve protection systems and monitoring systems for information security and information and telecommunication facilities.

VI. Model developed Ontology System

The ontological approach to knowledge representation allows the use of the existing and approved algorithms to execute analytical queries. Execution of analytical queries to the data is ensured in the course of interaction of the system end user with the software implementation of a model describing the field of knowledge.

The information extraction problem is different from the information retrieval and query problem. The information extraction systems may be be divided into the following four types according to the degree of participation of an expert in the system development and adaptation:

1. Customizable manually where the user defines, in a certain language, rules for information extraction from specific websites.

2. Training/learning. The user manually marks a training set of documents, which is used to build an information extraction module.

3. Partial training/learning. The user does not mark the whole training set but only provides some additional information, for example, he selects a template from the options provided by the system and marks data to be extracted.

4. Without training/learning. The system automatically marks the teaching selection and creates an information extraction module completely without the participation of the user [10, 11, 13].

A query in using ontologies may be executed automatically by the inference engines. As a query language for ontologies, SPARQL may be used.

In the paper, examples [7] of using SPARQL are given. A relation between the queries, the formal model of a system under development and the query code in the SPARQL language allows the monitoring of the impact of:

1.Modifications of the plurality of received requests in the system and the ontologies used upon the in the software system code;

2. Modifications of the software system code on the ontologies used and the requests under consideration.

The latter circumstance creates additional opportunities for an effective verification of the software at all stages of its life cycle [7].

In such cases, to identify the user, mathematical linguistics methods may be applied. Thus there occurs a need to develop:

- An identifier model for an Internet portal user based on the tuple of linguistic features of a short message;
- A method for creating a an Internet portal user based on the identifier model containing a tuple of linguistic features;
- A method for identifying an Internet portal user based on the component profile;
- A method for creating an Internet portal user's component profile, which implies a number of steps to be performed;
- Processing user communications within the Internet portal;
- Analysis of messages by the parts of speech followed by the use of templates (syntactic patterns) to select the most common phrases;

- Lexicographical analysis of a message and selection of phrases structures in accordance with the described patterns, and collection of statistics about the use of punctuation marks and special characters;
- Selection of lexical phrases the basis of words and word forms of the language, and also identification of thematic special words and phrases typical for audience of a specific form.

Once the Internet portal user's profile has been studied, as well as the essence of the methods and means applied, and the reasons, which induced to commit violations, these reasons may be either affected, or the requirements for protecting against such violations may be defined more precisely.

And the model of a violator should reflect his practical and theoretical capabilities, a priori knowledge, time and place of action etc.

In developing a user profile model, the following should be determined:

- A category of persons, to whom the violator may belong;
- Causes of the violator's actions (goals pursued by the violator);
- Qualification of the violator and his equipment (methods and tools used to commit a violation);
- Restrictions and assumptions about the nature of possible actions of the violator.

According to the results the researches revealed that, one of the most promising areas of scientific research as related to the analysis, forecasting and modeling of semi-structured and badly formalized phenomena and processes are a fuzzy logic.

The mathematical theory of fuzzy sets (fuzzysets) and fuzzy logic (fuzzylogic) are generalizations of the classical theory of sets and the classical formal logic. The fuzzy inference algorithms differ mainly in the form of rules used, logical operations and a kind of the defuzzification method. Some fuzzy inference models are developed by Mamdani, Sugeno, Larsen, and Tsukamoto [84]. Such approach allows us to solve problems of improving the functioning of different systems under the conditions of insufficiency and unreliability of information on the running processes if assessment is subjective.

The requirements for the other stages of implementing the algorithm for building ontologies and the entire algorithm overall are as follows:

1. The algorithm should extract hierarchical and associative relations between the terms;

2. The ontology should reflect the relevant state of the specified field of scientific knowledge;

3. The accuracy and completeness of extracted terms and relations should not yield to the existing and approved algorithms for building ontologies;

4. The algorithm should require no training, or there should be a possibility to receive the necessary teaching selections from the public sources without spending much effort for their processing;

5. The algorithm should not require a large scope of manual labor of experts in the predetermined object domain tuning;

6. The sources of data for the algorithm should be publicly available and regularly updated;

7. The algorithm should have a modular architecture;

8. The possibility of configuring the algorithm automatically for a specific field of knowledge.

The information security ontology must contain as much information as possible about the field of knowledge, in particular, not only the hierarchy of concepts and trends but also non-hierarchical (associative) relations.

VII. Conclusion

The formal model of the ontological object domain is a graph of concepts and relations. The use of ontologies is a natural development of the direction, in addition, mathematic models and algorithms, and architectural and technological solutions may be developed relying on the ontologies to establish a system of replenishment and storage, analysis and issue of that information on request, which characterizes the performance of the User - information on the Internet Web-pages. The hierarchical structure of data is used for the filling in/population in the information extraction task. To identify users on the Web-pages of social networks, the following methods should be applied:

- Identification, the use of which is difficult due to the possibility of changing technical characteristics of the device;
- Determination of the authorship of a text after a linguistic correction, which will require a substantial adaptation for the processing;
- Development of a tuple of linguistic features of a short message, which enables the identifier construction features to be taken into account.

By using the ontologies and SPARQL technology, queries to the system may be formally described, thus, creating guarantees of their calculation and additional features for an effective verification of the system code at all stages of its life cycle. It is necessary to create a software prototype to keep record of and to analyze data when modeling and identifying the user's profile in social networks under the conditions of the information war.

The information extraction direction by using ontologies has stood out from the general task of information extraction relatively recently but has already been marked as an outlook for development of information extraction systems. The information extraction traditionally aims to find data that describe a certain field of knowledge specified by the data structure.

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КОГНИТИВНАЯ ОНТОЛОГИЯ В ИНФОРМАЦИОННОЙ БЕЗОПАСНОСТИ СОЦИАЛЬНЫХ СЕТЕЙ

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Процесс обеспечения информационной безопасности должен быть всеобъемлющим и основан на тщательном анализе возможных негативных последствий. Этот анализ предполагает обязательную идентификацию возможных источников угроз, а также те факторы, которые способствуют их уязвимости, и, как следствие, выявление соответствующих угроз информационной безопасности. Исходя из этого принципа, то целесообразно моделировать и классифицировать источники угроз и их проявления, опираясь на анализ такого логического взаимодействия цепи. В данной статье рассматривается важность области знаний, используемых для описания онтологий информационной безопасности, а также структура и основные принципы технологии для создания компетентного SPARQL на основе профиля идентификации для пользователя сети Интернет социальной.

Thesaurus of the Discipline on Information Security Management System

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Abstract—**This paper, the technique of construction of an WordNet type lexical-semantic database in Kazakh language is offered , questions of this database integration with the same type of databases and its representation in the OWL format are described.**

Keywords*—*lexical-semantic database, thesaurus, OWL.

I. Introduction

The primary concern of this research is to build Kazakh-English WordNet of the discipline on information security management systems, which includes lexicons of Kazakh and English languages. The development of such a variant of the dictionary consists of two stages - constructing of Kazakh WordNet with describing of the vocabulary of the Kazakh language and combining of the resulting WordNet with the latest implementation of The Princeton WordNet by the use of ILI.

For reviewing and editing of dictionary en-tries of WordNet and hierarchy of their rela-tionships trees of hyponymies (species of the genus relations)and meronymies (part-whole relationships) are built. The editor is used to "finish" the processing of the dictionary.

II. Stages of constructing

The practice of designing and constructing of the dictionary has showed that editing of a specially prepared text files and a set of utilities for making changes to the database are the most effective. For each stage of building a dictionary formed a set of files and their means of treatment. These sets of files and their means of treatment are formed for each stage of building of the dictionary.

The basic structural unit forming a dictionary paper of WordNet is a synonymous series - "synset"- combining tokens with a similar meaning.

Each synset represents a certain value,a con-cept of a language. To clarify a value of a synset its interpreta-tion and usage examples of tokens of a syn-set in some context are determined. Each synset represents a certain value,a con-cept of a language. To clarify a value of a synset its interpreta-tion and usage examples of tokens of a syn-set in some context are determined. Information retrieval thesaurus (IST) - a con-trolled vocabulary of terms of a natural lan-guage, indicating the relationships between the terms and intended for information re-trieval.

Mains relation of thesauruses: Syno-nym, antonym, hyper-onym, hyponym, mer-ony.

EuroWordNet. Resource the WordNet, only developed for the English, called the world's great interest in the development of such re-sources for dozens of other languages.

Developing WordNet-s for the different languages within EuroWordNet project in-cludes two phases. In the first phase (1996-1999) EuroWordNet began as an EU project, with the goal of developing wordnets for Dutch, Spanish and Italian, and to link these wordnets to the English wordnet in a multi-lingual database. In 1997, the project was extended to include German, French, Czech and Estonian. EuroWordNet (http://www.hum.uva.nl/ewn) was completed at the end of 1999.

There was a need to do a serious choice in the project: whether to strive for the devel-opment of a language-independent struc-ture, with which it is necessary to compare the units of each language, or maybe it needs to have a common system of synsets - a new unit in the hierarchical network can be ena-bled, if at least one language from consid-ered has a token or a steady turnover with a value.

According to the adopted in the draft deci-sion , each WordNet must retain the speci-ficity of its language. Thus each WordNet should contain refer-ences to the values of the English WordNet that allows to compare WordNets, detect inconsistencies in their constructing and see the differences in the designs of language systems. At the same time a small top-level ontology was created in the framework of the project, to which must be attributed to each created WordNet.

Authors of EuroWordNet emphasize the dis-tinction be-tween a resource of wordnet clas-ses as linguistic ontologies and formal on-tologies. Linguistic ontology must reflect the relationship between lexicalized words and expressions of the language, for example, to describe what words can be used to replace the text in the word spoon (spoon) - object, tableware, silverware, merchandise, cutlery.

Thus, WordNet– is a network of language-specific lexical-ized units (as opposed to for-mal ontologies, which represent the data structure with a formal definition).

Basic alleged use of WordNet - the predic-tion of a possible replacement of lexical units in the text for the purpose of information retrieval, text generation, machine transla-tion, word-sense disambiguation.

Given the difficulties that arose in the appli-cation of WordNet applications, European developers have proposed a number of sig-nificant innovations in the structure created by WordNet. A large class of these changes is concerned with describing of the relations between synsets, which can be divided into the fol-lowing groups:

- Ascription of additional at-tributes to existing relation-ships;
- Introduction of relations be-tween the different parts of a speech;
- Introduction of additional re-lationships between words (synsets) of the same part of a speech.

RDF - language representing information about the WWW resources. In particular, RDF is used to represent the metadata asso-ciated with web resources, such as ”title”, ”author”, ”date last modified.” But RDF can be used also to provide information about the resources of the ”second type”, to which it is possible to refer only (or to identify on the Network through URI), but it is impossi-ble to get to them access through the Net-work directly.

It can turn out that in certain cases for con-trol of meta data it is enough to use XML and XML Schema (or generally to be re-stricted to a sub-element of HEAD of the HTML element). But this approach is poorly scaled: in case of increase in volume of meta data, complication of their structure control of the meta data constructed on the basis of XML Schema becomes the labor-consuming task for which decision RDF is intended.

Among the semantic relations in the diction-ary of the Kazakh thesaurus WordNet the following nouns are set: Hyper-onym, Hypo-nym, Meronim, Holonim, Ontonim, Homo-nym, Synonym. Having created the new project, we realize it further in the environment of Protege.

The last description of the standard language – the language OWL, World Wide Web Consortium (W3C).

Protégé OWL describes not only concepts or concrete objects. Protégé OWL has a great number of operators, for example intersec-tions, merges, denial and many other things. Mostly it is made on the basis of an informal logical model.

The main goal of our work consists in devel-opment of the Kazakh language WordNet. Such option of development consists of two stages - the subject area of the Kazakh lan-guage WordNet - lexicographic system and the qualifier of system. To program the project built in the program-ming environment Protege as a basis need to take a thesaurus ontological model, build in Python programming environment. The initial window of building of lexical analysis is WordNet Kaz. When searching for words we can see the full lexical analysis.

III. Conclusion

The considered system intends for creation and editing of a wide class of thesauruses and the close to them structures. Implemen-tation of a set of interfaces to these systems allows to use them as independent applica-tions – the lexicographic WordNet system and system of qualifiers, and to include them in composition of more difficult systems.

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ТЕЗАУРУС ПО ПРЕДМЕТУ СИСТЕМЫ УПРАВЛЕНИЯ ИНФОРМАЦИОННОЙ БЕЗОПАСНОСТИ

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В работе предлагается методика построения лексико-семантическои базы данных типа WordNet по предмету системы управления информационной безопасности на казахском языке. Описываются вопросы её интеграции с другими базами данных WordNet и представление в формате OWL.

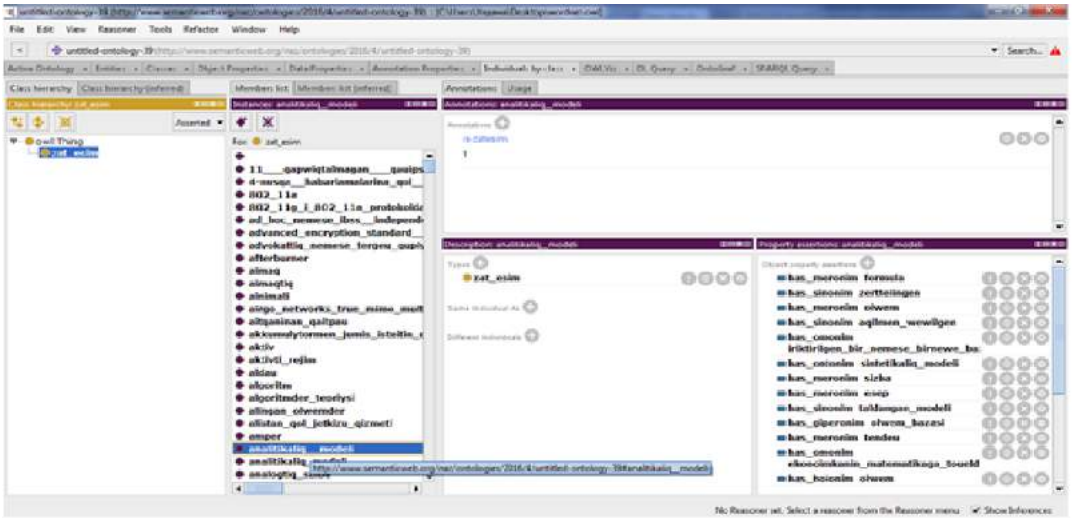

Figure 1. Writing the words of an individual

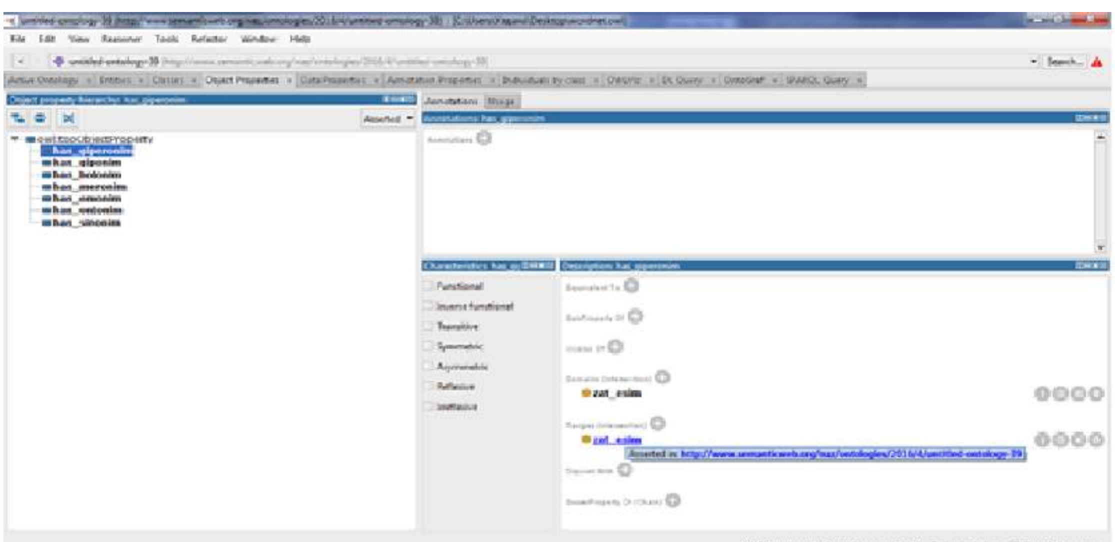

Figure 2. Window of properties of an object. (Object PropertiesTab)

Figure 3. Showing of object properties

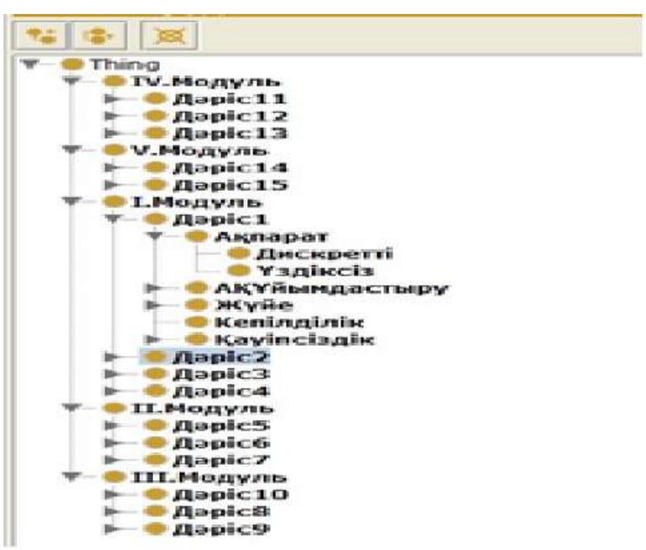

Figure 4. Division into classes and internal classes

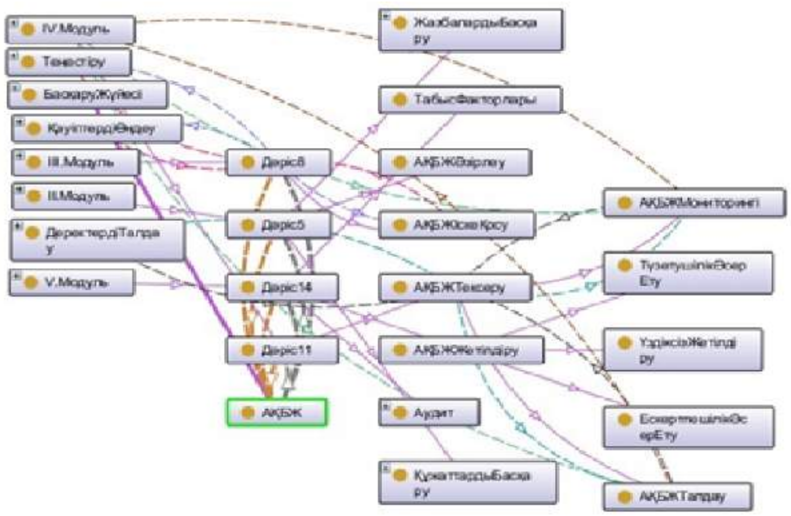

Figure 5. Relationship between classes and modules of concepts of ISMS

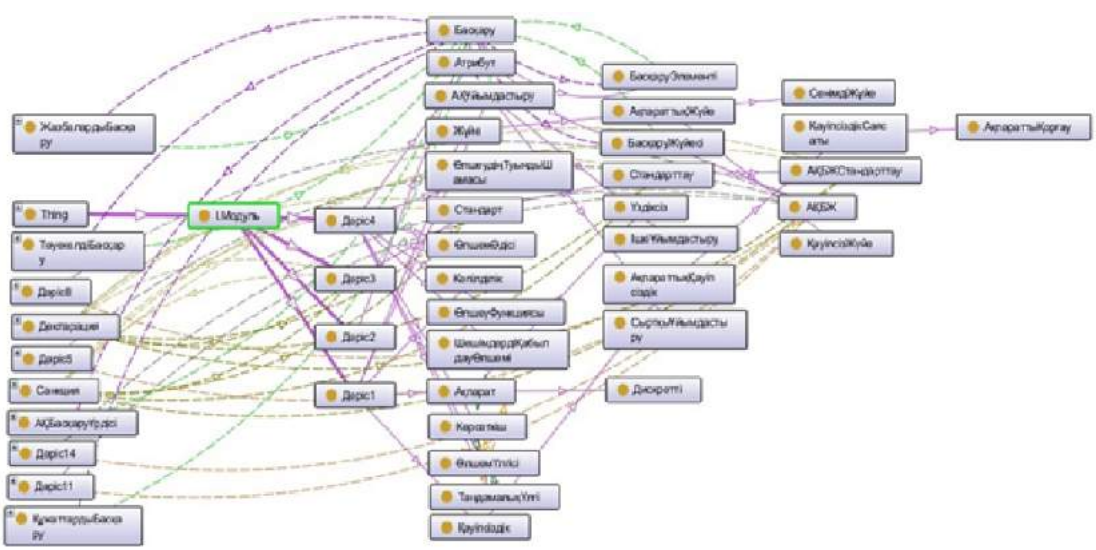

Figure 6. View of general ontological model 1

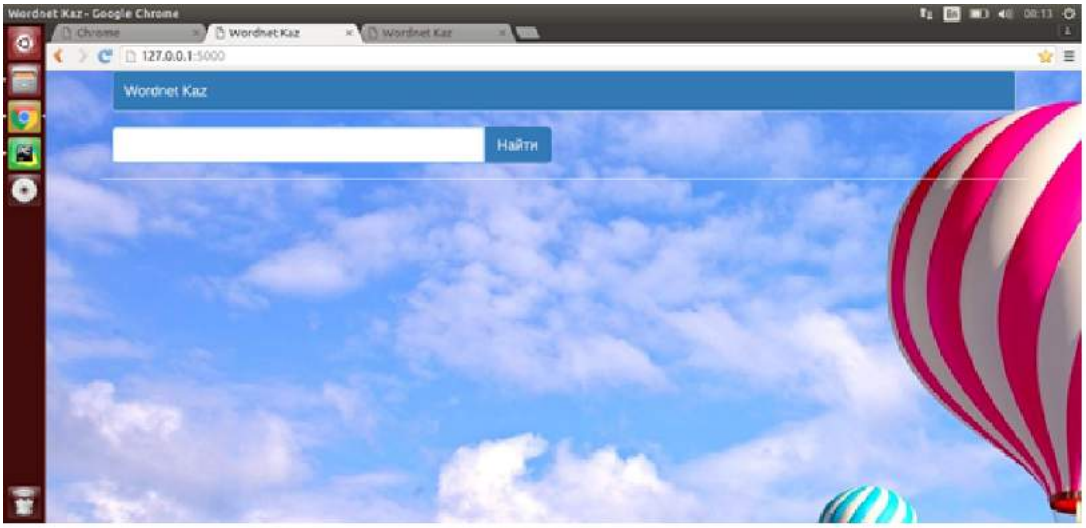

Figure 7. Showing of the Results of Wordnet Kaz

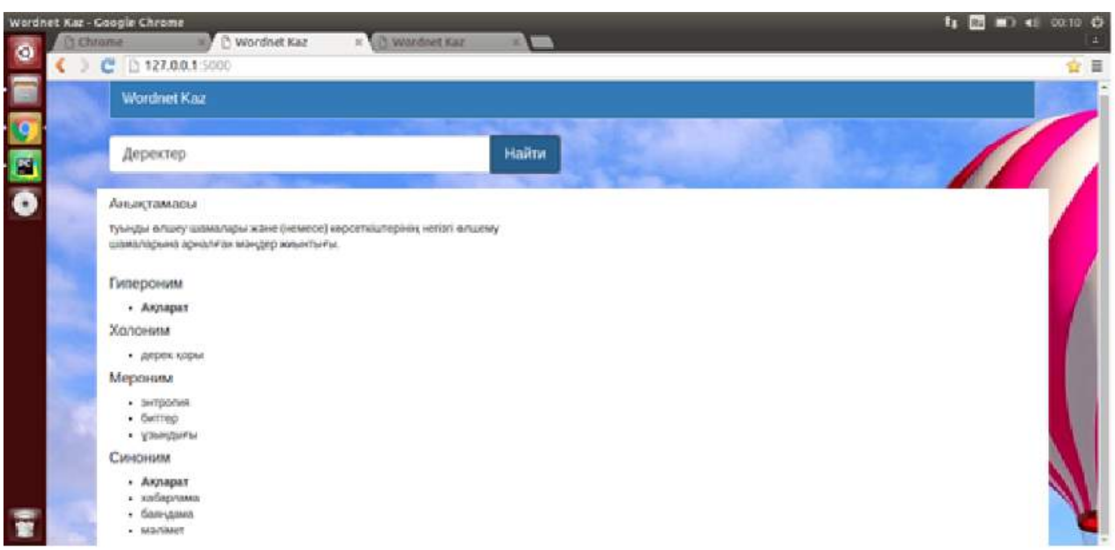

Figure 8. The main form

Elements of Information Security in Integration Corporate Information System on Base of Intelligence Technologies Use

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Abstract—**The main directions of information security when using intelligent technology are done. The uses of information security (IS) of corporate information system (CIS) using clouding computing (CC). The conception of integrated CIS is introduced. The model of ICIS using multi-agent technology is proposed. The main problems of information security ICIS are analyzed, authentification user mechanisms are shown, its models and algorisms are done.**

Keywords*—*intelligent technology, information security, authentification mechanisms.

I. Introduction

The IS situation is following: the present stage of development of the theory and practice of support IS – on the one hand, the reinforced attention to safety of information objects, increase in requirements for information defense (ID), acceptance of the international standards in information security field, the growing expenditures on protection support, with another – the increasing damage caused to owners of information resources what the published data on damage to world economy from the hacker attacks confirm [Vishnyakou, 2014].

Output is implementation at all stages ID the intellectual technologies acquiring the increasing distribution in ID systems. On the one hand, data collection and processing from the Internet about a status, the direction of development and level of threats of processes in the world community and synthesis of knowledge, the reflected in sources, realized on the basis of their intellectual processing, gives the new integrative quality allowing to predict, simulate and prevent development of security risks. On the other hand, the use of intellectual technologies of data handling gives an opportunity to raise the security level of different corporate information systems (CIS) and platforms of the cloud computing (CC) [Molyakov, 2014]. Development of technologies and environments of cloud computing (ECC) enters new sources of threats which need to be considered in case of safety of computer systems and services. The tendency of ECC use in CIS of organizations is entered [Ridz, 2011]. 2014].

II. The directions of intellectualization in ID

Intellectual systems of ID (ISID) providing detection of the attacks as the intelligent tool use the neural networks (NN), systems of a fuzzy logic and, based on rules, the expert systems (ES). If NN is presented in the form of the separate system of attack detection, then in case of traffic handling there is an information analysis on existence of abuses. Cases with specifying on the attack are redirected to the administrator of safety. This approach is high-speed as one level of the analysis is used. One of the main shortcomings of NN is «opacity» of formation of analysis results [the Kalatch, 2011].

In the knowledge base (KB) of ES contains the description of classification rules to the appropriate profiles of legal users and scenarios of attacks to CIS. ISID shortcomings on the base of ES are: the system isn't the adaptive and not always the unknown attacks are found. In systems of attack detection it is possible to select application of the neural networks added by ES. Sensitivity of system increases as ES obtains data only on events which are considered as suspicious. If the neural network due to training began to identify the new attacks, then expert system KB is necessary to update [the Kalatch, 2011].

Use of hybrid neuro-expert or neuro-fuzzy systems allows to reflect fuzzy predicate rules which are automatically adjusted in training activity of a neural network in structure of system. Property of adaptively of fuzzy NN allows to solve separately the taken problems of identification of threats, comparisons of behavior of users to the templates which are available in system, to automatically create new rules in case of change of threat field [the Kalatch, 2011].

Shortcomings of these systems are: need of presence of high qualification experts; the difficulties arising in case of adaptation of methods to needs of the specific organization; impossibility to estimate efficiency of the specific complex of security features applied on subject to protection; the requirement of existence at the enterprise of authentic statistics on incidents of information security.

III. The concept of integrated CIS

Development of technologies and the environments of ECC enter new sources of threats which need to be considered in case of safety of computer systems and services. The tendency of use of ECC was outlined in CIS of organizations, integrated CIS (ICIS). The dynamic nature of processes of information exchange complicates possibilities of operational assessment of risks of violation of confidentiality, integrity and accessibility of the program and infrastructure resources provided in the mode of remote access. In the report structures of ICIS, model for information identification in ICIS and the concept of intellectual system of support of its information security are considered.

Let's separate ICIS on technologies of CC application: small – on the basis of SaaS, averages – on the basis of IaaS, big on the basis of PaaS. Most the enterprises will work on hybrid model, providing and consuming cloudy services which will be integrated if necessary into the IT traditional models. The new model of information systems is created: instead of installation of application packages on the computers the companies will use browsers to get access to the wide range of the cloudy services available according to the first requirement. Rent of cloudy services allows: to carry the expenditures connected to use of IS to variables, but not constant expenses; to create the analysis systems of data displaying operation of the enterprise, integrating data from separately CRM and ERP systems; to create prototypes of new products and innovative projects, developing interaction between employees, overcoming boundaries of the organizations and states.

The directions of development of ID in ICIS can be defined as following [Vishnyakou, 2014]:

- development of models of violation and counteraction of ID in ICIS on the basis of a choice of an optimal variant of response to safety events;
- enhancement of ID system architecture for ICIS providing effective management in the conditions of uncertainty of a status of the information environment;
- enhancement of instrumental program complexes with intellectual support of decision-making with a research of efficiency of methods, models and algorithms;
- development of technologies the multi agent of systems for detection of the attacks, counteraction to threats of violation of ID, assessment of level of security of information in ICIS;
- development of models and security features of ICIS on the basis of a cloud instrumental platform of design of the ISID on the basis of semantic technologies.

IV. Information security models in ICIS

Input of the model considering dynamic character of resources and structure of protocols of network interaction is the flow of network packets which come to ID system fire-walls in the environment of CC, and an output is division of packets into the virtual connections, classification of everyone is this on accessory to connection and determination of a subset of rules of filtering for them. Model of counteraction to threats of ID in CIS in which the decision on option of reaction is made depending on probability of the attack estimated with use of the mechanism of fussy logical output [Mashkina, 2009].

For development of the ID models in ICIS it is offered to use object algebra (OA) [Vishnyakou, 2014]. In OA the description of carriers and communicators objects in computing environment are shown, also the abstraction layers of objects are developed; representation the unlinked, parallel, competing objects at one abstraction layer is done; the description developing, paused, created, nonexisten objects are entered that allowed to show that the main disjuncts (rule, fact, request, empty one) are similar to these types of objects [Vishnyakou, 2014]. In the ID models objects are transformed to models of agents. In a general view we will present the ID model in ICIS in the form:

$$M_{ik} = (M_t, M_a, M_s, M_p),$$

where M_t – model of detection of threats, M_a – model of user authentication, M_s – the model of the analysis and assessment of a software (allowing to receive an output about existence or absence of its destructive properties), M_p – model of counteraction to threats.

Taking into account multyagenthy approach this model is transformed to the following look:

$$M_{ik} = (A_t, A_a, A_s, A_{ta}, A_p, A_c),$$

where A_t – agents of detection of threats, A_t – agents, the users differentiating access rights, A_s – agents of the analysis and assessment of a software, A_{sa} – agents determination attack type, A_p – agents, the attacks building the scenario of behavior for reflection, A_c – agents coordinators of all multyagenthy system. For small ICIS this model will be reduced to a type:

$$M_{ik} = (A_a, A_s, A_p, A_c).$$

V. Models of authentication of users in ICIS

In article [Vishnyakou, 2016] approach elements for safe operation of users in the environment of CC are provided. Participants of interactions: the user (as users there can be persons and the organizations), an authenticator of trusty (Trusted Authenticator – TA), cloud provider of services (Cloud Service Provider – CSP), the digital signature (DS), the agent of CSP's. Functions of elements of this approach are given below.

1) The user has limited access to services from a cloud of the offered services, he requests cloudy resources from CSPs.
2) TA connection establishes trusting relationships with an authentication organ. The task TA in the cloudy environment – to provide to the user safe access to cloud services through service provider.
3) The cloud service can dynamically be scaled for satisfaction of needs of users because the service provider provides the equipment necessary for service, and the software.
4) The digital signature (DS), is the digital signature which identifies the identity of the message sender or signed the document, and certifies that original contents of the sent message or the document, didn't change.
5) The agents of CSP's are capable to make decisions on execution of tasks on behalf of the users. Agents have the right to interact with other agents by negotiations, cooperation and coordination. In CSP the agent works for rendering of services, service of negotiations, services of cooperation and their coordination.

Let's expand this model: X – user, Y – authenticity authenticator. For the description we will enter designations: t_x – time tag, r_x, r_y – random numbers X and Y respectively;

S_x, S_y – the signatures generated by X and Y; S_{koh}, S_{kou} – certificates of public key of X and Y. Let's give authentication algorithms.

1) One-sided authentications using time stamps:

   $X \rightarrow\ Y : C_{koh},\, t_x,\, I_x,\, S_x(t_x, I_x)$

   After acceptance of the message the authenticator of trusty checks correctness of time tag t_x, the got I_x ID, and using public key from the certificate S_{koh}, the correctness of the digital signature $S_x(t_x, I_x)$.

2) One-sided authentications using random numbers:

   $Y \rightarrow\ X,\ \ r_y$ Y (1); $X \rightarrow Y:\ C_{koh},\ \ r_x,\ \ I_y,$ $S_x(r_x, r_y, I_x)$ Y (2).

   The authenticator of trusty sends to the user the X random number of r_y. based on the message from X. Using public key X from the certificate S_{koh}, Y checks the correctness of the signature of $S_x(r_x, r_y, I_x)$ under r_x number, r_y number received in the first message and its I_x identifier.

3) Double-side authentications using random numbers:

   $Y \rightarrow\ X,\ \ r_y$ (1); $X \rightarrow Y:\ C_{koh},\ \ r_x,\ \ I_y,$ $S_x(r_x, r_y, I_x)$ (2); $Y \rightarrow\ X : C_{koy}, I_x, S_y(r_x, r_y, I_x)$ (3);

   In this algorithm message handling 1 and 2 is executed as well as in previous one, and the message 3 is processed similar to the message 2.

VI. Authentication algorithms

In the authentication server for authentication of the user and a cloudy Web-server providing services to the user the sequence of actions is executed.

1) The user enters the information for registration.
2) The system of the user sends them as input data to a Web-server.
3) The server of authentication generates one time code and sends to a mobile application.
4) The user enters this code as a contribution during session time as after user session shall log in again.
5) After successful login, the user can get access to resources.

Steps of an algorithm of user authentication for registration in the cloudy environment through a mobile application the following.

1) The user clicks on the registration button on the page of the website.
2) Goes request to the Web-server for registration.
3) The Web-server creates the login page and returns it.
4) The user enters authentification information.
5) The user clicks the registration button.
6) Information on the user is transferred to the Web-server.
7) The Web-server checks information for correctness (validity) of filling and creates filling errors.
8) The Web-server returns filling errors to the user
9) The user makes corrections and again sends information to the Web-server.
10) The Web-server confirms a filling correctness
11) The Web-server saves information.
12) The Web-server transfers the message on the carried-out registration for e-mail.

VII. ID architecture conception

The ID architecture includes system of input of influences, the knowledge base on the basis of rules of production and frames, the solver with use of an inference engine, the basis of agents, the communication medium with agents, the coordinator.

For the task of detection of the virus attacks, the system of influence input transfers the facts about external influences to the knowledge base. The solver inference-based works out the decision which is transferred to the coordinator about changes of an external environment. For the distributed decision the coordinator can use their different types from a basis of agents: subcoordinator, performers, integrator.

Agents can be connected among themselves in the form of multi-level architecture. Such multi-level architecture of agents is suitable for the decision of the task of detection of the virus attacks. Taking into account specifics of the solvable task the multi agent architecture shall include several types of agents which perform different functions. In an analysis result of information process of detection of the virus attacks on the ICIS networks it is possible to consider such agents: authentications of net surfers, detection of the attacks, determination of their types building the scenario of behavior for reflection of the virus attack which is the subcoordinator of all multi agent architecture.

(Expanded) solutions on an instrumental platform on the basis of multi agent technology are proposed [Vishnyakou, 2016]:

- the development of structure of the multi agent system of detection of the attacks including agents of workstations, servers, routers, a hypervisor and allowing to draw a conclusion about the attacks, a status and perspectives of its protection;
- receiving a method of acceptance by agents of the joint decision allowing to create communication of agents and based on analysis results of the data received from different sources, to estimate CC condition in general;
- the framing of a technique of detection of the attacks with use the multi agentny of technologies allowing to train multi agentny system and to use it for further detection of unknown influences of CC.

Such to an instrumental platform the designer of option includes, library of agents, the rule base, a basis of methods. Based on the description of requirements to ID option the designer generates system option for specific ICIS.

VIII. Conclusion

The direction in szi is development of models, methods, architecture and hardware and software of control of zee for the solution of the problem of protection of pussycats and the cloud instrumental platform of design of intellectual systems on the basis of semantic technologies.

Approach for safe operation of users in the environment of cloud computing is given. Participants of interactions: the user (to users there can be natural persons and the organizations), the authenticity authenticator, cloud provider of services – csp, the sign-code signature – ds, the agent of csp's. The model and autentifikafiya's algorithms, the concept of architecture of ib is provided.

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ЛЕМЕНТЫ ИНФОРМАЦИОННОЙ БЕЗОПАСНОСТИ ИНТЕГРИРОВАННОЙ КИС НА БАЗЕ ИНТЕЛЛЕКТУАЛЬНЫХ ТЕХНОЛОГИЙ

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Шираз

Показаны основные направления защиты информации при использовании интеллектуальных технологий. Введено понятие интегрированной КИС. Представлены направления использования информационной безопасности (ИБ) КИС с использованием ОВ (ИКИС). Предложены модели ИБ в ИКИС с использованием многоагентных технологий. Проанализированы основные проблемы информационной безопасности ИКИС, рассмотреы механизмы аутетификации пользователей, представлена ее модель и алгоритмы.

The Principles of Building Personal Data Integrators Using OSTIS Technology

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Abstract—**This paper describes principles of building personal data integrators using OSTIS technology. The main goal of creating such kind of systems is adaptation of heterogeneous services and transforming them into one personal information space. Personal data integrator is designed to become a one-way interface to the digital world, that will make an attempt to make this interaction easier and more efficient, allowing to solve user's specific tasks based on his specific context. Goal of the paper is to make design of personal integrator system that would understand the semantics of user personal data, understand how to interact with each specific user web service and be able to extend their functionality by creating intelligent agents. It is designed using the ontological principles and OSTIS technology. Personal data integrator is designed to be connected with several web-services to harvest the available user data and transform it into a powerful fragments of knowledge-base, integrated on semantic layer, that can be easily used by intelligent agents of the system.**

Keywords*—*personal data integrator, ontology, semantic network.

I. Introduction

During the evolution of information technologies absolutely new infrastructure appeared, that we currently can't imagine our life without: internet, web-services, smartphones, apps, social networks, etc. All of that changed the style of people's life and put them into a new type of space - information space. The personification of tools for this information access founded a new class of this space - personal information space. From the use cases point of view, it's very important to adopt this personal information space for goals and purposes of each concrete person, but there are no such technical solutions to solve that problem so far.

A. Problems and goals

The high demand of quick access to information resulted in a huge amount of different information services in internet, like email services, messengers, apps for time and task management, calendars, etc. Lack of any standards for building such kind of services resulted in theirs architectural, model and technological heterogeneity [1] [7] [8]. Models that have been used in each service were different both on technology and semantic levels as well, because of no binding between used technologies and domain objects.

All these factors influence on the end user in different ways:

- the need to adapt user to the interface in each service implementation;
- the complexity of initial service setup for personal needs;
- all user personal information is spread between different services, that leads to the search problems and duplications;
- the need to use several services to make task done.

All mentioned problems cause the need of special system creation, that will provide simple and efficient interface to manage the personal information space of a user.

To archive this goal we need to solve the following problems:

- Design an efficient method of data integration on the semantic layer. It's obvious that we need some common abstraction layer to integrate services from different domain objects. Integration of any data will bring us a value only if it would be integrated on the semantic layer [5] [12], otherwise some of the problems mentioned above still would not be solved. The problem of information services integration lies in the logical and semantic combination of heterogeneous data coming from different information sources, that will provide the unified representation of it and will give one common interface for manipulations [14].
- Design the universal user model and user information space. To personalize integrator for user's needs it's required to design the user model, that of course will be different for each person, but at least it should have unified skeleton.
- Design the universal information service model.
- Design models and methods of data integration. It's important to decide to consolidate data or only to integrate. The consolidation approach will solve issue of information spreading between sources by storing everything in one system, but will raise several other technical issues, like storing huge amount of data, keeping it in sync, etc. The virtual integration means that all data will still be stored in their source services, but user will get one common interface to manipulate it. Virtual integration doesn't exclude an ability of copying some most regular used information to the system, but at least the most of the data will stay in source services.
- Design the unified user interface of personal integrator.

The personal integrator of information services should allow user to get any personal information without a need of searching for source service, without a need of manual combining of data retrieved from different sources, without a need of using several services to get one task done. So the main goal of creating such kind of system is a personal maintenance of a user information need and making a one-way interface for communication with personal information space.

B. The analysis of current personal information assistants

Today there are a number of approaches to construct intelligent assistants and integrators of information services, which can be divided into several categories depending on the form of user and system intercourse and the way of system interpretation of coming information and queries. Primarily such solutions are focused on mobile platforms and employed by big companies that usually own information services are integrated.

1) Siri: Siri is a personal assistant made by Apple. It represents question answering system for the iOs operating system. Siri is based on the natural language recognition and machine learning technologies. Siri can be adapted to user pronunciation with time and can be integrated with a number of smartphone apps, such as calendar, contacts, music library, photo gallery [7].

Potentialities:

- Understanding of voice input. Siri knows how to react to a number of definite commands, respond to the questions.
- Reminders. Siri is able to remind the user about calendar events, some out-of-date tasks and other events, the user is subscribed for.
- Reporting of reference information. Siri can interact with search systems to seek the information and give the list of found resources conformed to the request.
- Interaction with other devices (Internet of things). Siri can control a TV-set, a laptop, a garage door, lights, watching cameras, etc.
- Interaction with social media.

In spite of impressive possibilities Siri has its own shortcomings. The key challenge is a weak personification, absence of exact user model, limited API given by implementers and primitiveness of build-in commands. Actually Siri is a natural language interface to interact with some apps which doesn't integrate user services into common information space, but delegate the execution of search and other user requests to the services.

2) Google Assistant: In contrast to Siri Google Assistant appeared not long ago as upgrade version of Google Now. Assistant represent a similar collection of possibilities but thanks to the absolute integration with other Google services, particularly with search service, gives wider capabilities to the user for the purpose of answers on different types of questions.

3) Cortana: Cortana is a virtual voice assistant with the elements of artificial intelligence from Microsoft Company. Cortana has the similar possibilities integrated Micrisoft services to each other. In contrast to Siri and Google Assistant the search system Bing is used. Cortana collects all the information about user accessible on the user laptop and cell, transforms it into internal representation and sends to Microsoft. Also Cortana demands gaining and sending off statistics about all information input to the computer from the operating system. One of the key Cortana advantage is the advanced system of different personal data authorization rules which is more flexible than the competitor ones.

C. Disadvantages

All the examined services have the similar set of possibilities and differ from each other in inconspicuous details. Siri has the best quality of speech recognition and synthesis, Google Assistant has excellent user model based on deep learning algorithms, Cortana has the control system of different personal data authorization rules. In spite of these advantages all the intelligent assistants listed above don't integrate personal information on the semantic level and don't solve a problem of personal information space heterogeneity [14] [22]. Examined intelligent assistants provide universal information access natural language interface and use service-oriented approach to integrate information resources for this purpose. This approach has a number of limitations [22] [23]. If we speak about intelligent system building, the main limitation is the impossibility of expansion of initial services capability and personification for concrete person tasks and necessity [21].

II. Provided method for personal intelligent integrator implementation

Data integration base of listed solutions is the search systems. Consequently they use syntax approach based on the data similarity. There is no doubt that machine learning methods, effective enough, are used in such powerful search machines as Google. These methods allow the photographs to be found even by text description. But even if machine learning is used, information is represented as a set of bits and bytes. The semantics is not taken into account. If data have their own semantics descriptions it will be possible to get to a whole new integration level – semantic level.

When this happens data semantics can be taken into account during data transmission and be used for its integration into knowledge base.

The idea of semantic technologies application to organize data interchange between information services is obvious enough [14]. If one system gives the other one not only the data but also information about its subject entity, it helps to treat exchanging system separately from each other better than using download to intermediate format or web-services SOA. Consequently systems report facts to each other. Classical integration solution consists of information services supplied information, mediators connected to them and an integration service. The main complication of this approach is the creation of united interface between mediators and the integration service.

Our approach to mediators creation is based on building of a united integrated services ontology, described all kinds of objects supplied by services and their connections, as well as services. Therefore there are models of information resources and models of data given by them in the ontology. As soon as the state of the data, the user is interested in, is changed in the information service, the proper mediator become active. It transforms necessary information according to the model described in the form of information resource ontology.

Such approach provides a number of advantages:

- Data transmission model doesn't depend on the model which presents data of donor information service;
- Mediator can be implemented in any programming language. Information services ontology is the standard and background information for its creation.

The main advantage of ontological approach to designing is considerable rise of design system flexibility. Except designing of subject domain ontology the meaning of ontological approach to information resource integration comes to the unification of data and its context and keeping of data with its metadata that provides an opportunity to take the data nature into account. The base of the integrator is the knowledge base containing both ontology of integrating information services and ontology of supplied data subject domains. The similar concepts from different resources are the points of integration. Therefore mediators are in fact agents of integrated knowledge base. Different kinds of agents and their groups (search agents, agents of marking subject matter out, conversion agent) can attend to knowledge base except mediators.

Primarily literary sources recommend Semantic Web technologies when choosing the semantic technology for data integration [16].

Unquestionable advantage of Semantic Web project is the commitment to independent distributed development of ontology. Knowledge of subject domain can be accumulated and defined gradually with the participation of great number of people without constant agreement. There are a set of tools ready for ontology designing and semantic repository implementation.

The most talked about problems of Semantic Web tools, especially of OWL language, are:

- Absence of answer, what part should be modeled with the help of classes and what part – with the help of samples. There is the ambiguity at determining of classes and their samples in Semantic Web tools [17].
- One more shortcoming is absence of possibility to define properties of properties directly. It prevents from modeling of subject domain attributes, n-ary relations and attributes of attributes.
- Web-orientation of the project and semantic network representation close to machine representation.
- Undeveloped standards of time variables view and fuzzy subject domains view.
- Weakly studied level of the ontology verification directed to the authenticity and completeness.

It's obvious that in spite of its popularity Semantic Web tools have a number of shortcomings. Firstly because Semantic Web tools were originally directed to the machine-oriented description of information resources in the web-space without including of comprehensive approach to the problems of semantic view in the context of artificial intelligence theory.

The alternative technology of intelligent systems designing is Open Semantic Technologies for Intelligent Systems (OSTIS) [24]. OSTIS project is intended to intelligent information systems and their components design. In this case such systems will be based on the knowledge presented in the form of ontology. As part of this article systems controlled by knowledge built on the OSTIS technology will be named as ostis-systems.

If there is a set task, information systems mediated on the base of OSTIS technology can be not completely intelligent but serve for the accumulation of data formalized by complicated model. As opposite to Semantic Web technology project OSTIS tools have a strict set-theoretic interpretation and aren't attached to specific application sector. That provides more compact and technically accurate view of the information.

It's defined by a number of properties that allows talking about language means of OSTIS project as about the most preferable integration means of different resources knowledge:

- Using of ontological approach to design knowledge bases;
- Step by step evolutionary design of system knowledge base;
- Modular design based on the libraries of typical reusable components;
- Same as in Semantic Web languages in OSTIS technology binary relation is preferred but there is a way to present relations of any arity;
- Relations are represented in the form of semantic network nodes that allow to define their attributes;
- Relation samples are highlighted as separate semantic network nodes that provide the possibility to define each relation sample in a unique way;
- There are elements of key nodes and arcs alphabet to describe fuzzy, negative and temporary objects;
- Semantic repository of OSTIS technology integrates the similar entities to the united network automatically;
- Connection of external thesauruses and OWL technologies (converter from XML models, PDF) is not hard. The proper converters are evolved as a part of OSTIS technology.
- The problem of knowledge based on homogeneous semantic networks including knowledge verification and critical errors repair is solved.

The main advantage of OSTIS technology is the flexibility of designing systems. OSTIS technology has already contained models, means, methods of intelligent system designing and a pack of subject domains ontology accumulated and formalized by this time [27]. That is why designing using OSTIS technology comes to its broad knowledge base designing.

III. IMPLEMENTATION OF PROPOSED APPROACH

The essence of the ontological approach during designing of such systems, meaning personal integrators, centers around the consideration of system knowledge base as the hierarchy of marked subject domains and proper ontology. The following subject domains must be marked as a part of designing system:

- subject domain of information system;
- subject domain of integrator user;
- subject domain of user information space;
- subject domain of agent-translators.

The analysis of each present subject domain is analytically complex and consists of multiple abstractions, as the result of which the most considerable and relevant to current task objects, their attributes and mutual relations is marked from the whole variety of them. Knowledge of subject domain, understanding of present processes, rules and existing limitations are the necessary condition of flexible and effective information service integrator designing [5]. From the perspective of gain knowledge we have the possibility to determine designing ontology scale which provides sufficient level of ontology detailed elaboration required to solve the tasks of information service integration and following work with them. It also helps to mark concepts and relations which are necessary to include into. Taking into account that integrated systems can be absolutely different, elaborated subject domains ontology allows keeping declarative content of knowledge stored in them in spite of their syntax and stylistic distinction of their representation [4].

Implementation of the reviewed approach to create personal intelligent integrator of information services is the OSTIS-system. At this stage agent of some heterogeneous resources data collection are implemented. They provide receipt and transmission of the information to internal representation of knowledge base, provided their semantic integration. By virtue of the foregoing approach we have the possibility to integrate not only similar services but also services from the cardinally different subject domains, because of the united and common model of the user and personal information space. Let's examine the architecture of developed system and features implemented agents a little more detailed.

The common simplified architecture of the personal intelligent integrator.

At this stage personal information integrator provides the possibility of integration with the following services:

- Facebook
- Google Tasks
- Google Calendar
- Google Mail
- Todoist
- Dropbox

The first task to solve to design the intelligent integrator was machine understanding of integrated services. In other words the system should know which resources it's integrated with, how to work with them, which protocols and accessor methods are used, how often they needs synchronization, etc. This task was solved by means of formalization of external resources model and including of this model into system knowledge base when linking the external resource of data. In such a way information about external information resources became a part of integrated information user space that allowed its flexible and simple extension.

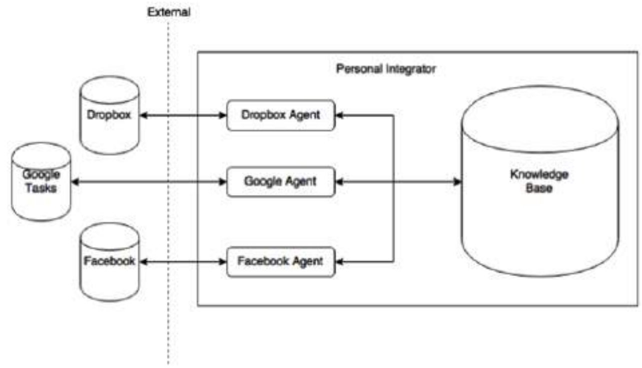

Figure 1. Simplified architecture of the personal intelligent integrator

Service formalized models formed so named user profile and are used to collect information about user. Collection of the information accomplished by specialized agents which acts as translators transforming the information received from the external resource to internal representation come from the predetermined template. The important aspect of heterogeneous resource semantic integration is the usage of knowledge of the service during collection of the information and formalization of the agent. Because of this the border between formal model and its technical implementation is removed. Also by virtue of semantic integration the user give the possibility to widen the usable services capabilities and self-adapt them. For this purpose he just has to write agent solving his specific task which won't depend on the resource of information and the service it needs to adapt because it will work with semantic integrated information. Therefore a user gives unlimited means to widen the functionality of integrated services which is inaccessible today.

Semantic integration of heterogeneous resources opens the possibility to solve the tasks which has been impossible to solve because they were on the junction of some services work. The example of such tasks can be meeting shift and its participants notification based on information about user geolocation, planning of training relying on user calendar and his medical constraints, book suggestion based on the list of read books and user current interests [7]. Therefore, information services, gained an access and had more detailed and all round user portrait, will get the possibility to improve provided services taking various aspects and each concrete case specificity into account. The user model should be formalized to uniform integration of information services and presentation of above-stated possibilities.

System user model will differ depending on concrete person interests as interests and requirements of each person are different, but the framework of the model for every person

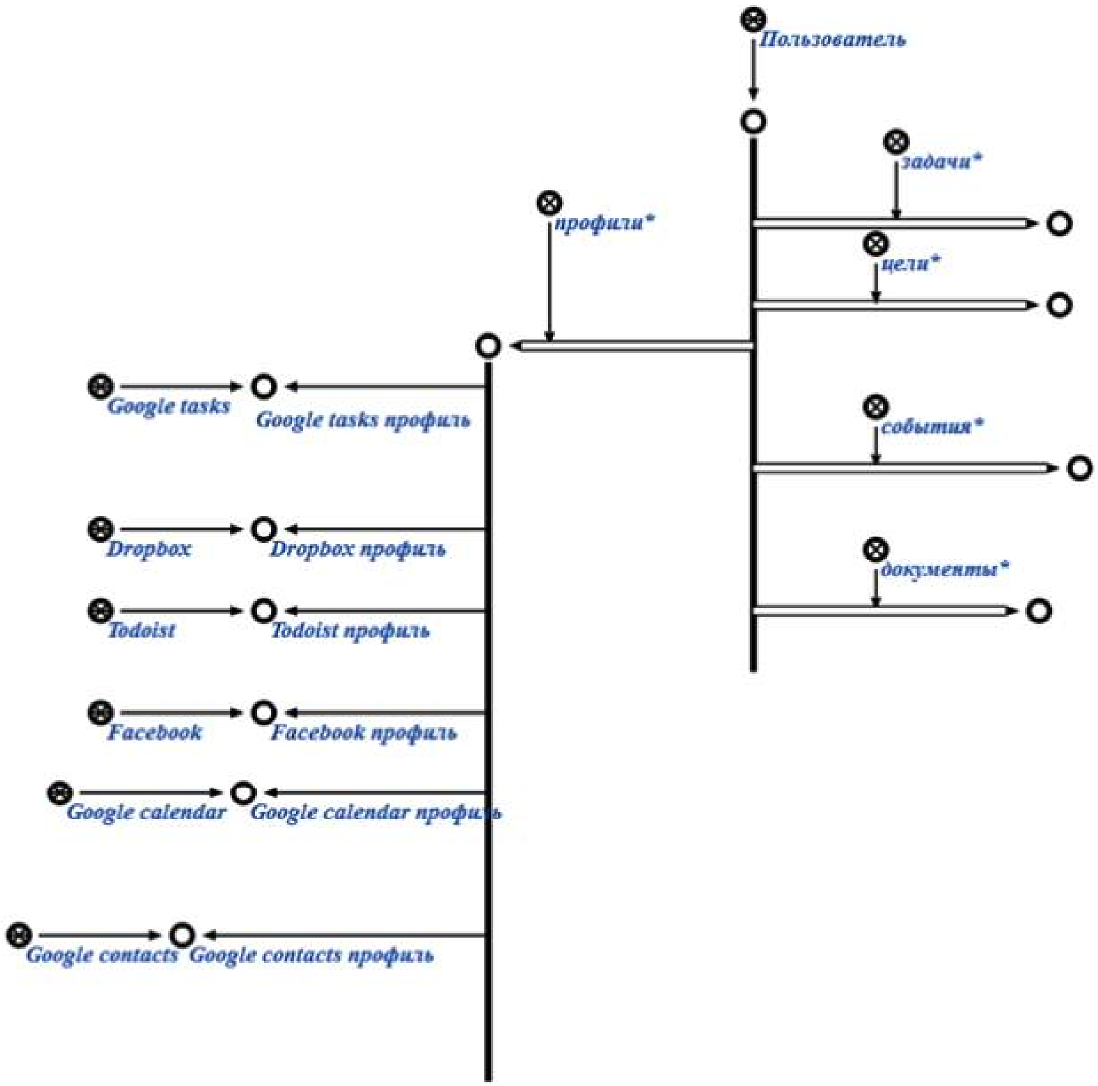

Figure 2. User profiles

will be the same. Depending on interests user will get the possibility to integrate usable service and knowledge base template which will conform to his subject domain. Therefore initial framework, common for every person, will be overgrown with more detailed models for each specific subject domain.

Current approach provides users to develop dynamically the semantic structure of their content which is made as "semantic halo" integrating information components into united semantic space. By virtue of that users will have the exact idea of the information surrounding them, possibility of semantic navigation through the system content and united universal interface to have an access to their information resources [13].

There is an example of user task model treated with the integration of some task services such as Google Tasks and Todoist on the diagram below. Each task received from these services is brought into united format by the agent-translator implemented for concrete service. Knowledge base contains the information where some information come from, so data refreshing will not break the consistence of integrated information and the user will have the possibility to work with this information not only within a designing system framework but also to continue manipulation of services integrated beforehand. Therefore the user isn't made to use designing system for solving any of his tasks but user gives an opportunity to choose and use the right service which let him solve his tasks fast and effective.

Let's examine the process of integration with service Google Tasks to understand the suggested architecture better.

The agent implementation begins with receipt of token which will thereafter be used to authenticate the application and to communicate with the service. The model of integrated service is created from the universal template and placed into the knowledge base. This model includes such information as access protocol, api version, accessible resources, api token, etc.

The example of such a formalization is below. When the service was added to the knowledge base, it became available for using by system agents.

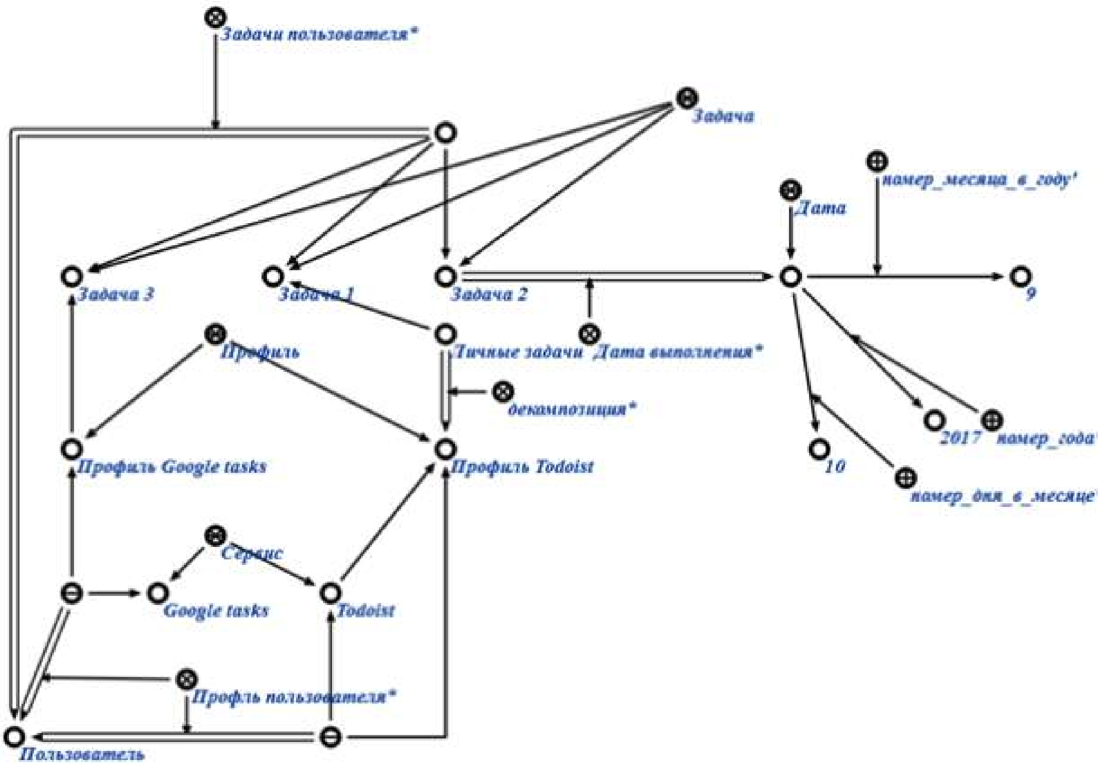

Figure 3. User tasks model

An agent is such a translator which receive the information about necessary service, find the necessary resource to maintain the operation, make requests and transform answers from JSON to the knowledge base content using the prepared templates. In case of conflicts, for example when some of the information will already exist in the knowledge base, it would be synced based on the unique identifiers. For resolving content conflicts a special interface should be designed to exclude chance of loosing important information and delegate (allow delegation) of making a decision to user.

The Google Task have the request of user tasks like this:

```
GET https://www.googleapis.com/tasks/v1
/users/@me/lists?key={API_KEY}

GET https://www.googleapis.com/tasks/v1
/lists/default/tasks?key={API_KEY}
```


```
{
 "kind": "tasks#tasks",
 "etag": "\"NEVtLf5Q_dTURZbE3G-zpPgGk\"",
 "items":
 [
     {
       "kind": "tasks#task",
       "id": "MDg0NDI4MTcwNTgwMjIyMNDk",
       "etag": "\"NEVtLf5Q_dTURZbE3E-
       zlPpPgGk\"",
       "title": "Task 1",
       "updated": "2016-07-25T17:36:41.
       000Z",
       "position": "00000000000001636797",
       "status": "completed",
       "due": "2016-06-16T00:00:00.000Z",
       "completed": "2016-06-16T21:35:26.
       000Z"
     },
     {
       "kind": "tasks#task",
       "id": "MDg0NDI4MTcwNTgwMjIyMNDk",
       "etag": "\"NEVtLf5Q_dTURZbE3E-
       zlPpPgGk\"",
       "title": "Task 2",
       "updated": "2016-06-16T21:35:27.
       000Z",
       "position": "00000000000001636798",
       "status": "completed",
       "due": "2016-06-16T00:00:00.000Z",
       "completed": "2016-06-16T21:35:27.
       000Z"
     }
  ]
}
```


This JSON format answer transform into temporary object which is brought into correlation with universal template, fill it and is preserved into the knowledge base. There is an opportunity to use libraries to simplify work with each concrete service. These libraries encapsulate process of communication with a service and provide it as a set of functions. In the case of Google API it's google-api-python-client package. Without regard for integrated service the integration process represent

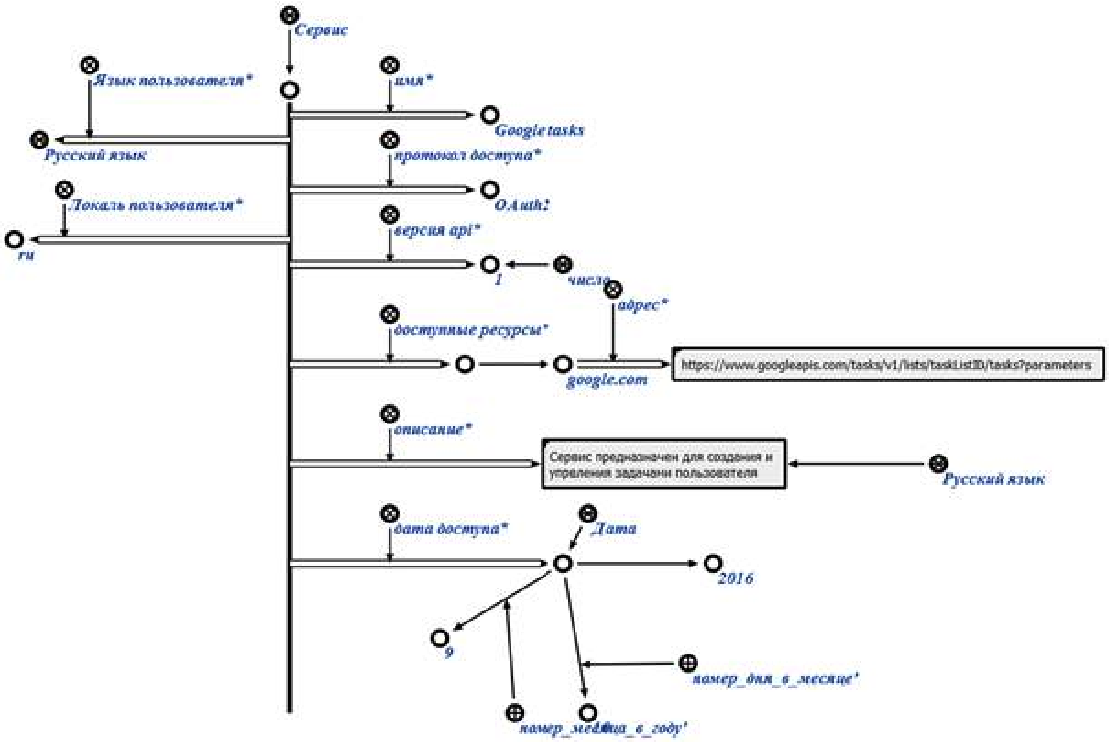

Figure 4. Web service representation

the following sequence of steps:

- registration of the application and receipt of the token to work with API service;
- addition of the service into integrator knowledge base;
- subject domain formalization;
- agent-translator elaboration.

In suggested implementation the problems of data semantic integration were solved by virtue of development of integrated services and their users' universal models. Thanks to using of semantic network as a model of representing knowledge about information service the configuration and adaptation in case of changing external resource model flexibility was reached. User universal model let us solve tasks on the junction of subject domains. Beforehand these tasks were inaccessible because of information distribution over user information space. The example of such task is the organization of meetings and events using information not only about participants' plans but also about participants' location, accessibility of places to hold events, traffic system state and weather conditions.

Also the important advantage of OSTIS technology is its modularity. All system components interact via united knowledge base that let us change system functionality without changing its common architecture. Addition of new user profile (integration with new information resource) doesn't influence on system work in general.

Conclusion

The complication of person information space structure leads to the necessity of development of new approaches to satisfy his information requirements. Information resource diversity leads to the problem of information perception fragmentariness. This problem brings to the appearance of new information system class – personal information integrators. In spite of existing set of personal assistants such as Siri, Google Assistant and Cortana the problem of semantic heterogeneity of personal information space wasn't solved.

On the base of OSTIS technology the system of personal information integrator was developed in which the problem of heterogeneous resources integration was solved. The design of information resources subject domain and user model ontology allowed to solve problem of data transfer between heterogeneous information services and to integrate received data on the semantic layer. Using the semantic networks approach the problem of unified information integration has been solved. According to this approach all collected information is stored inside a knowledge base of integrator system. OSTIS technology provides the united interface to work with knowledge base centered around SCg language. You can see this interface on 2-4 figures. Current implementation proposal has some problems, that just going to be solved and not deeply covered in scope of this paper. Designing the ontologies of each domain subject described in the paper is going to be improved to become a well-covered skeleton for future developments in this field. The user interface for personal integrator that would become efficient and domain subject independent is also a big task to do. To sum it all up the further development of personal assistant will be run into three directions: the increase of quantity of integrated information services, improving the ontology of domain subject and designing an approach for universal user interface.

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ПРИНЦИПЫ ПОСТРОЕНИЯ ИНТЕЛЛЕКТУАЛЬНЫХ ИНТЕГРАТОРОВ ИНФОРМАЦИОННЫХ СЕРВИСОВ НА ОСНОВЕ ТЕХНОЛОГИИ OSTIS

Титенков П.В., Каешко А.И.

В статье рассматривается принципиально новый класс систем персональных информационных интеграторов, которые призваны решить проблему гетерогенности информационного пространства пользователя. Проблема гетерогенности информационного пространства выражается в необходимости использования нескольких сервисов для решения одной задачи, разрозненности личной информации и ее распределенности по нескольким сервисам, затрудненных операциях поиска и во многом другом. В статье приводится анализ имеющихся интеллектуальных ассистентов, которые несмотря на впечатляющий набор возможностей, не интегрируют информационной сервисы на семантическом уровне, а лишь занимаются приведением естественно-языковых запросов к некоторому шаблонизируемому формату и делегированием их выполнения исходным сервисам. Рассматриваются технологии интеграции данных, приводятся достоинства и недостатки наиболее популярных подходов. Приводится анализ затрагиваемых предметных областей и соответствующих им онтологий. Рассмотрен пример реализации персонального интегратора нескольких информационных сервисов. Решение проблемы гетерогенности информационного пространства открывает широкие возможности для написания интеллектуальных агентов, которые обладая семантически целостной базой знаний, получат уникальный контекст для своей работы и смогут решать задачи находящиеся на стыке работы нескольких сервисов и не представляющие возможным их решение на сегодняшний день.

Intelligent Environment of System-Situation Management of Complex Socio-Technical System Using Multilevel Semantic Nets

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***Abstract*—The problem of construction of the intelligent environment of complex socio-technical system management based on system and situational approach to achieve the best result of activity and to form the effective development strategy is considered. The model of life cycle support system, the hierarchical model of property indicator and the genetic algorithms with the dynamic choice of genetic operators in group for search of the optimum managing parameter are offered**

Keywords—intelligent environment, socio-technical system, system and situational management, concept of life cycle, property of system, development indicator, genetic algorithm.

I. Introduction

In the 20th century, development of social sciences and engineering activity has led to formation of the concept the socio-technical systems (STS) [1].

This approach presents the research object – organization - as opened, self-organized complex system with heterogeneous structure and purposeful behavior.

The modern environment of STS development is characterized by the dynamic and unpredicting nature of changes [2,3]. In this regard the information asymmetry described by the untimely and distorted response to influences is formed.

Thus, STS development requires generating management allowing achieving goals effectively in the conditions of uncertainty and risk.

The solution of this problem includes development of the methodological instruments including models of STS, subsystems, their interactions and progress, and algorithms of search of the operating effect that are united in the uniform intelligent environment.

II. The model of complex socio-technical system development

Development of complex socio-technical system is based on obtaining a certain result and can be described on the basis of the concept of life cycle of the organization.

The strategy of goals achievement represents a trajectory in space of time and states. At the same time a condition of STS are characterized in the term of operation efficiency at the each stage.

Thus, an important task is development of the general model of STS progress which present a template of model of life cycle system support in the conditions of event set.

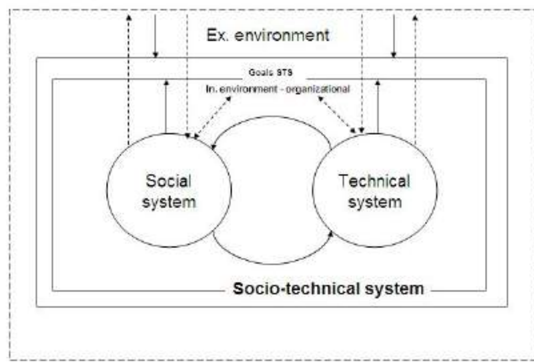

Figure 1. General STS model

In general this model reflects dynamics of system changes the highest order including socio-technical system and the external environment.

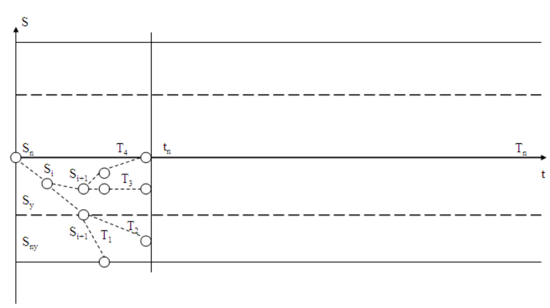

Figure 2. The life cycle of STS based on system and situational approach

The external environment which is characterized by stochastic behavior can be described in terms of the scenario and probabilistic model representing a tree of events. Approach of a certain event is characterized by the probability changing over time. The general set of probabilities at this stage is considered as a tree root matrix. Possible compositions of events form a situation so that a final element of a tree is the matrix of possible situations setting set of probabilities of approach of events with different scenarios.

Logically internal environment of STS includes the operated system which is representable in the form of structural - functional model, system of elaboration of the operating influences and the database and knowledge.

The structural - functional model reflects heterogeneity of the entering elements which are allocated on the basis of the carried-out functions and set of characteristic properties.

Properties create usefulness of the object and are estimated by the indicators characterized by intervals of changes and boundary values. Near these boundary values the element is nonfunctional, so it is not to ensure steady effective functioning of all system.On the other hand these changes influence on properties of other elements in such a way that the system passes into an unstable state.

The general hierarchy of properties of subsystems forms a complex indicator of activity efficiency of STS.

The internal operating system, contains two interconnected subsystems.

The first subsystem stores information on influence of this or that event and a STS situation. It carries out on the basis of parameters of the studied system and the external environment assessment of element and system state transitions by using operating parameter.

The second - contains information on resources and restrictions of internal system and on the basis of this information and functions of influence of the external environment forms the optimum operating influence from the point of view of effective achievement of goals.

After acceptance and implementation of the decision the system passes into the following state which will be optimum taking into account a condition of the internal and external environment, the functioning purpose.

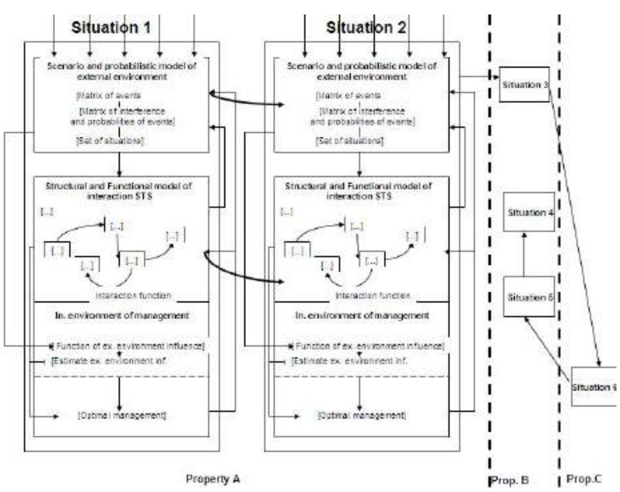

Figure 3. The model of life cycle system support

Further when state of STS is changed by the external environment and other phenomena, the total situation changes is formed.

Thus, process of effective achievement of the objectives, also changing under the influence of external and internal factors, is dynamic and continuous. It is controlled by system of support of STS life cycle.

The described model of support of system life cycle allows to predict on the basis of information on the external environment and the purpose of functioning of STS behavior without the operating influence, to estimate management in the conditions of multiple development of the external environment and to form the strategy of effective achievement of the objectives.

III. Mathematical problem definition of system and situational management of complex socio-technical system

Modern conditions require using of complex system and situational methodology of development of management decisions [4].

This approach will allow to satisfy to the basic principles of a systemology and to consider stochastic factors. The system approach forming a target vector and considering properties of each element and all system in general will create the general development strategy (the principle of a adaptability).

The situational approach will solve the unique tasks formed by the unstable, changing environment and will allow to create effective behavior (the principle of a unprediction).

Thus, key parameters in the task of system and situational management is the following:

- the state of system (S) depending on states of elements,
- the functional efficiency (F),
- expenses demanded for formation of the operating parameter (Z),
- restrictions (R),
- factors of the external environment (v).

So, life cycle of STS (L) can be presented in the form of the interconnected chain of transitions (x) between states (S) which are expedient for estimating in the terms of functional efficiency (F).

In that case, mathematical problem definition of system and situational management can be presented in a general view:

$$Y = f(L(x), S(F), Z, R, v).$$

where Y – the operating parameter.

S(F) accepts values from some set S1,..., Si , and F presents as a complex indicator. At the same time the optimum operating parameter of Y is formed provided that

$$F->max; Z->min; x->max.$$

This process is dynamic so each transition characterized by correction of a trajectory of life cycle in connection with change of internal and external conditions is carried out.

IV. Development of operation efficiency indicator of complex socio-technical system based on property indicators of subsystems using of multilevel semantic nets

Assessment of a condition of system by means of a complex indicator of efficiency of functioning demands the corresponding algorithm. The structure of complex socio-technical object is made by heterogeneous subsystems: social, technical, information, resource, process, ecosystem (marketing), administrative [5,6].

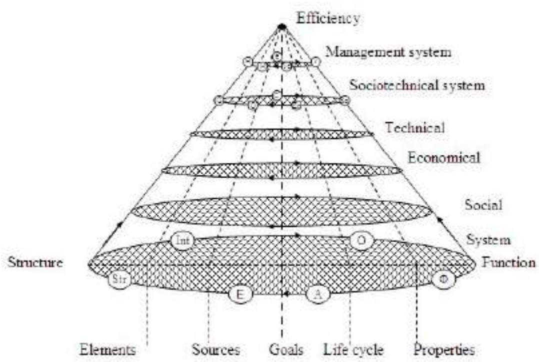

Figure 4. Hierarchical property STS model

Then, formation of efficiency of functioning has to based on the basis of hierarchical model of indicators of properties of subsystems:

- system, providing existence of system: synergetic effect, degree of structure, functionality, integrity, autonomy, organization;
- social (psychical and physiological and competence-based and behavioural);
- the technical, describing characteristics of devices and networks;
- the information, including indicators of assessment of technological level and the software;
- economic;
- resource;
- the marketing (ecosystem), including indicators of influence of competitors, partners and other contractors; process (formalization, stability, convertibility, description accuracy, for business processes and additional processes);
- socio-technical: heterogeneity, focusability, openness, self-organization, autonomy, adaptability;
- control systems: safety, reliability, stability, observability, controllability.

Formation of this hierarchy of property indicators is carried out on the basis of multilevel semantic network. In such a way that the model of properties of system is transformation of model of interrelations of elements of system and their parameters.

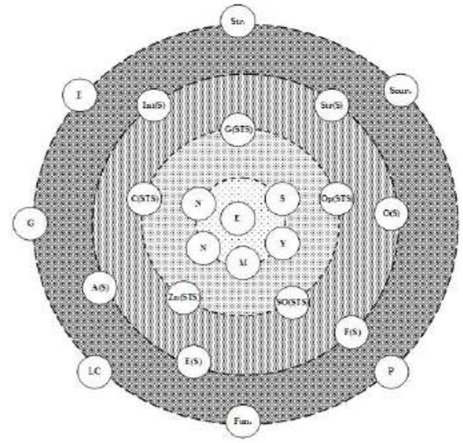

Figure 5. Centric property STS model

V. Formation of the optimum operating parameter with using of the genetic algorithm

It is effective to carry out search of the optimum managing parameter in the conditions of multicriteria with using the genetic algorithm with the dynamic choice of genetic operators in group adapting to the statements of the problem changing at each stage [7].

At the same time the choice of the genetic operator can be carried out on the basis of several parameters:

- decision accuracy (convergence to the optimal solution);
- working hours of operator before obtaining the best decision;
- variety of elements of set;
- stability of the received decision;
- the required resources;
- quantity of the received elements with suitability above an average.

VI. Conclusion

The offered information environment of system and situational management of complex socio-technical system includes model of life cycle system support in the conditions of multiple event set, hierarchical model of formation of operation efficiency as transformation of multilevel semantic networks of system elements for assessment of a STS condition, model of a genetic algorithm with the dynamic choice of genetic operators in group for the optimum managing parameter search.

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ИНТЕЛЛЕКТУАЛЬНАЯ СРЕДА СИСТЕМНО-СИТУАЦИОННОГО УПРАВЛЕНИЯ СЛОЖНОЙ СОЦИОТЕХНИЧЕСКОЙ СИСТЕМОЙ С ИСПОЛЬЗОВАНИЕМ МНОГОУРОВНЕВЫХ СЕМАНТИЧЕСКИХ СЕТЕЙ

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Рассматривается задача разработки интеллектуальной системы управления сложной социотехнической системой (СТС) на основе концепции жизненного цикла. Построение стратегии развития описывается как целенаправленный переход между состояниями СТС, которые оцениваются с точки зрения эффективности достижения цели. Формирование эффективности как свойства системы осуществляется с помощью иерархической модели свойств подсистем и их оценок. Частные оценки формируется на основе многоуровневых семантических сетей элементов. В условиях неопределенности и недостаточности информации системное управление осуществляется как поиск оптимальных с точки зрения эффективности достижения цели состояний СТС для перехода на основе генетического алгоритма с динамическим выбором генетических операторов в группе. При этом ситуационное управление реализуется на подуровнях путем достижения определенных значений параметров свойств оптимальных с точки зрения общей эффективности.

Automatic Multilingual Web Documents Metadata Extraction

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***Abstract*—This article describes the experience of robot development that crawls multilingual web documents, their language identification and extracting the metadata based on the metadata model of corpus manager of the electronic corpus of Tatar language "Tugan Tel".**

***Keywords*—metadata, data mining, web content mining, information retrieval.**

I. Introduction

Multilingual web documents metadata extraction problem is a topical for the national corpus development. The solution of this problem will allow to extract the semantics of corpus documents. The obtained results will help to reduce the amount of unrecognized word forms in the corpus documents.

Text corpuses which composed of web documents exist for many languages. Some of the most volume are ukWaC for English (about 2 billion word forms), frWaC for French (about 1.6 billion word forms), deWaC for German (about 1.7 billion word forms), itWaC for Italian language (about 2 billion word forms) and others.

Authors was tasked to crawl web documents in the Tatar language and extract metadata of these web documents. This article describes the steps to solve this problem within the context of the Tatar language, but can be applied to other languages.

II. Metadata Representation in the Corpus Manager

According to the EAGLES recommendations set of metadata to describe a text document in an electronic corpus is divided into three parts: external factors, internal factors and technical metadata. In the electronic corpus of the Tatar language "Tugan Tel" set of metadata is also divided into these three parts.

External factors:

- Text type (original or translation);
- Name;
- Author;
- Translator;
- Edition;
- Publishing house;
- Language;
- Creation date;
- The amount of words;
- The amount of words in Russian file;
- Original source;
- Translation source;
- Keywords;
- Copyright information;
- Short description;
- Note.

Internal factors:

- Style;
- Category/theme;
- Place.

Technical metadata:

- Number (ID);
- Source file name;
- Russian file;
- Flag of data validation by moderator.

For automatic web documents crawling an important aspect is the identification of the set of main metadata to be extracted. This set of metadata should be the basis for all received and processed web documents and must properly cover the mandatory (minimum) set of corpus metadata related to external factors. In the case of electronic corpus of the Tatar language "Tugan Tel", these include:

- Name;
- The amount of words;
- Number (ID);
- Source file name.

A. Metadata representation model in the corpus manager

Since the set of documents metadata can contain an unlimited number of properties and be supplemented with the new data in the future, these metadata representation model should ensure the completeness and scalability. The universal solution of the problem faced by the authors, is to use sematic web, which represented in the RDF data representation model. Thus, the information corpus metadata model is a semantic web. As a fundamental model, it was decided to use DCMI recommendations, that describes all of the metadata which are presented in the existing documents of the electronic corpus.

The list of the metadescription properties presented above, allows to define the main objects and relations between them to represent metadata. These are shown in Figure 1 and Table I.

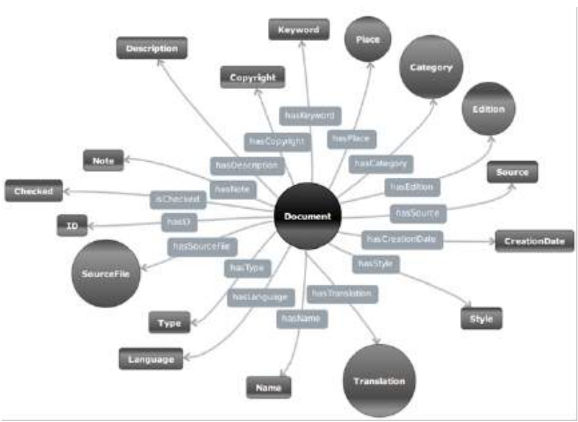

Figure 1. Metadata structure in the corpus manager

Table I. MAIN OBJECTS OF METADATA IN THE CORPUS MANAGER

Properties	Relation	Datatype/Class
Number (ID)	hasID	Integer
Source file, The amount of words	hasSourceFile	SourceFile
Text type	hasType	String
Language	hasLanguage	String
Name	hasName	String
Author	hasAuthor	Author
Translator, Russian file, The amount of words in Russian file, Translation source	hasTranslation	Translation
Style	hasStyle	String
Creation date	hasCreationDate	Date
Original source	hasSource	String
Edition, Publishing house	hasEdition	Edition
Category/theme	hasCategory	Category
Place	hasPlace	Place
Keywords	hasKeyword	String
Copyright information	hasCopyright	String
Short description	hasDescription	String
Note	hasNote	String
Flag of data validation by moderator	isChecked	Boolean

III. THE MAIN METADATA

Automation of the process of crawling web documents requires technical metadata needed for binding objects and identification data obtained.

Web documents crawling module described in this article, use the following technical data:

- Number (ID) of the web document;
- The file name of the web document on the local machine of the module;
- Web document URI in the Internet;
- The file name of the web document metadata on the local machine of the module;
- Data type that stores the web document on the local machine of the module after crawling;
- The amount of data;
- Time saving the web document on the local machine of the module.

These technical metadata stored for each web document and are mandatory for crawling module.

IV. ADDITIONAL METADATA

According to the metadata model in the corpus manager, each document in the system can have a different relation with additional metadata objects. This metadata are usually not semantically marked in web documents, despite the fact that there are recommendations from the W3C for marking those data. This causes some difficulties when trying to extract web document metadata. More details about this will be discussed in Section V.

All the additional metadata are optional, and some web documents can have none of objects of additional metadata.

For the web documents that have been received during the crawling, identified the following additional metadata:

- Language;
- Name;
- Author;
- Translation;
- Creation date;
- Original source;
- Category/theme;
- Place;
- Keywords;
- Copyright information;
- Short description.

V. HOW THE ROBOT WORKS

A. URI collecting for crawling

The first and very important step for the optimization of the robot working is URI collecting for crawling.

To minimize the load on the source machine, it is necessary to optimize requests to the source so that these do not cause problems in the source website working, but given sufficient data for each web document. To do this, the authors tuned URI collecting depending on the characteristics of a source website.

For example, often the quickest and most effective solution was a sequential scan of web pages' identifiers, which does not require additional requests to the web documents with URI list on the source website. This solution, of it is possible to apply to a specific website, not allowed to use the URI list for crawling and performed crawling of web documents directly. Another example is the processing of source website RSS feed, which significantly reduces the number of requests to the source web server. In this case, a single request can obtain data of several web documents, not even request them directly.

B. Web document language identification

Authors was tasked to crawl web documents to compile a corpus of the texts in the Tatar language. In the sources web sites list included as resources exclusively in the Tatar language as multilingual resources, on which the content is located in several languages.

In the case of resources in the Tatar language the language identification is not required. Whereas when crawling multilingual resources necessary to ensure that the text of a web document is written in the Tatar language. In most cases, the web document language can be restricted before crawling, at the stage of URI list collecting. The clear structure of the URI of web document where web document language identifier is often found, contributes to this. Since the robot configuration for each source website is performed manually, this restriction may be applied before the crawling and URI list collecting.

But if it is not possible to restrict the language of a web document content, it is necessary to identify the language and to make sure that the text of a web document is written in the Tatar language. Since the Tatar alphabet includes 6 additional letters (Ә ә, Ө ө, Ү ү, Җ җ, Ң ң, Һ һ), if any in the content of a web document we can confidently say that the language of a web document is Tatar.

C. Crawling and metadata extraction

After web documents URI collecting the robot proceeds to the sequential crawling of these web documents.

Each source website has its own characteristics of web document content representation, so a common approach to all web documents is not applicable. Each website has its own robot configuration file and its own algorithm of processing the content of web documents. The algorithm may consist of any of a finite number of steps, each of which has access to data obtained previously. The use of different types of custom variables, functions for arbitrary data processing, saving data in different formats and structures, stop triggers are defined directly in the robot configuration file and rule changes to the source code of the robot.

One of the most important components of the robot is the variables module. This module allows to crate different types of variables and change them while the robot is working. The variables module supports a variety of mathematical operators, operations with date and time, working with lists, arrays, cache, database, files, and other variables. This module provides sufficient functionality for a complete robot configuration and changing its state during a crawling.

Metadata extraction occurs by means of regular expressions. Depending on the structure of a web document, regular expression can be different in complexity and performed in several steps. An example of a web document that requires processing in several steps is the tatar-inform.ru website web document.

$$\begin{aligned} &< ahref = ''.*'' = ''grey'' > (.*) < /a > \\ &< h1 > (.*) < /h1 > .* \\ &< div = ''news\_info'' > .* \\ &(\backslash d[\hat{},]+), .* < div = ''news\_padd'' > .* < p \\ &class = ''anons'' > (.*) < /p > (.*) < /div > \end{aligned} \tag{1}$$

$$\hat{}[\hat{} <]* < p > \backslash(([\hat{},]+), .*, ([\hat{},]+)\backslash) \tag{2}$$

The first processing step is shown in (1) and it is a division of the web document structure to the main text, category, name and the block of metadata that require further processing. In the second step (2) from this block are extracted the author's name and location associated with the content of the web document.

The results of the robot working with the tatar-inform.ru website web documents shown in Table II and in the structure (3).

{"name":"Түбән Кама районы аграрийлары көчәйтелгән эш графигына күчә","class":"Авыл"}
(3)

Таблица II. Main objects of metadata in the corpus manager

ID	38681
File name	Авыл/http:__tatar-inform_tatar_news_2007_05_11_24643_?print=Y.txt
Type	original
Language	Tatar
Name	Түбән Кама районы аграрийлары көчәйтелгән эш графигына күчә
Author	unknown
Style	not literary
Creation date	11.05.2007
The amount of words	99
Source URI	http://tatar-inform.tatar/news/2007/05/11/24643/?print=Y

VI. Conclusion

The method of automatic web documents metadata extraction proposed in this paper allows not only to automate web documents metadata extraction process, but also as a part of the robot to crawl websites, allows to collect a volume corpus of texts presented on the Internet.

The presented results are part of the data obtained during automatic crawling. Automation of crawling websites in the Tatar language using the robot allowed to obtain the contents of about 200 thousand of web documents, totaling about 57 million word forms.

A common approach in the development of the robot and its components may allow the use of the robot not only with sources in the Tatar language, but also with sources in other languages, without having to change the source code. The architecture of modules provides full functionality for websites crawling and enables the robot to run with any configuration files.

Extracted metadata of web documents will help to further customize the morphological analyzer more accurately, thereby reducing the incidence of morphological ambiguity in the corpus. One of the possible areas of use is also a classification and clustering of texts in the corpus.

Currently we are actively exploring the possibilities of filling the internal factor metadata using semi-automatic or automatic semantic annotation. It is assumed the realization of the possibility of using identification of named entities and assign them to a particular class of the subject entity.

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АВТОМАТИЧЕСКОЕ ИЗВЛЕЧЕНИЕ МЕТАДАННЫХ МНОГОЯЗЫЧНЫХ ВЕБ-ДОКУМЕНТОВ

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В данной статье рассказывается об опыте разработки робота для обхода многоязычных веб-документов, определении их языка и извлечении метаданных на основе модели метаданных в корпус-менеджере электронного корпуса татарского языка «Туган Тел». В разделе II описывается структура и модель представления метаданных, применяемая в корпус-менеджере. Раздел III раскрывает информацию о необходимых для работы робота технических метаданных. В разделе IV рассказано о дополнительных метаданных, которые могут быть извлечены из веб-документов. V раздел включает в себя описание процесса сбора URI для обхода роботом, метод распознавания языка веб-документа, описание процесса обхода веб-документов и извлечения метаданных.

Проектирование интеллектуальных автоматизированных систем управления связью

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Аннотация—Система управления связью (СУС) с точки зрения системного подхода представляется совокупностью органов, пунктов управления связью и технической основы системы управления связью. СУС должна обеспечивать управление передачей информации с заданным качеством и предназначена для повышения эффективности управления системой.

I. Архитектура АСУС

АСУС в основном строятся на основе концепции сети управления связью TMN (Telecommunication Management Network – сеть управления телекоммуникациями).

Концепция TMN является основой для реализации интегрированного управления различными по структуре, составу и объему сетями электросвязи и позволяет:

- оптимизировать структуру системы управления;
- обеспечивать механизмы защиты и целостности данных;
- минимизировать время локализации и устранения неисправностей в сети;
- расширять спектр предоставляемых услуг связи пользователям, а также эффективность их взаимодействия.

Для описания различных аспектов построения АСУС применяются следующие архитектуры:

- ***оперативная*** – отображает совокупность пунктов управления (ПУ) АСУС, способ базирования и связанные с этим требования к видам информационного обмена и спектру услуг, предоставляемых пользователям АСУС;
- ***функциональная*** - инвариантна относительно конкретных концепций построения АСУС, а так же функционально полная для рассмотрения перспективных сценариев ее построения с учетом требований к составу и качеству услуг, предоставляемых органам управления связью, и управляемым процессам;
  охватывает все уровни управления и отображает концептуальные основы и уровни интеграции управления, способы их реализации, предоставление пользователям услуг управления связью, формирование новых услуг и служб АСУС;
- ***физическая*** - определяет физические границы реализации основных элементов АСУС и связей между ними и с внешними системами;
  включает: серверные комплексы, терминальные комплексы, средства передачи информации;
- ***информационная*** - отображает форматирование, структурирование, передачу, накопление, хранение и предоставление информации пользователям АСУС;
  включает: информационные элементы, информационные модели управления.
  Информационные элементы должны отображать сведения об управляющих и управляемых объектах;
  Информационная модель управления: представляет собой информационную конструкцию с абстрактным описанием системных и сетевых ресурсов, необходимых для обеспечения управления; устанавливает требования к стандартным формам представления, структурирования, передачи, накопления, хранения и предоставления информации в АСУС;
- ***логическая*** – отражает состав протоколов, используемых на каждом уровне управления, обеспечивающем предоставление спектра услуг пользователям АСУС при решении задач управления.

Множество указанных архитектур составляет основу архитектуры АСУС.

Структура построения АСУС представляет собой иерархическую систему, включающую следующие уровни:

1) объектовый уровень (уровень сетевых элементов), на котором решаются задачи непосредственного мониторинга и управления сетевыми элементами;
2) сетевой уровень, на котором решаются задачи мониторинга и управления группами сетевых элементов, образующих различные сети связи, сегменты сетей и пр. структуры;
3) уровень процессов и услуг, на котором решаются задачи автоматизации процессов поддержки принятия решений и управления услугами.

II. Обеспечение контроля работы сети

Постоянный контроль над работой сети необходим для поддержания ее в работоспособном состоянии. Процесс контроля работы сети делится на два этапа – мониторинг и анализ.

На этапе мониторинга выполняется процедура сбора первичных данных о работе сети: статистики о количестве циркулирующих в сети кадров и пакетов различных протоколов, состоянии портов концентраторов, коммутаторов и маршрутизаторов и т.п.

На этапе анализа (процесс обобщения собранной на этапе мониторинга информации) осуществляется сопоставление данных с ранее полученными данными, и вырабатываются рекомендации о возможных причинах замедленной и/или ненадежной работы сети. Здесь происходят процессы:

- обобщения собранной на этапе мониторинга информации;
- сопоставления с ранее полученными данными;
- выработки предположений (прогнозирование) о возможных причинах замедленной или ненадежной работы сети.

Задачи мониторинга решаются программными и аппаратными измерителями, тестерами, сетевыми анализаторами, встроенными средствами мониторинга коммуникационных устройств, а также агентами систем управления. Задача анализа требует более активного участия человека и использования таких сложных средств, как экспертные системы, аккумулирующие практический опыт многих сетевых специалистов.

III. Мониторинг сетей

Мониторинг сети представляет собой систематический сбор и обработку информации, которая используется для поддержки принимаемых решений по связи.

Мониторинг сети включает в себя процессы сбора, регистрации, хранения и анализа небольшого количества ключевых (явных или косвенных) признаков/параметров описания сетевых элементов – объектов мониторинга – для вынесения суждения о поведении/состоянии СЭ в целом (т.е. для вынесения суждения об объекте мониторинга в целом на основании анализа небольшого количества характеризующих его признаков).

Наблюдение за состоянием СЭ позволяет определить (и, в дальнейшем, спрогнозировать) моменты перехода СЭ в предельное состояние. Результат мониторинга состояния СЭ представляет собой совокупность состояний составляющих его субъектов, получаемых на неразрывно примыкающих друг к другу интервалах времени, в течение которых состояние СЭ существенно не изменяется.

Событие представляет собой поддающееся обнаружению явление, имеющее значение для управления инфраструктурой сети или предоставления сетевых сервисов.

На этапе мониторинга выполняется процедура сбора первичных данных о работе сети: статистики о количестве циркулирующих в сети кадров и пакетов различных протоколов, состоянии портов концентраторов, коммутаторов и маршрутизаторов и т.п. Процесс мониторинга делится на фазы (этапы):

- *Предварительная фаза / этап:* анализ и концепция построения системы мониторинга сети: оценка текущей ситуации, определение целей и задач, определение степени охвата контролируемой сети (сегмента) процессами мониторинга и системой мониторинга, определение архитектуры системы (модели построения);
- *Планирование.* На этой фазе происходит определение: целей мониторинга; задач мониторинга; функций мониторинга; степень охвата контролируемой сети (сегмента) процессами мониторинга и системой мониторинга; интеграции с другими процессами;
- *Процесс мониторинга и управления событиями:* конфигурирование системы; работа в процессе; управление событиями: обнаружение, реагирование, разрешение, взаимодействие с другими процессами;
- *Проверка (оценка достижения целей):* проверка решения поставленных задач, пересмотр конфигурации (настроек системы, деревьев сервисов и т.д.), отчетность.
- *Воздействие:* анализ и совершенствование процесса мониторинга; новый горизонт планирования: оценка необходимости реализации новых функций мониторинга, расширение контура мониторинга и охвата объектов мониторинга, внедрение дополнительных средств мониторинга, реализация расширенной отчетности и др.

IV. Выводы

В настоящей статье предложен системный подход к проектированию автоматизированных систем управления связью. В отличие от современных тенденций построения СУС, которые представляют в основном «лоскутные» способы разработок, предлагается рассматривать АСУС как совокупность органов, пунктов управления и средств управления связью. При этом система управления представляется как совокупность подсистем (элементов) и определяются прямые и обратные каналы управления внутри АСУС и формулируются функциональные требования к её элементам.

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Artificial Neural Networks for Evaluation of Psychophysiological State

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***Abstract*—In this document, we make an analysis of the possibility of using neural networks in the development of tests to evaluate the psychophysiological state of a human. Also, in this paper, the developed system of psychophysiological diagnostics is presented. This system will automate the execution and processing of results of the express testing methods for evaluation the psychophysiological state.**

The described model of evaluation the human's psychophysiological state using a neural network has the following advantages: remote diagnostics, stability and accuracy of the results, the ability to self-training by detecting complex dependencies, identification of typical trends for people of a certain profession or in a particular area.

It has been proved that the usage of neural networks for processing the results of psychophysiological tests will improve the accuracy of diagnosis.

***Keywords*—diagnosis, human physiological state, brain asymmetry, physiological tests, decision-making support, neural network.**

I. INTRODUCTION

Nowadays, psychophysiology has a lot of methods and tools for evaluation of the human psychophysiological state. This branch of psychology is rapidly developing and adjusting under the ever-changing requirements. The results obtained from psychophysiological diagnostics are used in different fields of human activity, ranging from career counseling up to monitoring the condition of the person prior to admission to work. The tools used for diagnosis have come a long way from the old techniques with paper blanks and patient monitoring to hardware and software systems and mobile applications. One of the ways to improve the quality of diagnosis and the search for new patterns is the use of neural networks.

Artificial neural networks are one of the artificial intelligence technologies used for solving such complex problems. Today neural networks are widely used in science and technology with applications in various areas of chemistry, physics, and biology [1].

For example, artificial neural networks are used in chemical kinetics [2], prediction of the behavior of industrial reactors [3], modeling kinetics of drug release [4], optimization of electrophoretic methods [5], classification of agricultural products such as onion varieties [6], and even species determination [7][8][9].

An analysis of the use of neural networks for medical diagnosis has given the following result: in many cases, neural networks have been able to diagnose the disease two times more accurately than the expert. Using of the neural networks has a few significant advantages, such as:

- The ability to conduct remote diagnostics, which is quite an important criterion for a lot of people who do not have the opportunity to visit a good specialist;
- The stability of the diagnostic results, regardless of the expert mood and interpersonal interaction;
- The ability to process large amount of data;
- The ability to find complex dependencies in an input data;
- Reduction of diagnosis time.

It is proved [13], that the use of neural networks has a number of drawbacks. For example, a neural network can inherit specialist's knowledge gaps if they are into the training sample. Consequently, the high quality of input data is vital. Accordingly, using data obtained from several experts in different (but related) profiles, we can assume that the neural network will diagnose more accurately than the average medical consultant.

The purpose of this paper is an analysis of the existing solutions that use neural networks in medical diagnosis and attempt to use one of the considered models for the evaluation of human psychophysiological state using the data obtained from the developed tests.

II. USING NEURAL NETWORKS FOR SOLVING THE PROBLEMS OF MEDICAL DIAGNOSTICS

A. An analysis of the applications of neural networks for the diagnosis of myocardial infarction

Neural networks are used for medical diagnosis because each person has a unique, specific set of peculiarities. This makes it difficult to develop a universal method of diagnosis for all people. The approach of using neural networks in this case allows to increase the accuracy of diagnosis, as compared with the results obtained by using amplitude-time methods [12]. In a training sample, the final estimate of psychophysiological state was based on the solutions of several experts, according to the majority decision. Every decision can correspond with two propositions:

- Suspected myocardial infarction;
- Signs of a heart attack are not detected.

Learning Vector Quantization (LVQ) Neural Networks has been used for implementation of this analysis (Fig. 1).

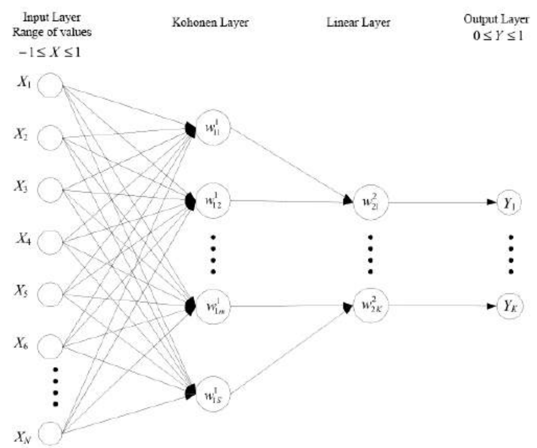


Figure 1. The structure of the LVQ Neural Networks

The value of the output signal of the LVQ neural network determined by using this formula:

$$S = \sqrt{\sum_{i=1}^{N} * \left(x_i - w_{im}^1\right)}^2 .$$

$$Y_k = F_{lin} + \left(\sum_{j=1}^{s} w_{jk}^2 * F_{compet}\left(S\right)\right) .$$

where x_i – i-th element of the input vector, w_{im}^1 – i-th element of the vector of weight m-th neuron in kohonen layer, w_{jm}^2 – j-th element of the vector of weight k-th neuron in linear layer, F_{compet} – the function of kohonen layer, F_{lin} – the function of linear layer, N – the number of elements in input vector, S – the number of elements in the kohonen layer, Y_k – k-th value of the output vector.

B. An analysis of the applications of neural networks for the recognition and expression of emotions based on physiological parameters

The necessity of using neural networks [11] is due to the complexity of the relationships between physiological and psychological states, which are based on the interaction of the various systems of the body and are characterized by non-linear and multi-layered structure.

To display the relationship between physiological and psychological states, the neural network with backpropagation method of training was used. This neural network is composed of several layers of neurons, wherein each neuron of layer *i* is connected to each neuron of layer *i + 1*. In this case, three layers have been realized:

- The first layer contains basic physiological parameters;
- Second – physiological functional systems;
- Third, depending on the first two, the cognitive and regulatory abilities.

Twelve factorial estimates calculated from the primary physiological parameters are used as input parameters. The rhythm of the front and lateral cortex of the brain, the reactivity of the nervous system, vascular reactions, changes in blood pressure and other emotional pressure are examples of physiological parameters. Parameters of the emotional competence are the output data. The relationship between physiological parameters and varying functional system was revealed during the analysis of the model of the neural network, that will accordingly formalize the diagnosis of emotional competence, taking into account the physiological characteristics.

Diagnosis of psychological indicators using physiological parameters with help of neural networks promotes the creation of an instrument to consolidate existing psychological and physiological methods of diagnosis psychophysiological state [11]. To date, the problem lies in the fact that the physiological and psychological techniques were developed in isolation from each other without considering the relationship of psychic and physiological systems of a human. The use of neural networks for solving this problem would integrate the existing psychological and physiological methods of diagnosis of psychophysiological state of a human. In this case, backpropagation is used for training of neural network. One of the improvements of this model is the method of steepest descent at the training.

C. Using neural networks for diagnosis of psychophysiological state of a human

Successful using of neural networks in the field of medical diagnosis was the basis of research on the use of neural networks for the classification of psychophysiological states, using data that was obtained from psychological tests.

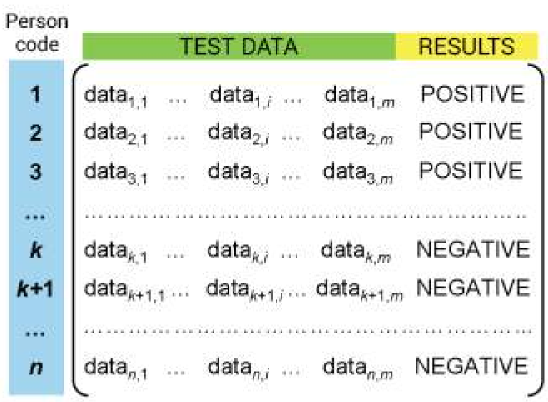
The system of analysis of a psychophysiological state of a human contains a set of tests of a different kind for identification of psychophysiological characteristics of a human. To date, the system has two psychophysiological tests: the reaction to a moving object and a tapping rate.

Designed reaction to a moving objects test suggests that the subject will respond at the moment when the moving object crosses fixed marks as fast as possible. Initially, the test was used to determine the ratio of excitation and inhibition processes. Prevalence of correct answers indicates a high functional condition of the nervous system, the high number of outrunning errors proves the predominance of excitation processes, and a high number of lag errors shows predominance of inhibitory processes. Realized test also helps to evaluate the functional asymmetry of the human brain.

The tapping rate is used to identify the strength of the nervous system of a human by analyzing their psychomotor performance [10]. This test monitors changes of the maximum rate of wrist movements and provides the following data for the analysis: number of errors, the average time of pressing, the duration of the test, the number of taps every five seconds.

To collect statistical data, a sequence of five experiments with pupils from sports school and students has been conducted. A total of 30 people were tested. The age of subjects varied from 14 to 22 years of age. The final decision on the psychophysiological state of a human is based on the assessment of several experts. The resulting experimental data is a training database for the neural network.

The database is a table (or matrix) of data concerning persons for whom the psychophysiological state is already known. Each row of the matrix refers to one person (Fig. 2). The first m elements of the row are test data and the last n elements represent the output (results). The term “test data” indicates results of tests and other information provided by the person.



Person code	TEST DATA					RESULTS
1	$data_{1,1}$	...	$data_{1,i}$	...	$data_{1,m}$	POSITIVE
2	$data_{2,1}$	...	$data_{2,i}$	...	$data_{2,m}$	POSITIVE
3	$data_{3,1}$	...	$data_{3,i}$	...	$data_{3,m}$	POSITIVE
...	...					
k	$data_{k,1}$	...	$data_{k,i}$	...	$data_{k,m}$	NEGATIVE
k+1	$data_{k+1,1}$	...	$data_{k+1,i}$	...	$data_{k+1,m}$	NEGATIVE
...	...					
n	$data_{n,1}$	...	$data_{n,i}$	...	$data_{n,m}$	NEGATIVE

Figure 2. Example of training database structure. Each row refers to a different person labeled with a numerical code.

Let’s determine the number of neural networks. Since each test involves a different dimension of the input vector to the neural network and is used to determine a different number of psychological parameters, it is advisable to use the number of the neural networks that is equal to the number of tests. Also, unique parameters of each individual test should be taken into account during the training.

D. A generalized description of the neural network to process the results of various psychophysiological tests is offered

The neural network that was discussed in details in [10] was implemented to solve this problem. This neural network is a multilayer backpropagation network. The structure of a neural network is formed by an "input" layer, one or more "hidden" layers, and the "output" layer (Fig. 3).

The neurons in the input layer receive the data and transfer them to neurons in the first hidden layer through the weighted links. Here, the data are mathematically processed and the result is transferred to the neurons in the next layer. Ultimately, the neurons in the last layer provide the network’s output.

By the final user, the neural network can be viewed as a "black box" that receives a vector with m inputs and provides a vector with n outputs (Fig. 4) [1].

For each of the tests, we established its own neural network, because the dimension of the input and output vectors are different.

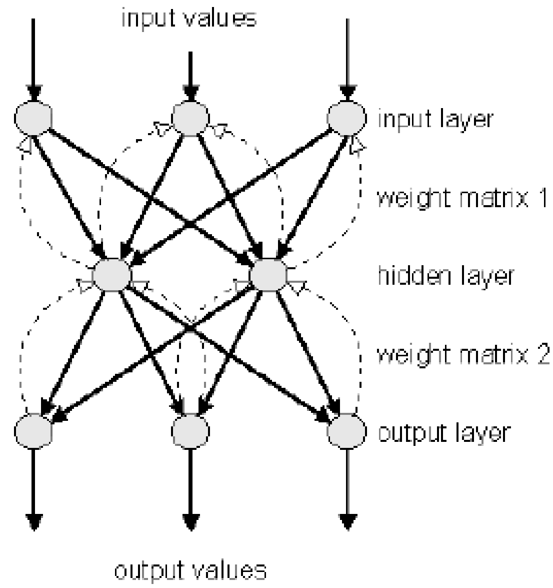


Figure 3. A multilayer neural network with backpropagation error and one hidden layer

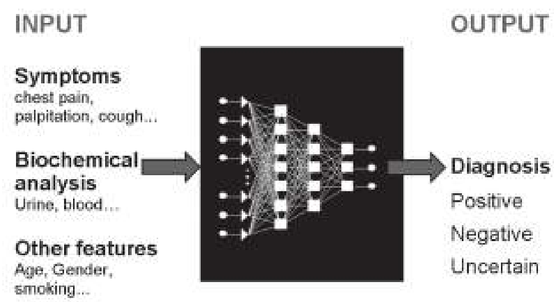


Figure 4. Details of input and output items concerning neural networks based diagnosis

An example of the input and output vectors for neural network used to process results of reaction to a moving objects test is presented here. Six test results are given to neural network. Results contain 2 parameters and 16 discrete values. Here is an example of one of this test results:

- The velocity of the object 100 pixels/sec;
- Direction of the object: from left to right;
- Difference between the position of the label and the fixed object (15 values): -1, -4, -3, -3, -4, 5, -3, -4, -4, -3, 1, -4, 0, -6, -2.

Thus, the dimension of the input vector N = 17 * 6 = 102.

The neural network is able to identify the following properties of the human nervous system:

- Strength of the nervous system: strong / weak;
- Functional asymmetry of the brain: the left / right / not expressed;
- Ratio of excitation and inhibition: excitation / inhibition / balanced.

The dimension of the output vector K is defined as a composition of the number of options and the count of values of each of the recognized properties of the nervous system; and is equal to K = 2 * 3 * 3 = 18.

III. Conclusions

The article shows that neural networks are an effective tool for the study of a stochastic system, such as a person. The usage of neural networks in the psychophysiological diagnostics improves accuracy by identifying the hidden relationships between different human systems. In addition, their use makes the diagnosis more reliable and therefore increases patient satisfaction. It is worth to remember that the psychophysiological state of a person depends on many factors such as physiological condition, emotional area, behavioral sphere.

This hierarchy corresponds to a multilayer structure of the neural network shown in Fig. 3 and has the following properties:

- The presence of a nonlinear relationship between the first and last layers can determine the number of layers and the number of neurons in each layer;
- Each intermediate layer represents one level of the system and is interpreted separately.

The ability to use the neural networks for processing the results of psychophysiological tests was confirmed with the help of a generalized description of the neural network, and examples of input and output vectors for processing results of the reaction to moving objects test. Thus, it justified that the use of neural networks for the processing of the results in the developed tests will improve the accuracy of diagnosis. However, despite their wide application in modern diagnosis, they must be considered only as a tool to facilitate the final decision of a clinician, who is ultimately responsible for critical evaluation of the artificial neural network output.

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ИСКУССТВЕННЫЕ НЕЙРОННЫЕ СЕТИ ДЛЯ ОЦЕНКИ ПСИХОФИЗИОЛОГИЧЕСКОГО СОСТОЯНИЯ ЧЕЛОВЕКА

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В работе исследуется возможность использования нейронных сетей при разработке тестов для оценки психофизиологического состояния человека. Описана компьютерная система психофизиологической диагностики человека, позволяющая автоматизировать выполнение и обработку результатов экспресс-методик. Представленная модель оценки психофизиологического состояния человека, использующая нейронную сеть, имеет следующие преимущества: возможность проведения диагностики удаленно, стабильность и точность результатов, способность к самообучению путем обнаружения сложных зависимостей, выявление типичных тенденций для людей определенной профессии или в той или иной области, обработка большого количества данных и снижение времени диагностики.

Controlling the Correctness of Physical Exercises Using Microsoft Kinect

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***Abstract*—This document contains the description of the program for controlling the correctness of physical exercises using Microsoft Kinect. The method of the comparison between live motions performed by the user and recorded motions is described. Presented short review of existing systems and description of testing the program.**

***Keywords*—Physical exercises, motions, Microsoft Kinect, motion comparison, production rule system.**

I. Introduction

Nowadays the automation is used in many areas, including sport and physical culture. Most of the modern consoles have motion sensors. It gives developers big opportunities. The application of the new technologies and methods may be interesting and popular among people who care about their health, but do not have time for the gym and gamers who are interested in new experience. It is possible that in the near future people will give up going to the gym and hiring personal trainers and will use a virtual coach instead, doing physicals exercises at home in front of their consoles.

Program that is being developed may be useful both for the people who are recovering from injuries and for the people who just don't have enough time to go to the gym. The main objective of the program is to compare a predetermined sequence of the human movement with actual human movement captured via Kinect. The program should allow user to train at home controlling the way exercises are performed by the user and reporting to user about the mistakes he makes.

II. Existing virtual training systems

A. Nike+ Kinect Training

This system allows user to train at home with the help of the virtual coach using Microsoft Kinect sensor.

The biggest advantage of this system is the diversity of physical exercises and automatic selection of these exercises according to the user's goals. With the first launch of the system the user is tested for his shape and abilities and then he can choose the goal of the training sessions.This system also provides user with the feedback about the performance of the exercises through the voice tips of the virtual coach.

Considering disadvantages it is worth mentioning that the accuracy of the exercises performance tracking is not really that good. System may sometimes ignore quite poor form of the exercise performance by the user or on the contrary may not count repetitions with the good form.

B. The Vera System

The Vera System is a program that is used by the medical institutions to help people in rehabilitation after injuries, surgeries, diseases etc. It is available only for the clinics that ordered it, so it's quite hard to fully review this system.

According to the developers, doctors and patients this system suits perfectly exactly for the rehabilitation. Doctor can track the progress of his patient and for the patient it's a lot easier to do exercises because system demonstrates the technique and tracks the performance of the movement. And the accuracy of exercises performance tracking is the biggest advantage of the system. It reports about any inaccuracy in the user motions.

C. Your Shape: Fitness Evolved

Your Shape: Fitness Evolved is a game for Xbox 360 consoles. It allows user to do usual physical exercises and also to do some different physical activity such as boxing movements, dancing, yoga etc.

The game is quite colourful, interface looks nice and bright. User can move around and have fun. Represented exercises are divided by muscle groups.

Overall, the game looks pretty good, but it's not very accurate at tracking performance of the movements. The repetitions may be counted even in those movements that reminds the standard only remotely. This is the main disadvantage of this system.

D. Conclusion

Three of the most popular and convenient existing virtual training systems are described in the sections above. There are some other similar systems that weren't mentioned, but the majority of them look more like games for entertainment than training systems.

As for the systems that were mentioned above, though they are better than most of the alternatives, each of them has it's disadvantages. Nike+ Kinect Training and Your Shape: Fitness

Evolved aren't accurate enough to detect all the mistakes in the user motions and The Vera System is available only for the medical institutions (most of the people do not have any access to it).

III. Analysis methods of the control of the correct physical exercises performance

The implementation of the program for the control of the correct physical exercises performance was divided into two main phases: recording phase and comparison phase.

A. Recording phase

In the first phase we needed to record the exercise and save it to file for the further use as a movement with a perfect form.

A few approaches have been tried for the recording. Firstly, we were trying to save only the coordinates and types of the joints. But this approach was too inefficient. Another suggested method was serialization and in the end it was decided to use it.

Serialization is the process of converting an object into a stream of bytes in order to store the object or transmit it to memory, a database, or a file. Its main purpose is to save the state of an object in order to be able to recreate it when needed. The process of the serialization is shown on the figure 1.

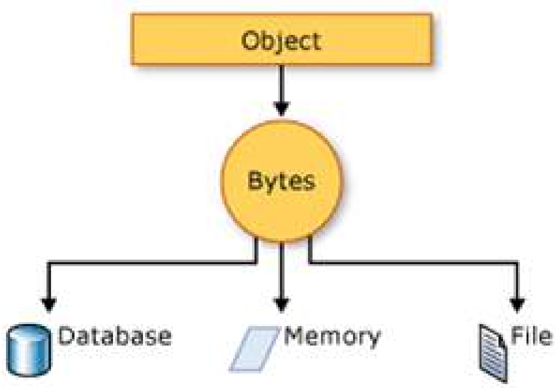

Fig. 1. Overall process of the serialization

The object is serialized to a stream, which carries not just the data, but information about the object's type, such as its version, culture, and assembly name. From that stream, it can be stored in a database, a file, or memory.

Thus, with the use of the serialization the collection of frames with the data about the skeleton is saved to the file. This approach is good because we don't need to divide skeleton data and take only particular parts of it. Instead, the collection of frames is saved and each frame contains the whole information about the skeleton including coordinates, joints, type of joints, positions, orientation etc.

After we got the file with the information about the exercise we needed to read this file and process the data. To do it we used deserialization (the reverse process to the serialization).

B. Comparison phase

Now that we have saved motion data about the exercise that will be considered as a standard, we need to compare the standard with the user motion.

The basic idea is to compare the angles of the joints in the recorded motion standard with angles of the joints in the user motion. So, everything comes down to the calculation of the angles between vectors and comparison of these angles. In our case parts of the human body may be considered as vectors. Thus we need to know the values of the angles of the joints in the recorded motion standard and in the user motion. These angles are calculated with the use of the same method.

Method takes 4 arguments: skeleton data and 3 arguments which represent the types of the joints. For example, in addition to the skeleton data it could be three joint types - JointType.ShoulderCenter, JointType.ShoulderLeft, JointType.ElbowLeft. If we pass these arguments in our method the angle will be calculated in the left shoulder joint (JointType.ShoulderLeft). Combining the joints, we can get two vectors that have one common point, and this point will be the joint in which we are calculating the angle. Coordinates of vectors are obtained, vectors are normalized, cross product and dot product are calculated and then the angle between vectors is calculated using Atan2 method. This method returns the angle whose tangent is the quotient of two specified numbers.

The angles of the joints in the user motion are calculated every frame. For the motion standard angles are calculated in advance and stored in list.

Because it's almost impossible to repeat the motion standard with 100 percent accuracy program takes into account little errors in the user motion. At this point the error is 15 degrees in the value of the angles. Also, program compares current frame of the user motion not only with the one frame of the motion standard but with the 16 closest frames (8 previous and 8 subsequent) because user may do exercise a little faster or a little slower than standard motion demands. Angles of the joints in the recorded motion standard and angles of the joints in the user motion are compared in the loop. If the difference between angles is less than 15 degrees it means that user is doing motion correctly.

To calculate the accuracy of the particular repetition in a particular exercise using described above algorithm the result of the comparison (whether the motion has been done correctly or not) is saved and stored. And the results of the comparison are stored for every joint involved in the exercise. When motion standard "ends" (all the frames of the recorded motion has been played) the analysis of the results starts. For the analysis the percent of the exercise performance correctness is calculated. The amount of frames in which the motions of the user were correct is divided by the total amount of frames in this exercise. It is done for every joint involved in the exercise. And after this the conclusion is made about whether this repetition may be considered as the correct or not. If the percent of correctness for each joint is above 85 and the arithmetic mean of all the percents is above 90 then this repetition may be considered as a correctly performed.

To analyze whether the motion is done by the user correctly or not we also used production rule system. All the exercises were divided into groups by the joints that are used in the exercises. And the production rules were set for each group. The example of the production rules for one of the exercises (overhead squats) is described below.

The next joints are used in this exercise:

- Shoulders
- Elbows
- Spine
- Hips
- Knees

Production rules for this exercise:

- Rule 1: IF (exercise = jumping jack) OR (exercise = squats) OR (exercise = overhead squats) OR (exercise = hip raises) THEN (compare angles in shoulder joints = yes) AND (compare angles in elbow joints = yes) AND (compare angles in spine = yes) AND (compare angles in hips = yes) AND (compare angles in knees = yes)
- Rule 2: IF (difference between angles in shoulder joints < 15) THEN (result of the shoulder joints comparison in the current frame = true)
- Rule 3: IF (difference between angles in shoulder joints >= 15) THEN (result of the shoulder joints comparison in the current frame = false)
- Rule 4: IF (difference between angles in elbow joints < 15) THEN (result of the elbow joints comparison in the current frame = true)
- Rule 5: IF (difference between angles in elbow joints >= 15) THEN (result of the elbow joints comparison in the current frame = false)
- Rule 6: IF (difference between angles in spine < 15) THEN (result of the comparison in spine in the current frame = true)
- Rule 7: IF (difference between angles in spine >= 15) THEN (result of the comparison in spine in the current frame = false)
- Rule 8: IF (difference between angles in hips < 15) THEN (result of the comparison in hips in the current frame = true)
- Rule 9: IF (difference between angles in hips >= 15) THEN (result of the comparison in hips in the current frame = false)
- Rule 10: IF (difference between angles in knee joints < 15) THEN (result of the knee joints comparison in the current frame = true)
- Rule 11: IF (difference between angles in knee joints >= 15) THEN (result of the knee joints comparison in the current frame = false)
- Rule 12: IF (percent of correctness in each joint >= 85) AND (average percent of correctness >= 90) THEN (repetition is counted = true)
- Rule 13: IF (percent of correctness in each joint < 85) AND (average percent of correctness < 90) THEN (repetition is counted = false)

The screenshots of the program while user is doing the exercise are shown on the figures 2 and 3.

Fig. 2. Exercise is performed correctly

Fig. 3. Exercise is performed incorrectly

IV. Testing of the program

The program has been tested by 10 users and each of them tested all 10 exercises represented in the program. The results of the testing are shown in the tables 1 and 2. If the user was able to do a few repetitions of the exercise in the table this exercise was marked with +. If the user wasn't able to do even one repetition of the exercise in the table this exercise was marked with -. If the user was able to do a few repetitions of the exercise with some difficulties in the table this exercise was marked with +-.

Thrusters and hip raises caused the biggest difficulties among users. It means that we need to make these exercises easier (for example, by decreasing the percent of correctness threshold value) or replace them with the other exercises.

It is also worth mentioning that most of the users needed some time to get used to the way the exercises should be performed. Perhaps, decreasing the percent of correctness threshold value of the exercises would be the good idea not

Table I. RESULTS OF THE TESTING, PART 1

	User 1	User 2	User 3	User 4	User 5
Hand raises	+	+	+	+	+
Elbow rotation	+	+	+-	+	+
Military press	+	+	+	+	+
Jumping Jack	+	+-	+-	+	+
Side bend	+	+-	+-	+-	+-
Squats	+	+-	+-	+-	+-
Overhead squats	+	+	+-	+-	+-
Thrusters	+	-	-	-	-
Side lunges	+	+	+	+	+
Hip raises	+	-	-	-	-

Table II. RESULTS OF THE TESTING, PART 2

	User 6	User 7	User 8	User 9	User 10
Hand raises	+	+	+	+	+
Elbow rotation	+	+	+-	+	+
Military press	+-	+	+	+	+
Jumping Jack	+-	+-	+-	+	+-
Side bend	+-	+	+-	+	+-
Squats	+-	+-	+-	+	+-
Overhead squats	+	+-	+-	+	+
Thrusters	-	-	-	+-	-
Side lunges	+	+	+	+	+
Hip raises	-	-	-	-	-

only for those movement that caused some difficulties among users but also for the other exercises.

Summing up the results of the testing we may say that users handled the performance of most of the exercises quite well. Nevertheless, some of the exercises still need corrections or replacing.

V. CONCLUSION

This document contains the description of the program for the control of the correct physical exercises performance implementation using Microsoft Kinect.

The implementation of the program was divided into two main phases: recording phase and comparison phase.

In the first phase we had to record the human-motion and save it into a file for later processing. A few approaches (on how to read and save those data from tracked human skeleton) have been tried here. The successful approach that is used now is a serialization – saving the collection of skeleton frames into a data structure in binary format.

The second phase is a comparison between live motions performed by the user and recorded motions. The main idea is to calculate recorded motion's joint angles and user's joint angles, compare them, considering a little error and then with the use of the production rule system analyze performed exercise to know whether the motion was correct or not.

At the moment there are ten exercises represented in the program, involving different joints and muscle groups. Program gives user the feedback about the performance of the exercises by marking the joints in which user make mistakes with red colour. Also, for more detailed information about the accuracy of the repetition performance user can open the output file that contains the percents of the accuracy for every joint in every exercise in every repetition. The format of the output file is shown in the appendix A.

The further development of the program is planned for the future. The plan is to combine the current method of the comparison with the gesture recognition methods to increase efficiency and accuracy and also to include more exercise to the program.

APPENDIX A
FORMAT OF THE OUTPUT FILE

Designations "L Sh", "R Sh", "L El" etc. are abbreviated names of the joints. L and R mean left and right side respectively. Name of the joints may be written fully (Spine, Hip etc.), or reduced to the first two letters (Sh - Shoulder, El = Elbow etc.).

An example of a fragment of the output file:

Exercise 1: L Sh=90 R Sh=90 R El=78,8888888888889 L El=81,1111111111111 Hip Center R=100 Hip Center L=100 Spine=98,8888888888889 Overall = 91,2698412698413

Exercise 1: L Sh=100 R Sh=98,8888888888889 R El=100 L El=100 Hip Center R=100 Hip Center L=100 Spine=100 Overall = 99,8412698412698

Exercise 2: L Sh=93,3333333333333 R Sh=83,3333333333333 R El=90 L El=93,3333333333333 Hip Center R=100 Hip Center L=100 Spine=100 Overall = 94,2857142857143

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ПРОВЕРКА ПРАВИЛЬНОСТИ ВЫПОЛНЕНИЯ ФИЗИЧЕСКИХ УПРАЖНЕНИЙ С ИСПОЛЬЗОВАНИЕМ КАМЕРЫ MICROSOFT KINECT

Выборный А.И., Розалиев В.Л., Орлова Ю.А., Заболеева-Зотова А.В., Петровский А.Б.

В данной работе рассмотрен подход контроля правильности выполнения физических упражнений с использованием технологии Microsoft Kinect, а также метод сравнения заранее записанных движений с движениями, производимыми пользователем. В работе рассматриваются системы для проведения тренировок с использованием различных видеокамер. Описывается продукционная модель для проверки правильности выполнения физических упражнений. Приводятся результаты экспериментов при тестировании разработанной системы. Планируется дальнейшее развитие системы для проверки большего количества упражнений, в том числе и произвольных.

Finding Geometric Parameters of the Vertebrae on Spine X-ray Profile Pictures

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***Abstract*—In this paper we offer an searching algorithm of the vertebrae in profile image of a human spine and an algorithm for calculating the geometric parameters of the vertebrae. These algorithms have been developed to diagnose osteoporosis automation.**

***Keywords*—Biomedical image processing, DICOM**

I. Introduction

X-ray photography is one of the best ways to study the internal state of human bodies [1]. The advantages of this method are easy and fast taking pictures process and a small dose of radiation. Also, modern equipment allows to receive images in digital form, which makes it possible to process images on a computer. Image file format was standardized and named DICOM. It contains information about the survey, patients, doctors, scanner characteristics, etc. [2].

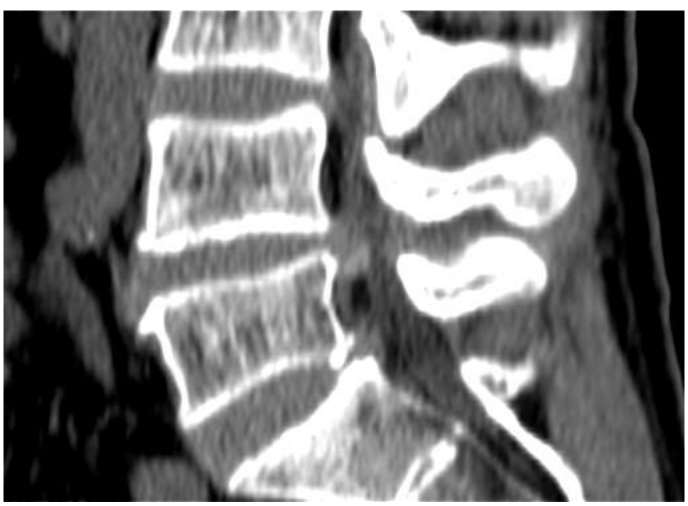

Figure 1. Lateral vertebra image

X-ray DICOM images contain two-dimensional matrix of densities, which represents part of human body picture. Each of these values corresponds to a tissue site. To identify the type of tissue it is used Hounsfield Scale [3], which describes the relative tissue density relative to the density of water. So practically all tissues contain water, it is difficult to uniquely identify tissue.

For diagnosing osteoporosis there are three types of parameters necessary to determine [4]:

- Vertebrae shape parameter
- Intervertebral joint parameters
- Spinous processes parameters

According to the statistical analysis of data for the diagnosis of osteoporosis patients significant parameters form the vertebrae are:

- Height of the ventral h_a and dorsal h_b (sagittal plane) of the vertebral body contour
- Length of the cover l_a and basal l_b end plate
- Wedging angle α_p and trapezoidal angle α_t of vertebrae
- The angle of inclination of the vertebral body to the vertical α_v and to the horizontal plane α_h

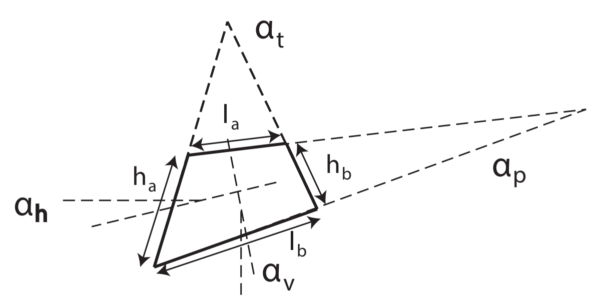

Figure 2. Vertebrae shape parameters

Significant diagnostic parameters of the intervertebral joints are:

- Height of the ventral d_1 and dorsal d_2 (in sagittal plane) parts of intervertebral disk
- Wedging angle α_d of intervertebral dis
- Angle α_m between vertebrae bodies
- Linear displacement s of vertebral body in the plane of the disk
- Displacement angle α_s of vertebrae

Significant diagnostic parameter of the spinous processes is:

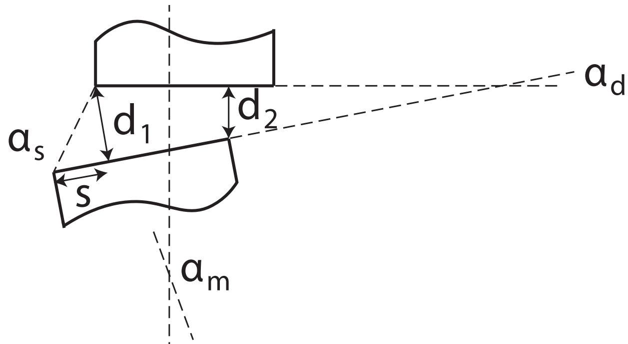

Figure 3. Intervertebral joint parameters

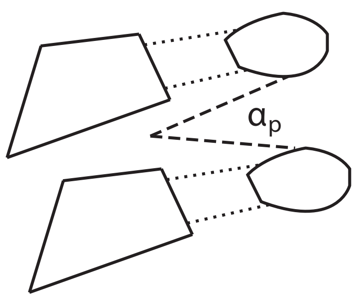

Figure 4. Spinous processes parameters

- Angle α_m between spinous processes

The process data description parameters for a long time was mainly manual work, which took a lot of physician time. Also, one of the disadvantages of manual separation of vertebrae is subjectivity in defining the boundaries of anatomical structures of the vertebrae, which in turn may reduce the value of diagnostic and prognostic investigation. complete set of parameters for the calculation is quite time-consuming manual calculation, and, moreover, the calculation results is difficult to store, organize and use statistical analysis.

Therefore, automation of the vertebrae and calculate their parameters search problems will accelerate the diagnosis of disease and to predict the effects of surgical procedures.

II. Formulation of the problem

Based on the format of X-rays and the parameters of the vertebrae to be obtained, the task is divided into the following main sub-tasks.

- Finding vertebrae on the image
- Calculation vertebrae parameters
- Calculation intervertebral joints parameters

A. Finding vertebrae on the image

For isolation of bone tissue on image authors proposed to use clustering densities. The pixels on image after the clustering procedures are replaced by the centers of clusters, which belong to the pixels, and thus, the image is smoother and

Figure 5. Clustered vertebrae image(bone tissue is marked by beige color)

tissues essentially differ from each other, have a clear border [5].

To determine the geometric characteristics of vertebrae and intervertebral joints we need to have information about the shape of vertebrae on image. Good vertebra forms characteristic of image is the contour. Following contours of the tissue clustering can easily identify on image.

Since the images are monochrome, then they can apply a significant range of image processing operations. The most commonly used operations to highlight the following statements are the contours:

- Sobel operator [6]
- Canny operator [7]
- Laplace operator [6]

For edge enhancement the image Laplacian was selected which showed the best results among the test.

Mathematically, the Laplace operator is the sum of the squares of the second partial derivatives of the function. Discrete analog Laplace operator used in image processing, in particular for determining the edges of objects in the image. The ribs are formed of a plurality of pixels, wherein the Laplacian becomes zero, since zero second derivatives of the function correspond to the intensity of extreme differences.

$$D^2_{xy} = \begin{bmatrix} 1 & 1 & 1 \\ 1 & -8 & 1 \\ 1 & 1 & 1 \end{bmatrix}$$

Contours, after image processing Laplace operator, can be seen in the picture 6.

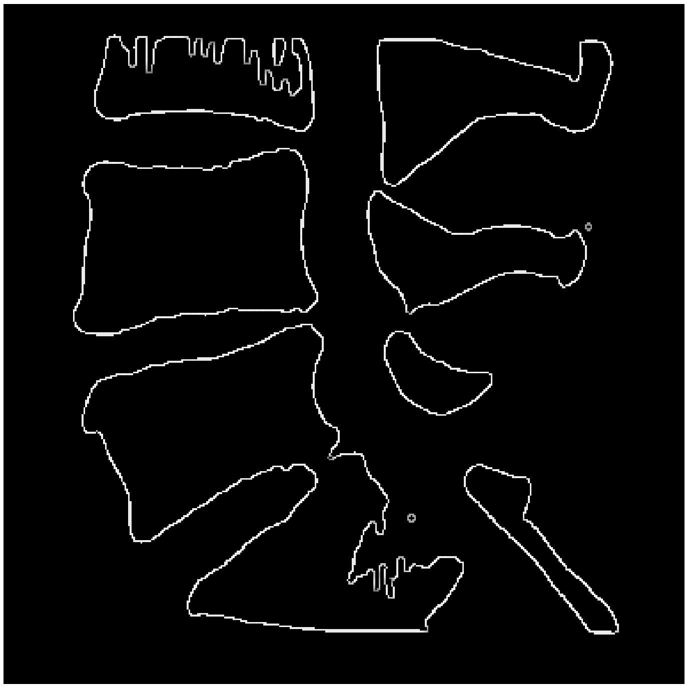

Figure 6. Found contours on the image

After selecting the contours of image must correctly identify the contours that belong to the vertebrae, and discard those that belongs to other tissues.

Since the vertebral body at the cut has a certain shape, vary slightly depending on the type of vertebra, the presence of individual vertebrae circuits is not a difficult task.

However, by using clustering or manually adjust the image contrast, some vertebrae can be "glued" in one contour that prevents their recognition.

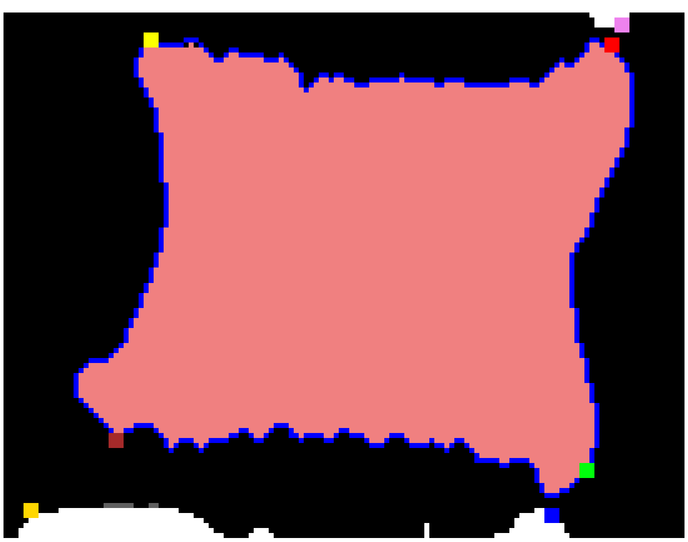

Figure 7. Found vertebrae on the image(color points – edges of vertebrae)

To solve this problem the authors was an algorithm that separates the vertebrae from each other in case of "gluing". This algorithm is based on the following assumptions:

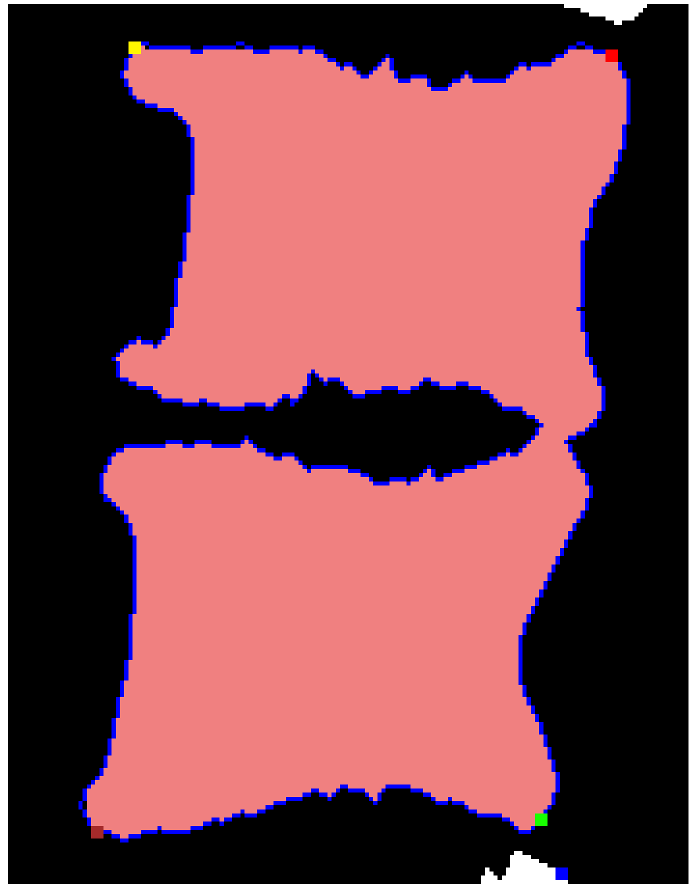

Figure 8. "Glued" vertebrae

- Vertebrae are connected in a single place, and this place does not change its position
- Height of connected vertebrae equal to the sum of vertebrae height and the height of connections between vertebrae

Algorithm consists of the following steps:

- Based on the height of the vertebral group calculated the number of vertebrae
- Prepared histogram the number of pixels belonging to the vertebrae, with each row
- According to an exemplary arrangement of jumpers from an assumed vertebra height and number of pixels per line, lines are built, which are separated from each other vertebrae

After that separated vertebrae treated in the same way as standing alone.

B. Calculation of parameters of vertebrae and intervertebral joints of image

Since finding of vertebrae on image was also searched edge points, building a line passing through these points, it can be quickly found the shape parameters vertebra.

III. Analyzing vertebrae software

Software which uses algorithms has been developed and it allows to carry out the processing of X-ray images of vertebrae. The software has been implemented as a client application. To design was used C# programming language. Main features of the software are:

- View images in DICOM format
- Adding images to the database for later use in research
- Possibility of manual tagging vertebrae in images
- Possibility to automate finding the vertebrae in the image according to the developed algorithms
- Possibility of calculating parameters of vertebrae and export them as Excel table
- Export in XML format


```xml
<?xml version="1.0" encoding="utf-8"?>
<storage pixelWidth="0.127124846" pixelHeight="0.127124846">
  <spines>
    <spine key="L5">
      <points>
        <point x="1119" y="1642" />
        <point x="1155" y="1845" />
        <point x="1432" y="1727" />
        <point x="1389" y="1558" />
      </points>
      <geomertry>
        <param key="alpha_h" value="-20.268518447875977" />
        <param key="alpha_p" value="5.7921614646911621" />
        <param key="alpha_t" value="4.2190437316894531" />
        <param key="alpha_v" value="11.989548683166504" />
        <param key="h_a" value="26.208999633789063" />
        <param key="h_b" value="22.168619155883789" />
        <param key="l_a" value="35.946445465087891" />
        <param key="l_b" value="38.275558471679688" />
      </geomertry>
    </spine>
```


Figure 9. Output XML file content

A	B	C
Участок	Угол наклона к горизонтали	Угол клиновидности
L5	-20.26851845	5.792161465
L4	-9.926244736	-3.393434048
L3	0.902995527	-3.833319426
L2	5.99253273	-3.928757191
L1	2.711440563	-6.212532997
Диск	Угол клиновидности диска	Угол между телами позвонков
L4-L5	9.11943531	9.11943531
L3-L4	14.39763546	14.39763546
L2-L3	8.865114212	8.865114212
L1-L2	1.847606421	1.847606421
Угол между остистыми отростками		
L4-L5	19.10409927	

Figure 10. Output XLS file content

IV. Conclusion

The work was proposed algorithm and corresponding software search vertebrae and determining their size and relative position with the purpose of diagnosing osteoporosis automation. These software tools allow as to obtain more accurate diagnosis of the disease and predict the actions of operational and other treatments.

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ОПРЕДЕЛЕНИЕ ГЕОМЕТРИЧЕСКИХ ПАРАМЕТРОВ ПОЗВОНКОВ НА ПРОФИЛЬНЫХ РЕНТГЕНОВСКИХ СНИМКАХ ПОЗВОНОЧНИКА

Курочка К. С., Цалко И. Н.

В статье приведен алгоритм поиска позвонков на профильном изображении позвоночника человека. В ходе работы алгоритм сегментирует изображение по тканям. Следующим шагом алгоритм классифицирует сегментированные области изображения с целью нахождения тел позвонков и межпозвоночных дисков. Следующий алгоритм, вычисляет геометрические параметры найденных частей позвоночник. Данные алгоритмы были разработаны с целью автоматизации диагностики остеопороза.

The Introduction of Intelligent Prediction as the Rendering Technology Component Heat Flows

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***Abstract*—The introduction of elements of forecasting, as a part of computer-aided design systems, walling (CAD PD), to avoid problems of incorrect determination of the temperature in the design. At the design stage of the building will allow the most accurate prediction to choose thermal units and heaters to maintain optimal indoor climate, as well as improve energy efficiency of thermal points.**

Keywords*—*CAD, forecasting, visualization, heat flow, protecting designs.

I. Introduction

During the effect of the type of research design and sharp temperature spikes when calculating the correction value for predicting the nature of the distribution of heat fluxes on various sections of the structure were found a number of laws related to the typical error values that require additional formalized description. That description in the system are the values of the analytical calculation error compared with practical values with to collect temperature data units. [1] One of the key practical value technology developed elements is in compliance with the micro-climate and hygiene requirements [2] imposed on walling. Violation of these requirements often occurs with a sudden change in external influences, as analytical calculations from a physical point of view, they do not take into account, in other words there is no element of forecasting such surges, resulting in a breach of these rules. Consider an example when the outdoor temperature is changed to eight degrees or more for several days. Comparing the results of analytical calculations without prediction and without changing external temperature conditions and using elements based on these components to clarify the nature of the heat flow (Fig. 1.) it can be concluded on the accumulation of impermissible values of the error. The value of each of the waves from the heater to the enclosing structure corresponds to a decrease in temperature by five degrees.

The relevance of the developed system is due to a significant increase in requirements for the thermal protection of buildings, according to changes in building codes (Building regulations 02-03-79). According to the requirements of the temperature on the surface of ti enclosing structure, should be above the dew point of not less than $2 - 3^{\circ}$ C.

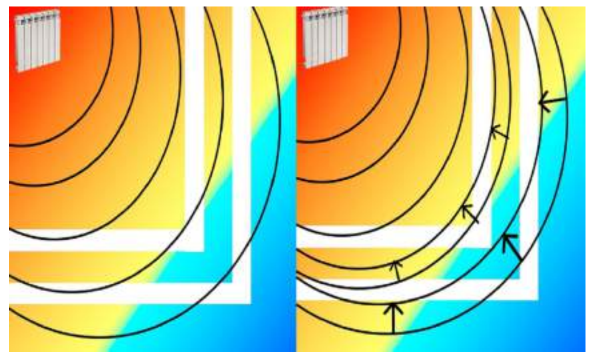

Figure 1. Visualization of the distribution of heat flows in building envelopes with intelligent forecasting components

II. Consideration of distinctive features for building envelope components predictive forecasting

A. The main parameters of the building envelope used to predict

For the most accurate prediction of CAD PD accounted for the following design features:

- overall heat transfer coefficient;
- heat transfer coefficient of the insulation layer;
- the thickness of the insulation layer;
- one layer thickness;
- location factor;
- thermal resistance;
- values of temperatures on the inner and outer surfaces;

B. To forecast the correction coefficients

On the basis of the calculation of the value of the amendments for the implementation of the nature of heat flow distribution forecast proved violation of the rules in 2-3 C. [1], which can lead to condensation, violation of sanitary norms, reduction of design life and its thermal properties. On the basis of the calculations was proposed solution to this problem is to introduce correction factors for each selected layer. The value of the coefficients are not fixed and are directly dependent on the temperature conditions, temperature zone of the temperature jumps forecasts based on historical data [3], the knowledge base and rules [4], and also depend on the particular layer that you want to consider as an analytical calculation method. It involves the accumulation of errors by layers.Based on the temperature data samples occurs recognition situation: the presence or absence of problem zones. The method of recognition of the situation lies in the ability to set ambient temperature conditions outside the contour, as well as granting councils in the case where the heat flux from the heater can heat the entire path.Task CAD to offer the most optimal variant layout, trace a connection point with the heat, as well as visualize the resulting heat flow from the heater and the loop of the building. The final step of the algorithm is to visualize the nature of heat flow to a specific situation in view of the identification algorithm situations and decision-making.

The result of the processing of the measuring information received from multiple sensors - recognition of options situations subsequent trace heaters. Hierarchy overlay flows represents a fusion of the two fronts - the heat from the heaters and the cold loop. The result is the total heat flow, which is then used to make decisions about repackaging heaters.Identifying situations thermal circuit eventually has only two options: no problem zones (zones freezing), or their availability.The task module CAD walling to offer the most optimal variant layout, trace a connection point with the heat, as well as visualize the resulting heat flow from the heater and the loop of the building. General Ingredients intelligent prediction visualization of thermal flows of various types with the basic parameters of the building envelope show on Fig.2.

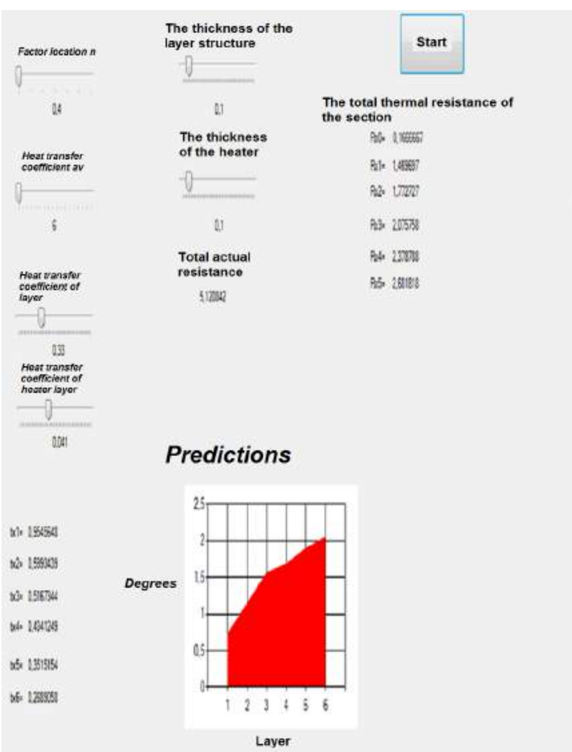

Figure 2. Core components of intelligent prediction visualization of thermal flows of various types with the basic parameters of the building envelope

Using the Intelligent forecasting the shortage of information about the nature of the distribution of heat flows, it allows you to:

1) verifying for each pick of the layers with maximum accuracy;
2) avoid the accumulation of errors in layers;
3) take into account all the parameters of the building envelope;
4) choose the type of building envelope and its properties for the design of the engineering network.

III. Example of intelligent prediction of heat flux distribution patterns

Consider the example of the calculation of the distribution pattern of heat flow. The temperature distribution for one of the days of the receipt on the basis of analytical calculations is shown in Figure 3.

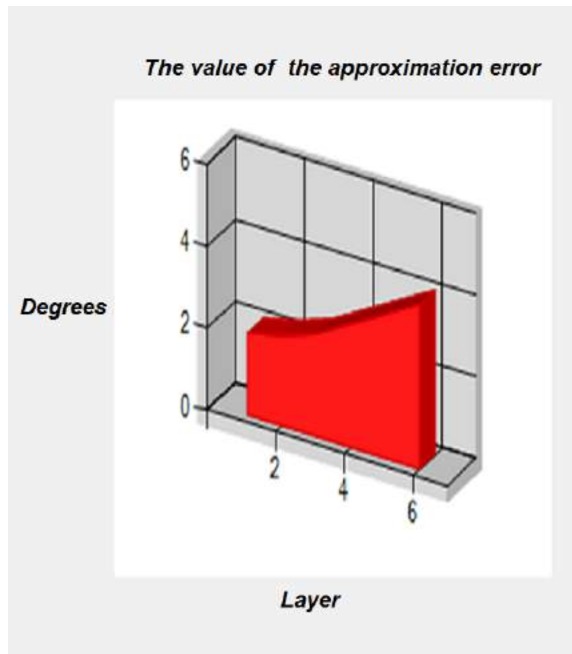

Figure 3. Analytical calculation of the temperature

Calculate the predicted values for the coefficients of the temperature distribution (Figure 4).

Thus, it is proved in violation of 2-3C., which can lead to condensation, violation of sanitary norms, reduction of design life and its thermal properties.Intelligent components of CAD allow most effectively interact with the user by means of comments.

Comments to the nature of heat flow distribution are displayed when you hover over one of the heat flows or to cross a few. They contain information that freezing problem areas have been identified and selected type of heater corresponds to the type of circuit. Comments heat flows to the zones displaying information about a particular part in the stream and provide information about the temperature of each part of the flow. Removal CAD data by using OK sensor system and the device "Terem-4" . In depending on the requirements to the thermal circuit, may also be included additional additive criteria, for example, the threshold for average energy ratio for

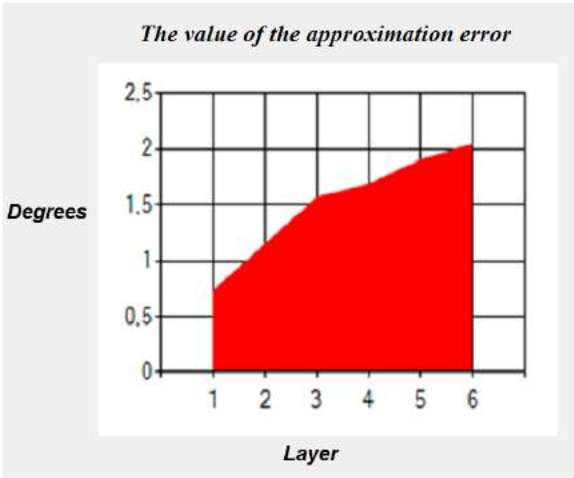

Figure 4. Prediction amendments nature of heat flow using the basic parameters of the enclosing structure

all heaters used to heat the circuit . The introduction of more stringent criteria for the comments can increase the energy efficiency of the designed circuit, however, it should be noted that not all circuits are possible to achieve the optimal limit [1].Example of intelligent prediction show on Fig.5.

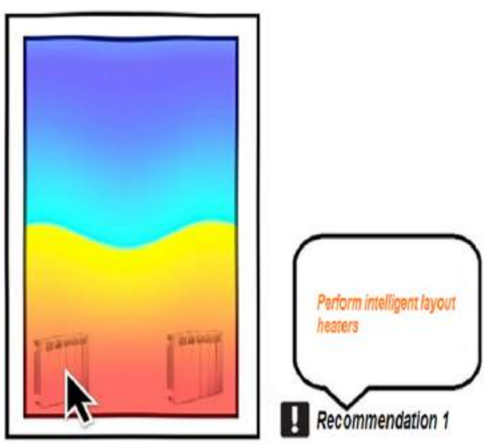

Figure 5. Example of recommendation based on intelligent prediction

IV. Layout algorithm based on intelligent prediction of heat flows

The task of the layout component CAD thermal utilities, to provide the most op-timal variant layout, traces a connection with the heating unit. The final step of the algorithm is to visualize the nature of heat flow to a specific situation in view of the identification algorithm situations and decision-making. The practical use of the software module using the algorithm allows using it as the design of new buildings and the reconstruction of old ones. Identifying situations thermal circuit eventually has only two options: no problem zones (zones freezing), or their avail-ability. Identify the main steps of the algorithm identifying situations and decision-making:

- Step 1. On the basis of a priori constraint matrix formed with the use of IP-linear programming tech-niques form the principal-WIDE intervals.;
- Step2. We form the matrix of restrictions contour defining the edge-tzu to heat flow;
- Step3. Checking matrix "code solution" to the exis-tence of adequate solutions;
- Step4. If a solution is found, then the operation code decides on visualization heat flow in a certain way;
- Step5.If solution is not found or there are several solutions (add situation), then using a probability matrix is a solution with maximum probability;
- Step6. If the poll matrix "code solution" unique situa-tion, absent from, in binary code relationships memory values selected the most suitable frames sector, where it is then the criterion of confidence Eden ratifies the most suitable situation;

Thus, the selection function is implemented by the new sit-uation of choice (code binary operations) the most appropriate sector of frames in the knowledge base. Examples of rules in the Knowledge Base:

- Rule1. IF the coordinates of the distribution of the heat flow heater and the coor-dinates of the heat flow path of engineering networks are THEN calculate the re-sulting heat flow;
- Rule2. IF the resulting heat flow at a temperature above the optimum THEN find the area of the problem area;
- Rule3. IF I find a problem area zone THEN build a minimal vector to the contour of utilities to find on field problem;
- Rule4. IF I find a problem area or problem area THEN you give a certificate of non-optimal arrangement and recompose again. Example visualization component layout is shown in Figure 6;

Layout algorithm based on intelligent components, help to avoid some of the problems related to the visualization of the data in the calculation of the CAD module to reduce the error in the calculations, and to increase the visibility of the results, as well as to provide support for decision-making in the field of building automation systems. Efficiency calculations utilities can reduce the time for calculation of parameters walls and improve their accuracy, which is an important requirement in the design of buildings and structures. The need to use these components for the CAD due to the requirement to solve the problems of distribution of thermal heating elements, as well as the need for detection of problem areas. These tasks are currently among the most intractable in the environment of poorly formalized and demanding automation applications. The complex offers intelligent components when building CAD integration will allow more accurate visualization of the heat flows . This will increase the accuracy of calculations and impact in the future on the quality of the layout of the heating elements in the circuit utilities. At the initial stage of the algorithm takes the form analysis of changes in the

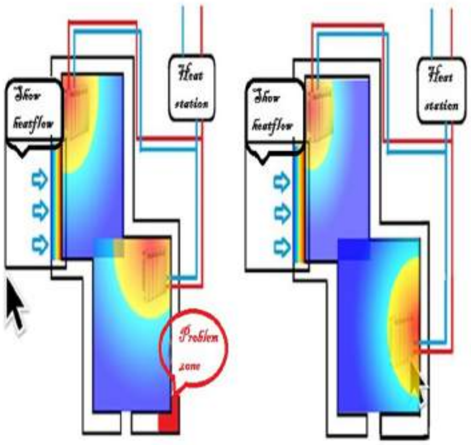

Figure 6. Example visualization component layout based on intelligent prediction

thermal circuit, which is initialized in the team to change the settings. When initializing is performed to detect the temperature sensors and the formation of the data samples. Based on the temperature data samples occurs recognition situation: the presence or absence of problem zones. The method of recognition of the situation lies in the ability to set ambient temperature conditions outside the contour, as well as granting councils in the case where the heat flux from the heater can heat the entire path. Problematic areas (PA) in this case will be considered the region in which the effect is minimal and insufficient heaters for heating engineering network or part of the air flow in the room.

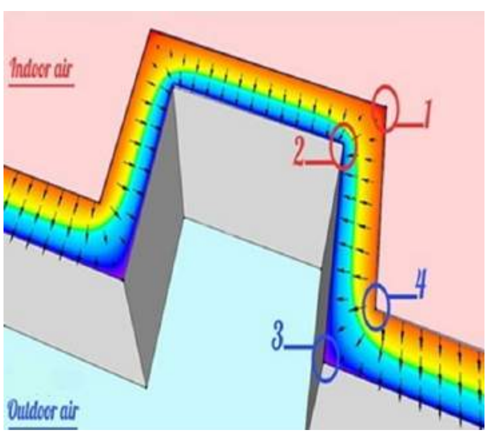

Figure 7. Visualization of detected PA with component layout based on intelligent prediction

Layout algorithm based on intelligent prediction, to avoid some of the problems related to the visualization of the data in the calculation of the CAD PD to reduce the error in the calculations, and to increase the visibility of the results, as well as to provide support for decision-making in the field of building automation systems. Efficiency calculations utilities can reduce the time for calculation of parameters walls and improve their accuracy, which is an important requirement in the design of buildings and structures. The need to use these intelligent components for the CAD PD due to the requirement to solve the problems of distribution of thermal heating elements in the construction, as well as the need for detection of problem areas. These tasks are currently among the most intractable in the environment of poorly formalized and demanding automation applications. The complex offers intelligent components when building CAD PD integration will allow more accurate visualization of the heat flows. This will increase the accuracy of calculations and impact in the future on the quality of the layout of the heating elements.

V. Conclusion

Thus, in the course of clarifying the nature of the distribution of heat flows in CAD PD to determine the magnitude of error of actual temperature values.Walling, that would solve a number of issues related to ensuring the required level of thermal protection of buildings, and to avoid violations of sanitary norms, ensuring a longer life of the structure and preserving its thermal properties. The effectiveness of the implementation of this intelligent technology forecasting at different stages of the design of buildings and structures, as well as an add-on CAD PD due to the reduction of time for calculations, higher precision, automation of related parameters associated with insulated construction, as well as the ability to take into account the relationship of the past influence on the final correction factor. Predictive forecasting component allow for visualization of the heat flows Walling insufficient even if the statistical information that can be used in engineering networks to reduce the total time for the design.

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ВНЕДРЕНИЕ ИНТЕЛЛЕКТУАЛЬНОГО ПРОГНОЗИРОВАНИЯ КАК КОМПОНЕНТА ТЕХНОЛОГИИ ВИЗУАЛИЗАЦИИ ТЕПЛОВЫХ ПОТОКОВ

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Внедрение элементов прогнозирования, в составе средств систем автоматизированного проектирования ограждающих конструкций (САПР ОК), позволит избежать проблемы некорректного определения температуры в конструкции. На стадии проектирования здания прогнозирование позволит наиболее точно подобрать тепловые узлы и нагреватели для поддержания оптимальных климатических условий в помещении, а также повысить энергоэффективность работы тепловых пунктов.

Semantic model for high-level synthesis of dataflow pipelines

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***Abstract* — A semantic model of computational hardware and software pipelines has been developed. Several relations, graphs and logic inference rules constitute a basis for the construction and high-level synthesis of dataflow pipelines. The behavioral specification pipelining tool is capable of optimizing parallel implementations of logic inference and knowledge dynamic processing algorithms.**

Keywords* — *semantic model*; *pipeline*; *knowledge processing*; *high level synthesis*; *optimization

Pipelining is an efficient way of increasing the operating frequency and throughput of data intensive digital systems in various application fields. Among them, pipelining of knowledge representation and processing tools as well as logic inference tools is the most important task. A pipelined system is usually described in an appropriate programming or hardware description language. Pipelining can be seen as a transformation of a source behavioral specification into pipeline-stage-fragments that are executed in time-sliced fashion.

Complex digital systems are typically characterized by irregular structures, thus it is impossible to perform a straightforward mapping of the specification into a pipeline implementation. Therefore, this paper develops an efficient semantic model of pipelining designs that imply several "low cost" chained operators in one basic processing block. The model takes into account key parameters of the behavioral elements including the variable sizes, the operator delays, the relations on the set of variables and operators, and the behavior of mutually exclusive branches.

Various languages and representations are used for describing pipelines: the concurrent language, CAL [1], programming language, C/C++ [2], data flow graphs [3], signal flow graphs [4], transactional specifications [5], and other notations. A pipeline system is characterized by several parameters such as the clock cycle time, stage cycle time, number of pipeline stages, latency, data initiation interval, frequency and throughput.

The pipeline high-level synthesis algorithms as follows have been proposed: list scheduling [6], force directed scheduling [7], iterative modulo scheduling [8], speculative loop pipelining [9], and integer linear programming [10]. The loop winding method [11], percolation based scheduling [12], loop rotation scheduling [3], pipeline vectorization method [2] and modulo scheduling followed by stage scheduling [13] aim at pipelining loops. The macro pipelining based scheduling technique [14] is capable of pipelining heterogeneous multiprocessor systems. A pipeline decomposition tree based scheduling framework is presented in [15]. The cost-optimized algorithm for the selection of components without sharing resources in the pipeline is presented in [16].

Since modern technology provides large amounts of available resources, faster and larger pipelines for knowledge processing without (or with minimal) sharing of resources can be synthesized with advantages in performance [17-19]. In order to realize this challenge, a systematization of knowledge on pipeline construction, synthesis and optimization has to be conducted.

This paper is organized as follows. Section II presents the semantic model of the behavioral specification under pipelining. Section III describes the semantic model of computational pipelines. Section IV presents the semantic model of pipeline high level synthesis and optimization. The last section concludes the paper.

I. Semantic Model of Behavioral Specification under Pipelining

A. *Behavioral specification for pipelining*

The system behavior that is under pipelining is represented as a program in a system representation language. The key parts of the representation are variables, operators and relations. Each variable is characterized with a type and a size. The set of operators includes logic scalar and vector operators, arithmetic operators and others. The assignment, conditional and loop instructions allow to represent any computational behavior of the system under pipelining.

Rule 1. The pipeline synthesis and optimization is performed from a system behavior and constraints on pipeline parameters.

B. *Control-data flow graph*

The control-data flow graph (CDFG) is a result of translation of the behavioral specification into an intermediate representation. The original control dominated CDFG is not efficient for pipeline high-level synthesis. It should be transformed to a data flow graph (DFG) that is more convenient for pipelining. The transformation is based on splitting and eliminating control structures as shown in [17] and on rules 2-5.

Rule 2. If the behavioral description contains loops then it is transformed to a single loop with an infinite iteration scheme, one linear basic block and *break* instructions inside it.

Rule 3. If the behavioral description is a branched one then it is transformed to a sequence of short *if-then* instructions with an assignment inside which are considered as data flow elements.

Rule 4. If an assignment instruction contains more than one operator in the right part expression then it is transformed to a sequence of simpler assignments by adding intermediate variables.

Rule 5. The mixed control/data flow graph is transformed to a pure data flow graph and a set of relations.

An example of pure data flow graph is shown in fig.1. The graph consists of the variables and operators that are reported in fig.2. The operators are located on the levels according to the data dependences and critical path.

C. Data dependency relation and graph

Let V be a set of variables and N be a set of operators. A set of input variables of operator $i=1,\dots,n$ is denoted as $in(i)\subseteq V$ and a set of its output variables is denoted as $out(p)\subseteq V$. From these sets, a set $cons(v)\subseteq N$ of consumers and a set $prod(v)\subseteq N$ of producers is being computed for each variable $v\in V$. The data dependences among operators are represented with a binary matrix (relation and graph) D whose rows and columns correspond to operators. An element $d_{ij}=1$ if operator j is data dependent on operator i. For CDFG with loops the graph D is cyclic, otherwise it is acyclic.

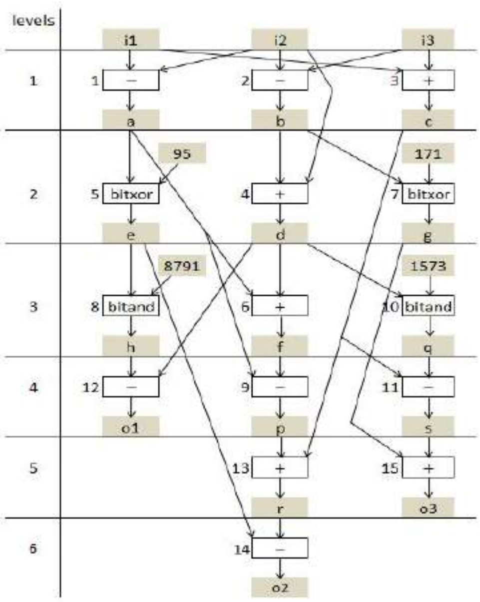

Fig.1. Example data flow graph

Operators			Variables			
No	Type	Relative delay	No	Name	Mode	Size
1	–	2.20	1	i1	in	16
2	–	1.65	2	i2	in	12
3	+	2.00	3	i3	in	12
4	+	1.75	4	a	loc	16
5	bitxor	0.10	5	b	loc	10
6	+	2.00	6	c	loc	13
7	bitxor	0.10	7	d	loc	14
8	bitand	0.10	8	e	loc	18
9	–	2.20	9	f	loc	16
10	bitand	0.10	10	g	loc	6
11	–	1.93	11	h	loc	18
12	–	2.48	12	p	loc	13
13	+	1.62	13	q	loc	14
14	–	2.48	14	r	loc	13
15	+	1.25	15	s	loc	10
			16	o1	out	17
			17	o2	out	14
			18	o3	out	10

Fig.2. Operators and variables of example data flow graph

Rule 6. The data dependency graph is constructed taking into account the input and output variables of operators, feedbacks in CDFG with loops and mutually exclusive execution conditions.

D. Operator precedence relation and graph

The operator precedence relation P describes a partial order on the set of operators.

Rule 7. The partial order is derived from the analysis of data dependences between operators in DFG taking into account the orthogonality of test variables in conditional statements.

The operator direct precedence relation P_{direct} is computed as a minimal anti-transitive relation of the transitive closure P_{trans} of relation P (fig.3). This relation represents the direct precedence graph as well. The graph can be cyclic or acyclic. It describes a mixed sequential-parallel execution of operators and short conditional instructions.

$$P_{trans} = \left|\begin{array}{ccccccccccccccc}
0&0&0&0&1&1&0&1&1&0&0&1&1&1&0\\
&0&0&1&0&1&1&0&1&1&1&1&1&1&1\\
&&0&0&0&0&0&0&0&0&1&0&1&1&1\\
&&&0&0&1&0&0&1&1&1&1&1&1&1\\
&&&&0&0&0&1&0&0&0&1&0&1&0\\
&&&&&0&0&0&1&0&0&0&1&1&0\\
&&&&&&0&0&0&0&0&0&0&0&1\\
&&&&&&&0&0&0&0&1&0&0&0\\
&&&&&&&&0&0&0&0&1&1&0\\
&&&&&&&&&0&1&0&0&0&1\\
&&&&&&&&&&0&0&0&0&1\\
&&&&&&&&&&&0&0&0&0\\
&&&&&&&&&&&&0&1&0\\
&&&&&&&&&&&&&0&0\\
&&&&&&&&&&&&&&0
\end{array}\right|$$

Fig.3. Transitive matrix P_{trans} for the example dataflow graph

Rule 8. The minimal anti-transitive precedence relation speeds up the optimization process in high-level synthesis.

E. Operator delays

Timing models and delay estimation techniques for operators depend on the implementation platform: ASIC, FPGA, multi-core processor etc. The rules as follow are used.

Rule 9. Timing models of operators that are executed on words of bit depend on the operator type, operands width and implementation style.

Rule 10. Time delays of operators that are implemented on a LUT-based FPGA are measured in LUT (lookup table) levels and are estimated through bit-level interpretation of word operators and decomposing them into logic LUT-fragments.

F. Longest delay paths in operator precedence graph

The lengths of longest paths between operators in the operator precedence graph constitute a basis for realizing pipeline constraints. A matrix L represents the lengths for all operator pair. As the precedence graph is DAG for a non-loop behavior, matrix L can be computed in a polynomial time. For P_{trans} shown in Fig.3 and its elements described in fig.2, the matrix L is given in Fig.4.

Rule 11. Additive timing models are used in many cases of pipeline implementation. More complex and precise timing models of operators and paths are used in several design flow, in particular, for FPGA.

II. SEMANTIC MODEL OF COMPUTATIONAL PIPELINES

A. Classification of pipelines

Fig.5 and 6 show two architectures of hardware pipelines and fig.7 shows architecture of a software pipeline. The number of clock cycles within one stage is called a pipeline initiation interval (II). The increase of II dramatically influences the resource sharing.

Rule 12. If the goal is to minimize the resources by sharing, II is increased. It costs a growth in the hardware pipeline latency and a reduction in the system throughput.

$$L = \begin{vmatrix}
2.20 & 0.00 & 0.00 & 0.00 & 2.30 & 4.20 & 0.00 & 2.40 & 6.40 & 0.00 & 0.00 & 4.88 & 8.02 & 10.50 & 0.00 \\
 & 1.65 & 0.00 & 3.40 & 0.00 & 5.40 & 1.75 & 0.00 & 7.60 & 3.50 & 5.43 & 5.88 & 9.23 & 11.70 & 6.68 \\
 & & 2.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 3.93 & 0.00 & 3.63 & 6.10 & 5.18 \\
 & & & 1.75 & 0.00 & 3.75 & 0.00 & 0.00 & 5.95 & 1.85 & 3.78 & 4.23 & 7.57 & 10.05 & 5.03 \\
 & & & & 0.10 & 0.00 & 0.00 & 0.20 & 0.00 & 0.00 & 0.00 & 2.68 & 0.00 & 2.58 & 0.00 \\
 & & & & & 2.00 & 0.00 & 0.00 & 4.20 & 0.00 & 0.00 & 0.00 & 5.82 & 8.30 & 0.00 \\
 & & & & & & 0.10 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 1.35 \\
 & & & & & & & 0.10 & 0.00 & 0.00 & 0.00 & 2.58 & 0.00 & 0.00 & 0.00 \\
 & & & & & & & & 2.20 & 0.00 & 0.00 & 0.00 & 3.83 & 6.30 & 0.00 \\
 & & & & & & & & & 0.10 & 2.03 & 0.00 & 0.00 & 0.00 & 3.28 \\
 & & & & & & & & & & 1.93 & 0.00 & 0.00 & 0.00 & 3.18 \\
 & & & & & & & & & & & 2.48 & 0.00 & 0.00 & 0.00 \\
 & & & & & & & & & & & & 1.63 & 4.10 & 0.00 \\
 & & & & & & & & & & & & & 2.48 & 0.00 \\
 & & & & & & & & & & & & & & 1.25
\end{vmatrix}$$

Fig.4. Matrix L of longest path lengths for the example dataflow graph

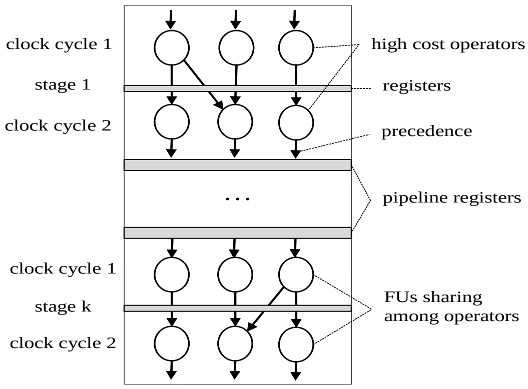

Fig.5. Hardware pipeline with two clock cycles per stage and resource sharing

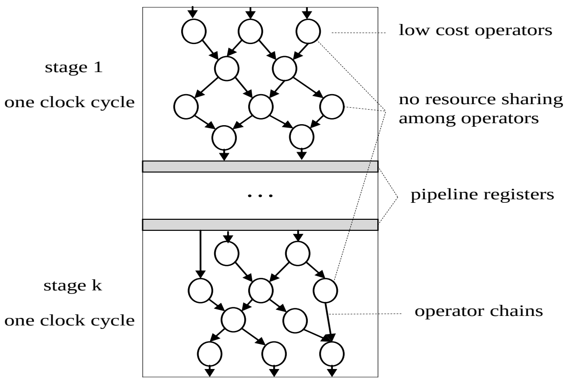

Fig.6.Hardware pipeline with one clock cycle per stage, operator chaining and without resource sharing

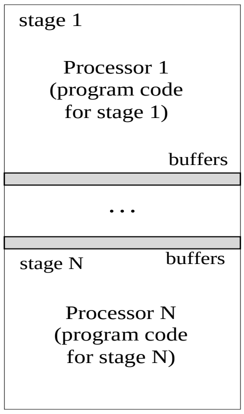

Fig.7.Software pipeline that consists of stages which are assigned a program code that is executed on a processor

Rule 13. If the goal is to minimize the hardware pipeline latency and maximize the throughput, II is decreased. Pipelines with one clock cycle per stage use operator chains within one stage and do not use resource sharing.

Rule 14. If the goal is to maximize the throughput of software pipeline, the program code is partitioned for the execution on processors which run in the time-sliced fashion.

Rule 15. If the goal is to optimize the pipeline, the tasks as follows are to be solved: choosing the number of stages and the pipeline initiation interval; selection of operator implementations, assignment of operators to stages and clock cycles, minimization of buffer sizes and minimization of the pipeline latency.

B. Pipeline stage time

In a hardware synchronous pipeline, the stage time, T_{stage} is evaluated in the number of clock cycles multiplied by the clock period. In pipeline optimization, the time is often considered as a constraint that essentially influences the resulting design throughput and load of equipment. In a software asynchronous pipeline, the stage time is the program code maximum execution time in a stage on the corresponding processor over all stages. If the data buffers which are inserted in between two stages are implemented as FIFOs, the stage time can vary over stages and data sets.

Rule 16. The pipeline stage time and the number of stages are mutually dependent values. The larger stage time implies the fewer number of stages.

C. Operator conflict relation and graph

For two operators i and j, if the value of $l_{i\,j}$ in matrix L is larger than T_{stage}, we say there is a pipeline stage conflict between these operators. To overcome this conflict, the operators must be assigned to different pipeline stages. The conflict relation and graph is described with a binary matrix, C. To speed up the pipeline optimization process, C is replaced with its minimal anti-transitive version which is computed from the transitive closure of C and contains the minimum number of value 1. Fig.6 presents the operator conflict relation for the example matrix, L and T_{stage}=3.825.

In a software pipeline, operators i and j have a conflict if the execution time of i and j plus the execution time of all operators which are successors of i and predecessors of j exceed the pipeline stage time.

$$C = \begin{vmatrix} 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 1 & 0 & 0 & 1 & 1 & 1 & 0 \\ & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 1 & 0 & 1 & 1 & 1 & 1 & 1 \\ & & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 1 & 1 \\ & & & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 1 & 1 & 1 & 1 \\ & & & & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ & & & & & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 1 & 1 & 0 \\ & & & & & & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ & & & & & & & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ & & & & & & & & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ & & & & & & & & & 0 & 0 & 0 & 0 & 0 & 0 \\ & & & & & & & & & & 0 & 0 & 0 & 0 & 0 \\ & & & & & & & & & & & 0 & 0 & 0 & 0 \\ & & & & & & & & & & & & 0 & 1 & 0 \\ & & & & & & & & & & & & & 0 & 0 \\ & & & & & & & & & & & & & & 0 \end{vmatrix}$$

Fig.6. Operator conflict relation C for the matrix L and T_{stage}=3.825

Rule 17. The conflict relation C is a basis for the estimation of the minimum number of pipeline stages and for the generation of a tremendous number of alternative but functionally equivalent hardware and software pipelines.

D. Mapping of operators onto pipeline stages

The mapping is described with a function *stage*: $N \rightarrow S$ where N is the set of operators and S is the set of stages. According to the mapping, s=*stage*(p) means that s is the stage which the operator p is assigned to.

Rule 18. The number of different solution, *stage* is equal to the number of different valid pipelines that are feasible and legal for the stage time T_{stage}.

III. Semantic Model of Pipeline High Level Synthesis and Optimization

A. Determining the number of pipeline stages

Rule 19. The number l of pipeline stages is determined by the length of a longest path in the operator conflict graph, C. The length is measured in the number of edges.

For a l-stage pipeline a minimum stage time is denoted $T_{stage}(l)$. The stage time for l stages is larger than the stage time for l+1 stages. Therefore all pipelines which are generated for the stage time in the range form $T_{stage}(l+1)$ to $T_{stage}(l)$ have the same number l of stages as shown in fig.7.

B. ASAP and ALAP pipeline schedules

The as soon as possible (ASAP) schedule assigns operators to the earliest pipeline stages and the as late as possible (ALAP) schedule assigns operators to the latest stages. Fig.8 and fig.9 show these schedules for the example dataflow graph.

Rule 20. ASAP and ALAP determine the mobility of each operator over pipeline stages.

Rule 21. ASAP and ALAP give the fastest pipeline schedule without sharing resources.

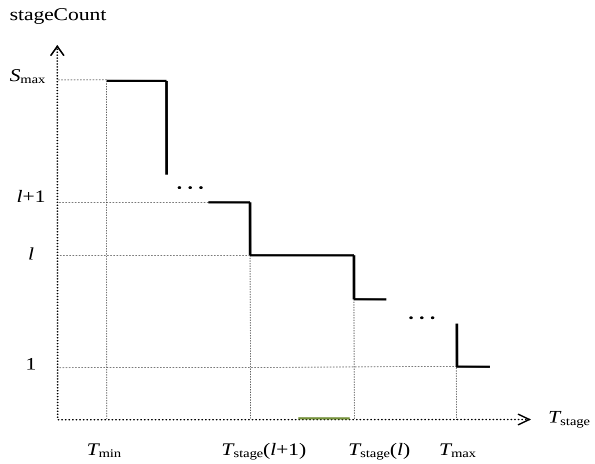

Fig.7.Number of pipeline stages versus stage time

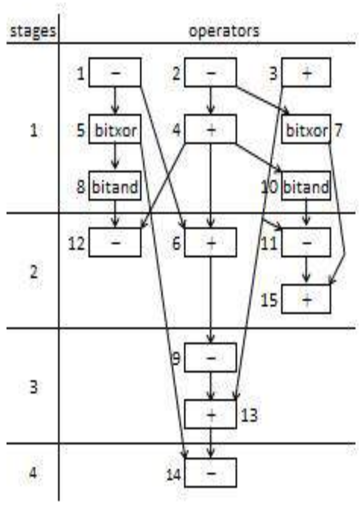

Fig.8.ASAP 4-stage pipeline schedule for the example dataflow graph and T_{stage}=3.825

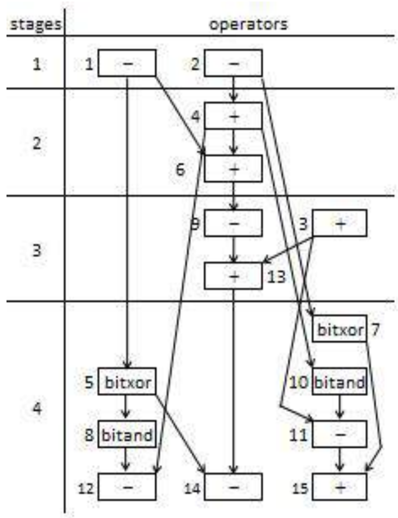

Fig.9. ALAP 4-stage pipeline schedule for the example dataflow graph and T_{stage}=3.825

Rule 21. ASAP and ALAP give the fastest pipeline schedule without sharing resources.

Rule 22. ASAP and ALAP do not yield the minimum overall pipeline buffer size.

C. A set of pipelines with the same stage time

A huge set of pipelines with the same stage count can be generated from the same operator conflict graph.

Rule 23. The number of feasible valid pipelines is estimated as μ^n where μ is the average operator mobility and n is the number of operators.

Rule 24. Heuristic optimization techniques must be used for large pipelined designs.

D. Overall pipeline buffer size minimization

The *lifetime*(v) of variable v over pipeline stages is determined by the difference of the earliest stage of its producers and the latest stage of its consumers (fig.10). Two and more producers must be conditional, *if* c_1 *then* v:=e_1; *end* … *if* c_k *then* v:=e_k; *end* with orthogonal test variables $c_1 \ldots c_k$ and expressions $e_1 \ldots e_k$.

Rule 25. The size of all buffers that represent v in a pipeline is computed as *size*(v)×*lifetime*(v). The overall buffer size is the sum of buffer sizes over all variables. This is true for both hardware and software pipelines.

Rule 26. In asynchronous pipelines the overall buffer size increases against the synchronous pipelines as each buffer is replaced with a FIFO.

E. Pipeline optimization algorithms

Exact and heuristic algorithms have been developed to optimize the dataflow pipelines. They assume the functional units and their parameters have been selected for the operator implementation and assume the processor parameters have been selected for the program code execution.

Rule 27. The algorithm of searching for the shortest path in the operator conflict graph minimizes the number of pipeline stages.

Rule 28. The overall buffer size minimization is a hard combinatorial problem that is solved by exact algorithms for small designed and heuristic algorithms for large designs.

Rule 29. The exact algorithm finds an optimal solution *stage* by means of logic inference with backtracking.

Rule 30. The heuristic algorithm finds a suboptimal solution *stage* by means of exploiting pipeline heuristics.

Fig.11 shows an optimal 4-stage pipeline schedule for the example data flow graph. This schedule consumes 13 pipeline registers (167 bit) while ASAP (fig.8) consumes 17 registers (247 bit) and ALAP (fig.9) consumes 16 registers (216 bit).

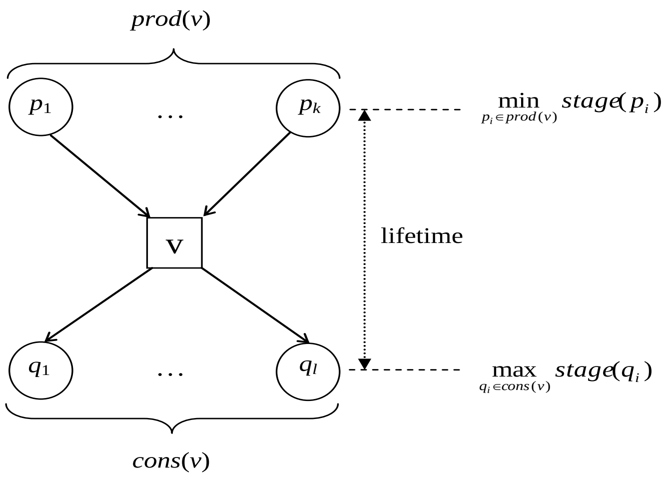

Fig.10. Lifetime of variable *v* over pipeline stages

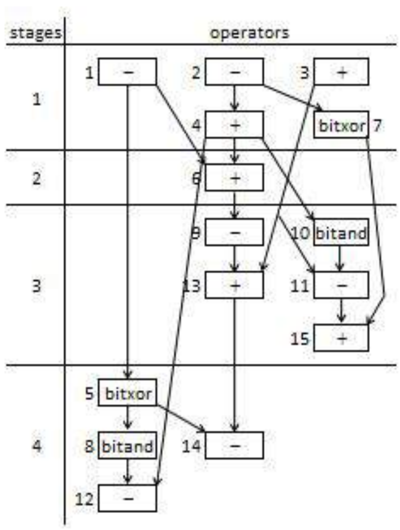

Fig.11. Optimal 4-stage pipeline schedule for the example dataflow graph and T_{stage}=3.825

F. Experimental results

The experiments have been conducted on designs from industry and on randomly generated designs. The proposed exact and heuristic algorithms of dataflow pipeline optimization yield much better results against ASAP and ALAP. They gain up to twice over ASAP and ALAP with respect to the overall buffer size. The exact algorithm is able to yield a solution for pipelines with 100 operators and 5 stages. The heuristic algorithm loses the exact one and gives only 2% larger buffer size on average over the exact algorithm. At the same time the heuristic algorithm is capable of handling large designs which consist of thousands operators and is capable of generating many-stage pipelines which consist of tens stages.

IV. Conclusion

This paper presents a semantic model for high-level synthesis and optimization of dataflow pipelines. Several objects, relations and graphs lie in the basis of this model, that are constructed in accordance with the set of inference rules which are formulated in this paper. Different architectures of hardware and software pipelines are analyzed and different optimization parameters and criteria are considered. Knowledge on the pipeline high-level synthesis and optimization techniques are represented with rules which allow the implementation of the synthesis by means of logic inference and heuristics exploration. The semantic model and pipelining tool aim at the parallelization and speeding up the knowledge acquisition and processing as well as increasing the throughput of the logic inference and knowledge manipulation tools.

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СЕМАНТИЧЕСКАЯ МОДЕЛЬ ВЫСОКОУРОВНЕВОГО СИНТЕЗА КОНВЕЙЕРОВ ПО ПОТОКОВЫМ ОПИСАНИЯМ

Прихожий А.А., Карасик О.Н., Фролов О.М.

Разработана семантическая модель вычислительных аппаратных и программных конвейеров. Отношения, графы и правила логического вывода составляют базис построения и высокоуровневого синтеза конвейеров для обработки потоков данных. Отношения и графы представляют конвейер на всех этапах, начиная со спецификации и кончая реализацией. Правила логического вывода представляют процесс трансформации поведенческого описания в структурное описание конвейера. Инструментальная система конвейеризации поведенческих спецификаций обладает возможностями оптимизации параллельных потоковых реализаций алгоритмов логического вывода и динамической обработки знаний.

From Linguistic Relativity to Ontological

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***Abstract*—Abstract - How to construct linguistic-ontological models as the main problem of cognitive linguistics. Describes the contradictions of the cosmos and the relativistic paradigm through an analysis of the hypotheses of the universal linguistic structures n. Chomsky and linguistic relativity Time-linguistic relativity. Identifies the role of logical-cognitive universals in the intellectual development of the child according to the theory of j. Piaget. Shows lingvo-ontological nature of the crisis in modern physics.**

Keywords*—Substantial and Relativistic paradigm. Linguistic relativity. Universalism. Cognitive development. Logical-cognitive universals. Paradigm in Linguistics and physics. Fundamental ontology. Lingvo-ontological model. Cognitive relativity. The principle of subsidiarity.

I. Language, thinking, culture.

Psycholinguistics or cognitive linguistics begins with the need to penetrate the "mystery of consciousness" by appealing to its instrument – language and word as an atom of consciousness. The metaphor of the "mystery of consciousness" involves the study of a number of epistemological issues: the mechanisms of understanding the world, of thinking, perception and other intellectual practices. Currently they are referred to as cognitive. The formulation and attempted solution of the problem of the relation of language and thinking was first implemented in the studies of Wilhelm von Humboldt (1767-1835), a distinguished German philologist and philosopher. He suggested one way such a solution: language should be studied not only as a result of cognitive activity, but also as a means. Important to consider the relationship of thinking and language through culture of the people (ethnos). In his opinion, language is an intermediary between man and the world of culture. Thus, mediation does not go unnoticed. On the contrary, the language, condensing in the culture of the ethnic group, determines the relation of man to the world of culture that develops. At the same time, the perception of future generations depends on the language of previous representations. Consideration of the relationship of language and thinking in the modern interpretation means the study of the problem of spiritually-valuable inheritance that occurs in culture.

From a methodological point of such linguistic innovations developed by W. von Humboldt's concept about the relationship of language and thinking can be expressed in the following way. Language is not simply a tool of thought. Thinking and language give rise to material and spiritual culture, which has active influence on the subjects of culture through language. Each culture is national, its character is expressed in language by a particular world view particular to each ethnic group of the inner form. As the word bears the burden of subjective views of the author, and the language itself influenced the formation of the system of concepts and values from the standpoint of the already established mentality and culture of the people. It offers a new vision of language - not as something fixed, a set of lexical, grammatical or phonetic units and how the process of "formation of thought", expressing not only individual consciousness but also the worldview of a people, "his spirit". In modern language this linguistic paradigm can be described as cultural anthropology as a means of exploring the "mysteries of consciousness" are not only elements of the language, but the process of thinking, formation of public consciousness. Of course, the main protagonist of this process - the subject is presented in a generalized form, in the form of ethnic group – people, as well as the results of conscious activity - the material and spiritual culture. However, the hypothesis of linguistic relativity as based on the idea of thinking from the language gets a formulation in the form of tacit knowledge.

The development of cultural-anthropological research paradigm continued the so-called neohumbertii, which include the famous German linguist Leo Weisgerber (1899-1985). L. Weisgerber went further in conceptualizing the hypothesis and introduced the concept of the language picture of the world that became popular not only in modern linguistics, but also philosophy and culture in General. Weisgerber believed that every language is unique and each language is fraught with its own specific scheme, the model of development of the world - the so-called language picture of the world.

II. Substatially and relativistic paradigm.

If the transition to reflexive methodological level solution to the problem, which involves the so-called transdisciplinary and cross-cultural synthesis, we can come to the following conclusion. From the point of view of the methodology as a reflection activity, it is not only about the allocation of language as a specific means of cognitive exploration of the world, but also the introduction of new concepts such as schema, defines the General vision of the problem in the form of a picture of the world. In this case, we are talking about ontological by introducing invariant quantities that are the basis of the substantial paradigm modeling world. This method of ontologization is the basic paradigm of classical science. In linguistics as a substance acts as first language culture, and then language picture of the world. It should be note that the concept of a language picture of the world Leo Weisgerber takes into account not only the specificity of ethnic groups, for example in the form of generalized and objectified the characteristics of the mentality, but also contains contradiction, which will manifest itself in the near future in the study of issues of comparative linguistics and the formation of relativistic paradigms in linguistics.

In other words, the substantial paradigm modeling the world does not hold the "anthropological turn" in linguistics and for his modernization introduces the principle of linguistic relativity. We can say that this principle is based on thinking from the language in the concept of the language picture of the world is becoming more and more clear sounding. With all natural ontological and objective picture of the world in classical science, the method of ontologization is unable to objectify the reality of the language when you change the subject of linguistic research. Namely, this shift occurs when the language is considered in the form of communications and other linguistic practices. When modeling linguistic phenomena as processes of "living" culture, a form of existence which are the various processes of cultural education object-substance paradigm fails, because the subject is organically included in cognitive activity is unavoidable in principle. Attempt to extend substantially ontology, characteristic of the classical type of rationality in linguistics, which deals with linguistic phenomena as objects (simple samosoglasovannye system) the world of cultural education, through the allocation of linguistic forms and ways of development of the world is not wealthy.

As became clear later (at the methodological conceptualization of the phenomena of quantum mechanics) the substantial paradigm of the study is fundamentally not complete and like a quantum-mechanical way of description of reality needs to be complemented by the relativistic paradigm. And it happened what had to happen. Through cross-cultural translation in linguistics originated non-classical rationality, "the anthropological turn" became more radical, bolder subject displaces the object, transforming the study design.

III. Linguistic relativity.

Relativistic concept of language in the form of the linguistic relativity hypothesis emerged in the discourse of ethnolinguistics, which boldly produces anthropological innovations. The founder of the famous hypotheses is not accidental is the great American linguist Edward Sapir, who was an engineer. And this engineering-structural discourse it should be borne in mind, since it reflects the design and structural style of thinking and methodology that guides the Designer. Note that Design (with a capital letter) is written not only as a tribute to developer E. Sapiro, but also meets cultural traditions. In modern culture Design is denoted with a capital letter in order to emphasize its fundamental status, along with scientific research. Thus, unlike classical science and the standard of objectivity of research, the relativity of design to means and goals is the starting presumption.

We will not dwell on the historical discourse of this problem, we only note that the principle of linguistic relativity went into science in the form of a hypothesis Sepira period. However, if we follow the methodological approach, it is necessary to say that this methodological principle plays a role is not a hypothesis. We are dealing with a fundamental innovation in methodological tools, namely non-classical paradigm of solving the problem of the relation of language and thinking. In fact, linguistics has moved to the Design principles in which dependency (or relativity) result from the goals and means is attributive. Note that the term "ratio" is used as a metaphor, because behind it lies a series of deep questions on the topic, how is the representation of thinking as cognitive activities and what role in this process is played by language forms. That is why, accepted a formulation that language defines thinking and a way of learning is not so much a hypothesis as presumption and in contrast to hypothesis does not require evidence (and only interpretations and justifications).

Note that the formulation of a hypothesis in this revision later became known as "strong". "Force" has emerged from the programme of study. In order to understand the "mystery of consciousness" should study the regularities of formation and functioning of language as an intellectual resource. Further studies showed that the formulation of a hypothesis "language defines thinking and a way of knowing" is a very strong abstraction and should be mitigated for the study of the phenomenon of consciousness and thinking is not confined to the study of linguistic forms (tools). I got a weak formulation of the linguistic relativity hypothesis: language influences thinking. The language was seen as a tool of consciousness, along with other ethno-cultural information and communication, paryzkoyi and other factors, to the tools. So, in the strong version of the hypothesis asserts that language defines (determines) thinking, and in the weak — that language influences thinking

IV. Substatially paradigm and universalism.

However, the contradiction between two solutions (paradigms) problems – insight into the secrets of consciousness manifested not only at the phylogenetic level, in the form of ethnic and cultural inheritance. Ontogenetic approach to the problem of socio-cultural and individual linguistic inheritance received General and applied solution in the theory of a universal generative grammar developed by the American linguist N. Chomsky. The essence of his ideas was the assumption that there are certain generic language regularities similar nature, which are subject to socio-genetic inheritance of each individual in the form of inclinations, abilities. In other words all languages of the world at a deep level inherent in some universal structures that are inherited not only in culture, but also at the level of individual development (ontogenesis) that allows the child to learn the native language. Thus, the assumption on the existence of a universal grammar was congruent language picture of the world that has a different mode of existence, and includes substantial paradigm on the level of ontogenesis. And the development of Chomsky has been called the universalist approach, as it fit into the substance-ontological paradigm, in which the role substances play a universal grammatical structure.

V. The system of linguistic universals and constraints.

"The deep structure of language" according to Chomsky N. are verbal syntax certain linguistic universals that underlie the learning child the native language. When you build your conception of N. Chomsky works in the context of object-substatially paradigm and is in line with the classical type of rationality. Because of this, he takes (often implicitly) a number of assumptions, idealizations - simplifications, in particular, comes from the subject-object schema modeling language activity: Word (Concept) - Value (Meaning). The object paradigm allows us to consider language as a process of meaning making, the result is every word as sign has a strictly defined value. Ignoring the subjects of word creation - the speaker and the listener, because in the communication process generated not only the meaning but also the importance of relative discursive (depends on context).

The subject – object relation is the basis of the classical object - substance paradigm that goes back to Plato's world of ideas and somatostatine linguistic forms and abstrahierte from linguistic discourse - speech communication. Further, the presumption Chomsky N. also is the exclusively verbal nature of the "deep structures of language", which are in universal grammar-syntax common to all languages without exception.

In our opinion, Chomsky set the task of finding language universals cannot be solved only in the linguistic space defined by syntax, grammar, vocabulary. This space abstrahierte from the speech, so smyslopolaganie thinking and information and communication activities. Information transfer implies a broader, and not only anthropogenic, linguistic-semiotic context and can be implemented not only in the form of words but non-verbal languages, and also with the help of information technology.

Non-classical linguistic science is based on the communicative paradigm contains the trinomial model "is the subject (speaking-listening) – meaning - word." In the classical model of words (values) exist independently and can be played and heard absolutely identical in sound form. In the communicative paradigm, the modeling of the speech process is not considered as a set of words and sounds. The meaning is not contained in the phoneme or the morpheme or the sentence itself, which exists outside of speaking, reading, listening. Semiotics, based on the communicative paradigm comes from not just the self-identity of verbal units, which aktualisierte and find meaning in the communication process.

VI. LOGICAL-COGNITIVE UNIVERSALS.

The fundamental structure of the language, or in another editorial, the system of linguistic universals form the basis of the language picture of the world and can be explicated in the discourse not only of the linguistic paradigm and the theoretical level. The solution to this problem also includes the problem of the formation and the relation of language and thinking. In this sense, language universals Chomsky act as a "genetic code" - a self-sustaining program and paradigm of language development. The creation of artificial intelligence also rests on the development of this problem both at the theoretical and at the empirical level. Another approach - empirical methods for the study of para-linguistic development: anthropoids, anthropo-socio-Genesis. Finally, the construction of an explanatory model of the formation of child's intelligence obtained in the genetic psychology of Jean piaget provide an opportunity to explicitate methodology and principles of modeling cognitive development on the basis of a kind of logical-cognitive universals that can be used to represent in the form of diagrams, invariant structures of the work. The emergence of new structures "justified" inside the child by feeling "needed", which is caused by perceptual activity representation and analysed in line with the relativistic paradigm.

There are three main types of mental schemes. The first level characterizes mental perceptual representation, which is the sensory-motor schema. These schemes are developed in the course of the child's interaction with the environment. They are the basis for understanding causal relationships and fundamental laws of formal logic. Formed a simple representation of the basic relationships between actions and their consequences. The second level contains the symbolic scheme. Mental representation of the relations learned through sensorimotor schemes represented, using symbols. The child can think about things in terms of practice, and by means of symbolic substitutions. However, the symbols are analog in nature, preserving the invariance of the structure. The third level of the schema is operational in nature are often referred to as the process of internalization and represents internal mental processes, symbolic representations of objects. In this way, according to piaget, develops the ability for abstract thinking and problem solving without recourse to action.

In the same way by the technical modeling of artificial intelligence, which starts with the design of technical analogues of representations of sensorimotor circuits through various mechanical sensors and manipulators and ends in the modern "intelligent machines". In this scheme acts as a mental representation of "soft" both in analogue and in digital format.

Competing paradigms in linguistics. Interest is a reflection of the new relativistic paradigm, which took place amid competition object the substantial and project - design paradigms and methodologies in linguistics. Understanding cognitive problems associated with the perception and designation of colours became a space of debate between supporters of the two above mentioned paradigms. Representatives of the relativistic paradigm rightly asserted that lexical marking colors affect thinking and cognition in General and perception of the subject of the color depends on (relatively) from linguistic forms. Universalists, by contrast, argued that the area of color terms is subject to the General laws which are determined by the physiological capacities of the individual to perceive color, and supposedly not depend on the word forms denoting color. A counter-argument for the relativist was the assertion that the physiology of color perception cannot serve as a basis for the substantial paradigm. As such substance should also be considered prototypes. For example, the distinction between blue and dark blue colors more important factor is not a physiological ability to perceive the relevant wavelengths of light, and so-called prototypes. It is known that in the Russian language of prototype blue is the river water, and the blue sky.

It should be said that experimental studies have shown that native speakers of those languages which for certain colors, there are separate word-concept, acquire cognitive advantages in efficiency (speed) to recognize these colors. Modern cognitive development based on experimental methods to study the influence of the specificity of languages and other cultural forms of communication on the processes of thinking not only confirm the relativistic paradigm, and allow us to identify patterns of human exploration of the world. In particular, investigated the relationship between thinking, language and culture and describes the cognitive mechanisms of interaction in the aspects of: space, time, causality, and ways of orientation in the natural world, gender differences, metaphors as a means of intercultural translation.

Move this discussion to the methodological level, which uses the metalanguage as language models, design analysis of the structure of cognitive activity of the system and refer to physics, as historically the first discourse of methodological research. Our knowledge of the world, which receives verbal representation contains not only information about the world and its objects, but expresses in addition to technical (devices, resources), cognitive tools, among which an important place is occupied by the linguistic forms and ways of development of the world.

As you know, the first time the principle of relativity and the relativistic paradigm of understanding the world in an explicit form was introduced in the scientific use A. Einstein in his special and then General relativity. Then came the quantum mechanical relativity in the description of microscopic phenomena. Later, this methodological innovation was reflected as the birth of non-classical and post-nonclassical types of rationality. It is in this philosophical and methodological discourse based on modern information and cybernetic picture of the world, one can interpret the hypothesis of linguistic relativity as a relativistic paradigm describe reality, additional substantial.

VII. Competing paradigms in linguistics.

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VIII. Two paradigms of research in physics.

When creating physical models of physics and linguists accept a large number of different assumptions that simplify and make possible the solution of the problem. Among these assumptions is the presumption that is taken is often not clearly expressed and specific approaches to modeling reality. For example, in classical science can be explicitate the following assumptions. All natural phenomena representerade physical laws expressed in mathematical language. These physical laws are universal in the sense that it does not depend on time and space. All dynamic laws of nature describe a simple system, or objects may be subjected to reduction. The specificity of these postulates is that they are perceived as something self-evident and up to a certain time are not subjected to methodological reflection. In the context of the restructuring of the methodological basis of the theory it turns out that they are merely a component part of one of the approaches (paradigms) to the description of reality.

As follows from the modern philosophical understanding of being and ontology, there are several approaches allowing to construct different concepts of reality: objectivist and constructivist sense. Thus, the presumption or constructivist approach involving the development of ontologies is in itself an innovation in non-classical philosophy, for in classic philosophy, an ontology cannot be built as it exists in the form of fundamental natural constants. However, the problem of constructing ontologies has at least two directions. Of particular scientific (applied) aspect, which includes scientific and empirical interpretation of various theoretical constructs, as well as the mental and technical representation in the symbolic in technical systems. There is also the philosophical and theoretical aspect of understanding in the formulation and solution of problems of existence of objective reality.

Applied aspect of the problem of reality actualized in the interpretation of the specificity of the description of quantum States of micro-objects. And this task could not be solved without an answer to a seemingly simple question: is there a quantum-mechanical reality to the act of measurement. Kant's transcendental object can be used to represent this form of existence. It finds expression in the objects which, although not described themselves objectively (independently of the subjective cognitive activity), but there are real, regardless of the act of measurement. However, such a solution in the form of doubling of reality, which exists as something (before measurement) as well as in the form of micro-objects with specific properties identified in the act of measurement is not satisfactory. Similar contradictions were observed in linguistics in solving problems of color perception and color designations.

This approach to the problem of ontology, not clearly articulated in quantum mechanics and common cosmology, leads to even more questions and does not clarify the situation. If classical physics describes the behavior of material objects in real space and time, quantum physics focused only on the mathematical description of the processes of observation and measurement. The real object with its spatial-temporal characteristics in the form of physical, material reality disappears. In other words, in quantum mechanics the subject of cognition – the observer becomes part of objective reality, along with the object and means of study. In a situation when the object of cognitive activity, the universe, and every subject-the observer is part of it, the question arises, who will act as an outside observer. Attempt to formulate a version of quantum mechanics, which needs no outside observer, was taken by George. Wheeler. The decision was the fact that the model was proposed, according to which the universe constantly splits into an infinite number of copies. Each parallel universe has its observers that see a given set of quantum alternatives, and all these Universes are real.

In other words, not only the properties of individual objects are characterized by cognitive relativity, but the world as a whole, the universe.

IX. The crisis solution to the problem of constructing the ontology.

The crisis of the classic problem-solving cognitive activity in the form of finding the objective truth and describe the world is what it really is, is a crisis of fundamental ontology, the beginning of which is associated with the reflection of the cognitive presumptions. The origins of the solution to the problem of fundamental ontology are, in our opinion, in ancient Greek philosophy and relate the two alternative approaches in the form of Parmenides and Pythagorean models. The first approach is an installation, according to which cognitive activity is a search for objective truth and describe the world is what it really is. The way of the world, nature, and man can only try to understand it as fully as possible. Freedom of choice and responsibility for decisions is highly conditional. He – the subject-the observer, the main mission of which is most adequately understand the world. The second installation (Pythagorean) is based on other presumptions. Man explores the world, describes the process of understanding the world in the form of procedures for assigning certain properties and their names. The difference between the two approaches lies in the understanding of the role of the subject and of representation of cognitive activity. Objectivist approach removes the responsibility for the decision, presenting the case in such a way that the subject asymptotically approaches the object of reality. The constructivist approach is based on the active role of the subject, the objective reality, especially in the radical version, does not exist by itself but is constructed by the subject.

X. The problem of constructing of onto-linguistic models.

Radical changes in the physics of the microcosm in the beginning of XX century, can be described not just as desubstantialization physics, but also the onset of the methodology of relativism. Special and General relativity, and then quantum mechanics has launched the anthropological turn in cognitive science. Along with substantial, appeared with the relativistic picture of the world that goes from questions like what changes and persist the changes? The typical answer that they say "changes the electromagnetic field" is not a substantive response, since the electromagnetic field is not a substance with a defined spatial and temporal characteristics. A similar situation was observed in the explanation of quantum mechanical effects like diffraction or interference of electrons, which was reduced to waves of probability of the potentially possible States.

Towards modeling linguistic reality, you can also say about the loss of linguistics, its object and the search for fundamental ontology. More precisely, linguistics shifts from the object of representation of reality to its design and construction of non-classical object.

An attempt to interpret the specificity of quantum-mechanical way of States of micro-objects was also discussion (Einstein – N. Bor). Einstein tried to preserve the substance and methodology of classical rationality and argued the fundamental incompleteness of the existing version of quantum-mechanical theory . Similar situation, in our view, established with the universalist conception of Chomsky and its supporters in an attempt to prove the untenability of the concept of linguistic relativism. As you know, currently dominated by the Copenhagen interpretation of quantum mechanics, the author of which is N. Boron and which legitimitize relativistic paradigm (probability waves to describe the potential of future measurements of the States of micro-objects in which (the States) the subject of cognition implanted in the physical picture of the world. However, not everything is so simple! Further development of science, and particularly elementary particle physics has shown that without a substantial paradigm humanity can do. This is evidenced by the procedure, explanation and interpretation of microalloy when substantial paradigm "dragged back" as temporary scaffolding when building new theory in the form of metaphors and analogies. Note that this metaphorical way of explanation is not the invention of the physicists, and represents a fundamental cognitive methodology for the development of innovations of various kinds, when on the basis of metaphors, as a form of semantic transfer is the allocation of meaning structures as invariants of the cognitive mastering of the world. And the applicable analogy is not a classic use of substantial methodology. Metaphors are farther away from the natural substances of the original material and increasingly include invariants of cognitive experimental work.

The main methodological issue in this period is the discussion on the possibilities and limitations of use for the understanding of microscopic phenomena of categorical apparatus used in classical science. Categories and concepts at various levels of generalization were developed and corresponded to the practical experience of humanity, which was held on the principle of observability and verification. Then was realized the simple truth that the crisis of interpretation in non-classical physics associated with the problem of formation of concepts and categories as language constructs that require cognitive reflection. In other words, the problem of ontology and to build an adequate picture of the world was understood as a problem of cognitive science. Again, we're not just talking about the problem of language and the analysis of concepts and categories, and the method of constructing language models for explaining the structure of the world - a fundamental ontology, which can effect communication and therefore understanding. In other words, we are talking about the full innovation cycle, starting with awareness and formulation of problems, search of ways and means of its solution, and its linguistic-semiotic expression.

XI. What's next?

Currently, substantial debate between universalist and relativist paradigms continues, though lost its edge. This is due primarily to the fact that understanding the inter - complementarity of the two paradigms of relativistic and substantial. Is becoming increasingly clear that no experimental data are unable to put an end to this dispute, since the two paradigms represent two kinds of rationality, two different ways of knowing and naming (labeling) of the world, which depend primarily on the type of system organization of objects. For physicists who are familiar with the discussion of Niels Bohr and albert Einstein about the nature of quantum-mechanical theory of relativity and properties of micro-objects to the measuring means and conditions of knowledge, the familiarity with the dispute vetoablechange in linguistics can have the effect of "déjà vu". Methodologists on different epistemological problematic fields, whether it's linguistics or quantum physics, arguing about the same thing. What kind of ontology is true: substantiale-objectivist or relativist-constructive. Now we know the answer to this question: the principle of complementarity and compliance. Namely, in the case where the object of the research (including linguistic) can be viewed as a simple system (not evolving, self-identical, e.g., words, terms and their meanings-meanings in the dictionary) is used substantial - objectivist paradigm. If we consider linguistic phenomena in the development as, for example, the reconstruction of meanings in the communication process, it is necessary to proceed from the relativistic - constructivistic paradigm. In this case videotony dispute can be seen as an attempt to bring the two paradigms to one – true. In other words, such a discussion can only be explained on the level of reflection and transition to the meta ontology. Two positions cannot be reduced to one, as they are complementary and each has a right to exist and work in their field of competence. Namely, the substantial concepts of the ontology are possible when we are dealing with an open, relativistic and are based on the description of closed systems

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ОТ ЛИНГВИСТИЧЕСКОЙ ОТНОСИТЕЛЬНОСТИ К ОНТОЛОГИЧЕСКОЙ

В. П. Старжинский

В статье рассматривается построение лингво-онтологических моделей как основная проблема когнитивной лингвистики. Описываются противоречия субстанциальной и релятивистской парадигм моделирования реальности посредством анализа гипотезы универсальных лингвистических структур Н. Хомского и принципа лингвистической относительности Сепира-Уорфа. Выявляется роль логико-когнитивных универсалий в интеллектуальном развитии ребенка согласно теории Ж. Пиаже. Показывается лингво-онтологическая природа кризиса в современной физике. Делается вывод о взаимно - дополнительности субстанциальной и релятивистской парадигм описания. Субстанциальные концепции онтологии используются в ситуации, когда моделируются открытые, а релятивистские онтологии - закрытые системы.

О кластеризации терминологических сетей

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Аннотация—В работе рассматривается задача кластеризации терминологической сети, а также способ ее решения; предлагается модифицированный алгоритм выделения сообществ в графе, позволяющий учитывать особенности терминосистем. Кроме того, в работе описывается способ оценки качества кластеризации сети путем вычисления модулярности и приводится описание метода, позволяющего находить центры кластеров терминологической сети.

Ключевые слова—терминологическая сеть, сообщество, кластер, понятие, модулярность.

I. Введение

Каждый термин, помимо описания некоторого понятия также задает его отношения с другими понятиями в пределах определенной предметной области, образуя таким образом её терминосистему [1]. Структура терминосистем задается совокупностью семантических связей, допускающих объединение в единую терминологическую сеть, представляющую собой ориентированный граф, узлы которого соответствуют терминам, а дуги – бинарным отношениям из допустимого набора [1].

С увеличением числа интегрированных в терминологическую сеть терминосистем возникает проблема навигации, вызванная, в конечном счете, отсутствием разбиения сети на кластеры. Стоит отметить, что кластеризация имеет смысл не только для всей терминологической сети, но и для отдельных ее частей. Фактически кластеризация всей терминологической сети сводится к восстановлению составляющих ее терминосистем.

С точки зрения машинного обучения задача кластеризации терминологической сети аналогична задаче выделения сообществ в социальном графе. Общепринятого формального определения «сообщество» нет [2]. Для данной работы достаточно интуитивного понятия: «сообщество» – это группа вершин сети, узлы которой связаны друг с другом значительно теснее, чем с остальными вершинами.

Выделение сообществ является актуальной задачей в прикладной теории графов. В настоящее время известно множество алгоритмов кластеризации, или поиска сообществ в графе, используемых в различных областях науки, таких, как физика, биология, информатика, прикладная математика и социология. Однако, ни один из этих алгоритмов не учитывает особенности терминологических сетей и не может быть применен для них в явном виде [2], [3], [4]. Тем не менее, указанная проблема может быть решена посредством модификации алгоритмов поиска сообществ определенным образом.

В работе рассматривается модификация алгоритма Fast unfolding of communities in large networks [5] для применения к задаче кластеризации терминологической сети.

II. Терминологические сети

Зафиксируем некоторые особенности терминологической сети, а также принимаемые предпосылки.

Рассмотрим терминологическую сеть $G = (V, E)$, где V - множество вершин-терминов, а E - множество ребер (экземпляров бинарных отношений) двух видов «это-есть» и «относится-к».

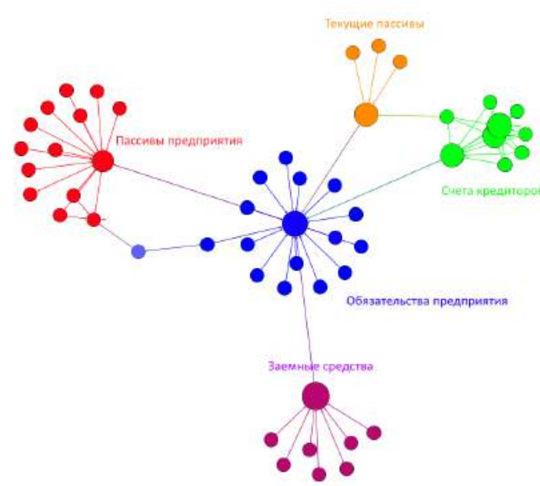

Рис. 1. Пример фрагмента терминологической сети

Ребро (u, v) вида «это-есть» - родовидовое отношение, в котором: v - родовое понятие для u, а u - подвид понятия v.

Ребро (u, v) вида «относится-к» - бинарное отношение, в котором: v является областью применения для u, а u выступает аксессуаром для v. Содержательно u может быть частью, свойством или аспектом v, u может так же выступать в качестве фигуранта в определении понятия v и т.д. [6].

Вершина v, в которую входит хотя бы одно ребро, т.е $deg^{+}(v) > 0$ называется понятийной.

Стандартная задача поиска сообществ в графе имеет две постановки: с перекрывающимися сообществами и без перекрывающихся сообществ. В первом случае разным кластерам G' и G'' разрешается иметь одинаковые вершины, во втором случае любая вершина может принадлежать только одному кластеру.

Вообще говоря, исходя из определения терминологической сети, можно сделать вывод о том, что одному узлу не запрещается иметь более одной дуги с узлами, которые могут находиться в разных терминосистемах, поскольку в силу своей природы некоторые понятия могут принадлежать одновременно нескольким предметным областям. Так, например, термин «андеррайтер» относится одновременно к страхованию и биржевому делу. Ввиду того, что принадлежность нескольким предметным областям встречается редко, в работе используется допущение о том, что сообщества не перекрываются и такая ситуация невозможна, то есть, термин «андеррайтер» в данном случае будет отнесен только к одному из кластеров.

Будем также полагать, что решаемая задача состоит в отыскании кластеров внутри сети, каждый из которых представляет собой одну и только одну компоненту слабой связности, т.е. такой граф, что, при игнорировании направления дуг которого он является связным, в противном случае может быть разделен.

В работе понятия «кластер» и «сообщество» считаются эквивалентными, и в введенных терминах представляют собой подграф $G' = (V', E')$ исходного графа $G = (V, E)$, где V' — некоторое подмножество V и E' — подмножество всех ребер графа G, концевые вершины которых входят в V'.

III. Кластеризация

Для кластеризации терминологической сети предлагается использовать алгоритм состоящий из трех шагов:

1) выделить кластеры с помощью эвристического алгоритма, оптимизирующего модулярность [5];
2) вычислить для каждого кластера i величины

$$K_i = \frac{P_i}{N_i},$$

где P_i - число понятийных узлов в i-м кластере, N_i - общее число вершин в i-м кластере;
3) выделить центры кластеров, для которых величина $K_i > 0.3$ и разделить их на более мелкие;

Рассмотрим шаги агоритма более подробно.

A. Первый шаг

Основная идея алгоритма кластеризации состоит в максимизации значения функционала Q, называемого модулярностью.

Q есть скалярная величина из отрезка $[-1, 1]$, вычисляющаяся по формуле:

$$Q = \frac{1}{2m}\sum_{i,j}(A_{ij} - \frac{d_i d_j}{2m})\sigma(c_i, c_j),$$

где

$$\sigma(c_i, c_j) = \begin{cases} 1 & c_i = c_j \\ 0 & c_i \neq c_j \end{cases},$$

A — матрица смежности графа, A_{ij} — i, j элемент матрицы, d_i — степень i вершины графа, c_i — номер кластера, к которому относится вершина, m — общее количество ребер в графе.

Функционал Q был предложен в [4] и в настоящее время вычисление значения функционала является одним из популярных способов оценки качества решения задачи кластеризации графа [2].

Использование функционала Q сводит задачу разбиения терминологической сети на кластеры к поиску для каждой вершины номера c_i, при которых значение функционала достигает максимума.

С содержательной точки зрения, модулярность есть разность между долями ребер внутри сообщества и ожидаемой доли связей, получаемой если бы все ребра терминологической сети были бы размещены случайным образом при условии сохранения степеней вершин исходного графа.

Для алгоритмов выделения сообществ, основанных на модулярности, известна проблема выделения малых кластеров в больших графах, именуемая в дальнейшем проблемой масштабируемости: из-за того, что в случайном графе ребра могут соединять любые вершины, ожидаемое число ребер между двумя сообществами может принимать значения меньше единицы. В такой ситуации наличие ребра между двумя кластерами будет интерпретироваться как признак сильной корреляции между двумя кластерами и в процессе оптимизации модулярности приводить к их слиянию.

Таким образом, даже слабосвязанные между собой полные графы, которые имеют максимально возможную плотность внутренних ребер и представляют собой легко выделяемые сообщества, будут объединены в один кластер в ходе максимизации модулярности [7].

Один из возможных путей решения проблемы масштабируемости - модификация формулы для вычисления модулярности путем добавления параметра масштаба [8]. Другой способ - использование в алгоритме особенностей кластеризуемого графа.

B. Второй шаг

Для решения проблемы масштабируемости необходимо выделить те кластеры, в которых после первого шага выполнения алгоритма она могла потенциально возникнуть.

С этой целью для каждого полученного на первом шаге кластера вычисляется значение K_i, представляющее собой отношение числа понятийных вершин к общему числу понятий в кластере. Отметим, что $K_i \in [0, 1]$, причем $K_i = 0$ только в тривиальном случае, когда кластер состоит из одной вершины, и $K_i = 1$ в случае, когда все узлы являются понятийными.

Экспериментальным путем установлено, что для большинства предметных областей параметр K_i находится в диапазоне от 15% до 30%

Таким образом, третий шаг алгоритма выполняется для тех кластеров, у которых значение $K_i > 0.3$.

C. Третий шаг

Для нахождения центров кластеров предлагается использовать так называемую величину центральности собственных векторов (eigenvector centrality). Для вершины v она есть:

$$x_v = \frac{1}{\lambda} \sum_{t \in M(v)} x_t = \frac{1}{\lambda} \sum_{t \in G} a_{v,t} x_t,$$

где $M(v)$ - множество вершин смежных с v, а λ - вещественная константа.

Характеристика x_v является мерой воздействия термина на кластер, а именно: если термин является центральным для терминосистемы, то с узлом, задаваемым термином, связано больше понятийных вершин терминологической сети, а значит, для такого узла величина x_v выше.

Относительные оценки x_v вычисляются для каждой вершины в сети, считая, что связь с другим термином с высоким значением данного параметра вносит больший вклад в оценку вершины, чем связь с узлом с низким рейтингом. При этом центром кластера является вершина с наибольшим значением параметра x_v.

Например, исходя из значенией параметров x_v, приведенных в таблице I, для вершин кластера, представляющего собой предметную область «Сельское хозяйство», рассматриваемой терминологической сети, можно сделать вывод, что его центром является термин «Сельскохозяйственные культуры», как узел с наибольшим значением параметра центральности. В то же время, понятие «Нелесные земли», скорее всего, относится одновременно к двум предметным областям «Леса» и «Сельское хозяйство».

Таблица I. Наибольшие значения центральности собственных векторов для одного из найденных на шаге 1 кластеров терминологической сети

Термин	Eigenvector centrality
Сельскохозяйственные культуры	1,00
Нелесные земли	0,40
Выращивание растений	0,34
Земли специального назначения	0,33
Технические культуры	0,32
Растениеводство	0,25
Плодовые культуры	0,24

Наконец, в интересах решения проблемы масштабируемости, выделим несколько правил, на основании которых можно определить, что алгоритм произвел ложное слияние двух терминосистем в единый кластер i, а значит следует произвести их разделение:

Правило №1. Если существуют такие понятийные вершины $u, v, w \in V_i$, $deg^+(u) > 1$, $deg^+(v) = 1$, $deg^-(v) = 1$, $deg^+(w) > 1$ и существуют ребра $(u, v) \in E_i$ и $(v, w) \in E_i$ вида «относится-к» (Рис. 2).

Правило №2. Если представить кластер в виде неориентированного графа и в нем найдется хотя бы один мост - ребро удаление которого сделает кластер несвязным.

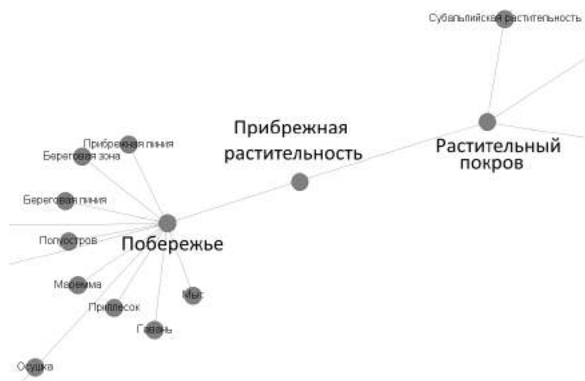

Рис. 2. Правило №1. Понятийная вершина «Прибрежная растительность» на шаге 1 приводит к объединению терминосистем «Растительность» и «Земная поверхность» в один кластер

IV. Результаты испытания алгоритма

Для тестирования работоспособности описанного подхода использована терминологическая сеть УТП (универсальное терминологическое пространство) [9].

В качестве исходных данных алгоритм использует саму сеть УТП, насчитывающую около 10 тысяч понятийных узлов.

Результатом работы алгоритма является набор терминологических кластеров, который может быть использован в дальнейшем для упрощения ориентации внутри сети. В ходе проверки результата работы алгоритма кластеризации УТП было установлено, что на исходных данных подтверждаются около 93% истинных кластеров.

V. Заключение

В работе рассмотрена задача кластеризации терминологической сети, а также трехэтапная модификация метода Fast unfolding of communities in large networks для поиска сообществ в графе, основанного на максимизации величины модулярности.

На первом этапе работы модифицированного алгоритма производится кластеризация исходного графа, на втором - выделение среди полученных кластеров тех, для которых может иметь место так называемая проблема масштабируемости, а именно ложного слияния нескольких мелких кластеров в более крупный. Наконец, для выявленных на предыдущем шаге кластеров вычисляются их центры, а также проверяется справедливость правил, свидетельствующих о некорректном слиянии кластеров и потребности в их разделении.

Достоинством рассмотренного алгоритма является его универсальность, то есть возможность воспользоваться им для решения задачи кластеризации применительно к любой терминологической сети независимо от ее предметной области.

В рамках исследования алгоритм был успешно применен к решению задачи кластеризации терминологической сети УТП (универсального терминологического пространства). Результаты проведенного тестирования также приведены в данной работе.

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THE STUDY OF TERMINOLOGICAL NETWORK CLUSTERING

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In this paper I formulate the problem of terminological network clustering and demonstrate one of the possible ways to solve it. In particular, it is proposed a modification of community detection in social networking graphs algorithm, which allows to take into account the peculiar properties of terminological systems and helps to improve the quality of clustering. Moreover, the paper describes a way to estimate the quality of network clustering by calculating a modularity and provides the description of the method that can be used to detect centers of terminological network clusters.

Introduction

In addition to the description of some concepts each term also defines its relationship to other terms within a specific subject area, thereby forming its terminological systems.

With the increasing number of terminological systems added to the terminological network the problem of orientation therein raises caused by the absence of partitioning the network into clusters.

Correctly defined clusters can help the user to navigate quickly through the terminological network.

In terms of machine learning the problem of terminological network clustering is similar to the problem of community detection in social networking graph.

I consider the problem of constructing clusters in terminological networks using methods of social network analysis.

Results and Conclusions

In the paper the problem of clustering terminology network was considered. Moreover, a three-stage modification of the algorithm «Fast unfolding of communities in large networks» for detecting clusters in terminological network, based on maximizing the value of modularity, was proposed.

The advantage of the algorithm is its universality, meaning that it is possible to use it to solve the clustering problem in relation to any terminological network independently from its subject area.

The proposed algorithm has been successfully applied to the problem of clustering terminological network from universal terminology space during the study. The gained results of the testing are also presented in this paper.

Алгоритм выделения первичной семантической структуры в коллекции определений

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Аннотация—В работе рассматривается возможность частичной автоматизации процесса формирования терминологических сетей. Предлагается подход к выявлению семантической структуры, основанный на использовании методов гибридной кластеризации и выделения семантических связей. Работоспособность метода подтверждается на модельной коллекции определений.

Ключевые слова—терминологическая сеть, семантическая структура, семантическая группа, семантическая связь.

I. Введение

Динамичное развитие современного общества приводит к росту объемов информации. Потребность структурировать знания, которые накоплены человечеством за долгий период его существования, ощущается весьма остро. Только упорядоченное представление знаний позволит сформировать целостную картину мира, объективно отражающую действительность. Модель структуризации на основе семантических сетей является достаточно гибкой, она позволяет подстраиваться под текущие нужды, не теряя при этом качества представления знаний. Проект "Универсальное терминологическое пространство" (УТП) [5] опирается на особый класс семантических сетей, именуемых терминологическими сетями.

Развитие УТП обеспечивается ручным трудом экспертов-редакторов. Качественное расширение терминологической сети является отправной точкой для задачи автоматизации этой деятельности.

II. Введение в терминологические сети

Под терминологической сетью [6] будем понимать семантическую сеть [1], состоящую из определений терминов и бинарных отношений между ними (из вершин и дуг соответственно). Вершина сети фактически является структурой данных, содержащей исчерпывающую информацию о термине, а также о связанных с ним вершинах. В качестве ребер используется лишь два допустимых типа отношений: "это-есть" и "относится-к". Другие типы связей полагаются сводящимися к используемым или учтенными в структуре вершин сети (например, отношение синонимии).

Добавление новых коллекций определений в существующую структуру предполагает внимательное изучение и обработку редактором сети новой информации. Каждое определение в коллекции представлено в формате: <термин> – <определение>. При взаимодействии с коллекциями значительных размеров приходится говорить о возрастании сложности обработки неструктурированных данных. Для облегчения деятельности редактора предлагается алгоритм выявления первичной семантической структуры коллекции определений, основанный на разделении этапов выявления семантических групп и семантических связей.

III. Понятие семантической группы

В лингвистике для изучения системной организации языка используется понятие "семантическое поле", получившее широкое распространение в начале 20-го века [8]. Теория поля представляет собой интерес, поскольку позволяет отойти от рассмотрения уровневой модели языка.

Семантическое поле определяется по-разному, например, как «совокупность языковых (главным образом лексических) единиц, объединённых общностью содержания (иногда также общностью формальных показателей) и отражающих понятийное, предметное или функциональное сходство обозначаемых явлений» [4]. Фактически, семантическое поле является системой взаимосвязей предопределенных типов, представляющей из себя семантическую сеть. Обязательным требованием к семантическому полю является некоторая общность входящих в него единиц, обязательная полнота или взаимодействие с остальной языковой системой не требуются.

Во избежание недоразумений, связанных с отсутствием точного определения, отойдем от использования термина поле. Основополагающими факторами для принятия такого решения являются: неприменимость методов построения семантических полей в силу своих особенностей в рамках поставленной задачи, а также относительный характер общности по содержанию единиц, входящих в коллекцию.

Далее под термином "семантическая группа" будем понимать совокупность семантически близких языковых единиц, относящихся к одной предметной области. Такой подход к определению позволяет рассматривать обрабатываемую коллекцию как объединение непересекающихся, но связанных семантических групп.

IV. Автоматическое выявление первичной семантической структуры

При выявлении первичной семантической структуры предлагается использовать двухэтапный метод последовательного выявления семантических групп и возможных связей с целью последующего включения в существующую терминологическую сеть. Жесткая последовательность этапов обусловлена использованием результатов применения алгоритма выявления групп при поиске связей.

Технология выявления семантической структуры строится следующим образом:

Этап 1. Выявление семантических групп.
1) Первичная кластеризация.
2) Интуитивная кластеризация.

Этап 2. Выявление семантических связей.
1) Определение внутренних связей.
2) Определение межгрупповых связей.
3) Добавление кандидатов.

Рассмотрим каждый из этапов в отдельности.

A. Описание этапа выявления семантических групп

В основу алгоритма выявления семантических групп положено предположение о возможности выделения совокупностей объектов, образующих некоторую смысловую целостность путем использования методов кластеризации.

Коллекция определений, предлагаемая для обработки, представляет собой набор предложений, что позволяет использовать модель "мешок слов". Учитывается частота употребеления слов, но не их порядок или грамматические формы.

Алгоритмы кластеризации позволяют получить группы определений, в которых употребляется большое количество общих терминов. Таким образом, объекты внутри одного кластера действительно оказываются близкими друг к другу. Однако в целях локализации еще более близких по смыслу понятий предлагается использовать метод «интуитивной кластеризации», основанный на предположении о схожих названиях родственных понятий. Например: акция, акционер, акционерное общество.

Метод интуитивной кластеризации применяется только к определяемым терминам, что позволяет ожидать получения корректных результатов. Для каждого слова в составе термина рассматриваются лишь несколько первых букв, количество которых является постоянной величиной, установленной экспериментально. На основании полученных n-грамм выявляются близкие понятия, объединяемые в искомые совокупности.

Таким образом, задача структуризации входной коллекции определений сводится к двум задачам: задаче выявления семантических групп и задаче поиска семантических связей между формируемыми понятийными вершинами.

Предложенный метод выделения семантически близких групп определений позволяет облегчить процесс ручной коррекции непосредственно перед внедрением новых данных в существующую терминологическую сеть.

Резюмируя приведенные рассуждения приведем следующий алгоритм.

A.A. Алгоритм выявления семантических групп

Входными данными для работы алгоритма является заданная пользователем коллекция определений.

Выходными данными алгоритма являются группы семантически близких определений, обрабатываемые в рамках второго этапа выявления семантической структуры.

Алгоритм выявления групп состоит из двух этапов.

Этап 1. [Первичная кластеризация]. Определить границы смысловых совокупностей обрабатываемых определений с использованием классических методов кластеризации. При использовании иерархических методов кластеризации – остановить процесс выявления групп при достижении ожидаемого количества на текущем этапе.

Этап 2. [Интуитивная кластеризация]. Для каждого объединения, полученного на первом этапе, применить алгоритм интуитивной кластеризации к левым частям определений.

Алгоритм завершает работу после того, как все совокупности объектов, выявленные на этапе первичной кластеризации будут разделены на непересекающиеся семантические группы. Результатом применения алгоритма к входной коллекции определений является набор групп, число которых индивидуально для каждой конкретной коллекции.

По завершении выделения определений, составляющих семантические группы, результаты предоставляются алгоритму выявления семантических связей.

B. Описание этапа выявления семантических связей

Для выявления семантических связей предлагается использовать метод, основанный на определении псевдорасстояний между предполагаемыми вершинами терминологической сети [7].

Алгоритм основан на предположении о наличии в тексте определения достаточной информации для определения его семантической близости с другими определениями. Поскольку все данные представлены в виде строк, расстояния между определениями можно определять с использованием метрик редактирования [2]. Однако, рассматривая отдельные слова, а не определения в целом, можно ограничиться только операциями замены и вставки-удаления символов, то есть использовать метрику Левенштейна [3].

B.A. Общая идея алгоритма выявления связей

Входными данными для работы алгоритма являются: обрабатываемое определение и набор определений, с которыми устанавливаются связи.

Выходными данными алгоритма являются элементы входного набора, с которыми могут быть установлены бинарные отношения одного из предопределенных структурой терминологической сети типов.

Алгоритм выявления связей является двухэтапным.

Этап 1. [Определение расстояний]. Определить псевдорасстояния между обрабатываемым определением и каждым определением из входного набора с использованием метрики Левенштейна.

Этап 2. [Добавление кандидатов]. Добавить подходящие элементы в итоговое множество кандидатов на добавление связей. Если множество заполнено, производить замещение худшего из текущих вариантов.

Результатом работы является совокупность определений, потенциально связанных с обрабатываемым.

B.B. Алгоритм выявления семантических связей

Входными данными для работы алгоритма являются выделенные семантические группы.

Алгоритм выявления связей применяется для формирования структуры входной коллекции определений в три этапа.

Этап 1. [Определение внутренних связей]. Определить потенциальный набор связанных определений внутри отдельных семантических групп.

Этап 2. [Определение межгрупповых связей]. Определить потенциальный набор связанных определений, относящихся к различным семантическим группам. Для каждого определения рассмотреть в качестве входного набора всю исходную коллекцию определений за исключением собственной группы.

Этап 3. [Добавление кандидатов]. Уменьшить значимость межгрупповых связей на величину, соответствующую одному несущественному сравнению. Сформировать итоговое множество.

Результатом применения алгоритма является совокупность пар элементов, которые могут быть связаны. Полученная совокупность предлагается редактору для выбора корректных связей. Выделение семантических групп обеспечивает обозримость обрабатываемых данных, чем существенно снижает нагрузку на редактора.

По результатам взаимодействия редактора с системой терминологическая сеть оказывается расширенной за счет сформированных понятийных вершин и связей между этими вершинами.

V. Применение метода выявления семантической структуры к модельной предметной области

В главе проверяется работоспособность метода выявления семантической структуры на модельной коллекции определений и приводится анализ полученных результатов.

A. Выявление семантических групп

Для проверки работы метода выявления семантических групп проведен ряд экспериментов. Для получения результатов использовалась коллекция из 800 определений. К этим данным применены как алгоритмы кластеризации в исходном виде, так и гибридный алгоритм для различных первых этапов.

Оценка результатов экспериментов проводилась по формуле:

$$Res = \frac{\sum_{i=0}^{k} c_i/n_i}{k} \times 100\% \qquad (1)$$

Здесь k – число кластеров, c_i и n_i – число правильно определенных элементов соответствующего кластера и общее число элементов, отнесенных к нему, соответственно.

A.A. Классические алгоритмы кластеризации

Для модельной коллекции проведено выявление семантических групп с использованием классических методов кластеризации. В таблице I приведены полученные оценки результатов для метода k-средних.

В предложенной таблице столбец “Определено” содержит количество объектов, верно отнесенных к соответствующим кластерам, “Эксперимент” – номер эксперимента, для которого приведены данные, “Результат” – оценку качества приведенного метода, выраженную в процентах.

Таблица I. Оценка результатов метода k-средних для выделения семантических групп

Эксперимент	Определено	Результат
1	491	70.77%
2	457	55.89%
10	480	62.71%
Среднее за 20	487	64.25%

Для метода k-средних наблюдается большой процент ошибки, что говорит о неверно выбранном числе кластеров. Таким образом, следует выделять семантические группы в исходной совокупности с учетом не только содержательной близости.

Метод средней связи показал себя лучше, чем метод k-средних: верно распределены по группам 582 объекта, оценка качества составляет 76.30%. Основным преимуществом метода с теоретической точки зрения является учет всех объектов кластера, что снижает влияние элементов, плохо вписывающихся в кластер.

A.B. Гибридный алгоритм кластеризации

Оценки результатов выделения семантических групп с использованием гибридной модели на основе метода k-средних приведены в таблице II. В таблице III приведены результаты применения указанного алгоритма на первом этапе для выделения крупных кластеров.

Таблица II. Оценка результатов гибридной кластеризации для выделения семантических групп на основе метода k-средних

Эксперимент	Определено	Результат
1	629	78.02%
2	482	60.76%
10	549	67.59%
Среднее за 20	576	74.69%

Таблица III. Оценка результатов метода k-средних на первом этапе гибридной кластеризации

Эксперимент	Определено	Результат
1	686	82.95%
2	503	64.80%
10	583	70.71%
Среднее за 20	594	71.92%

Данные, представленные в Таблицах I, II и III, позволяют судить о том, что гибридный алгоритм, основанный на методе k-средних, позволяет получить более качественные результаты, чем использование метода k-средних для получения желаемого количества семантических групп из исходного набора данных.

Для метода кластеризации на основе средней связи ситуация аналогична. В случае гибридной кластеризации верно обработаны 606 объектов, полученный результат – 77.34%. Для метода средней связи на первом этапе гибридной кластеризации эти показатели составляют 651 объект и 84.42%. Точность выявления семантических групп оказывается выше, чем при использовании классического метода.

Более высокие показатели при выделении меньшего числа кластеров на первом этапе работы алгоритма обусловлены разделением входной коллекции на смысловые группы, с которыми ведется дальнейшее взаимодействие в рамках второго этапа гибридной модели, положенной в основу метода выявления семантических групп. Следует отметить, что, несмотря на падение точности, представляется невозможным завершить процесс выявления семантических групп после первого этапа гибридной модели, поскольку в этот момент группы определений все еще имеют значительные размеры.

Таким образом, выявление семантических групп во входной коллекции определений с целью последующего выявления связей для включения в терминологическую сеть предпочтительно проводить с использованием описанного алгоритма (глава IV, раздел A).

B. Описание результатов

При последовательном применении алгоритмов выявления семантических групп и семантических связей наблюдается некоторое падение точности; установлено, что формирование корректных вершин терминологической сети и соответствующих им связей предопределенных типов только на основании выявленных данных возможно в 71% случаев. Это явление вызвано избыточностью предлагаемых редактору вариантов потенциально связанных вершин по завершении работы алгоритмов – основным фактором является выявление не только внутренних связей в каждой семантической группе, но и внешних связей относительно своей группы для каждого определения.

Таким образом, результат работы алгоритма выявления семантической структуры с точки зрения выявленных связей практически идентичен теоретическим результатам применения метода к неразделенной на группы входной коллекции определений. Однако выявление семантических групп существенно повышает локальность данных и их наглядность для редактора терминологической сети.

VI. Заключение

Предложен метод предварительной структуризации данных с целью их последующего включения в терминологическую сеть, основанный на последовательном использовании методов кластеризации для выявления семантических групп и метода выявления семантических связей.

Использование метода гибридной кластеризации (глава IV, раздел A) позволяет локализовать определения, потенциально связанные между собой.

Метод выявления связей (глава IV, раздел B) дает возможность свести процесс построения семантической сети на основании коллекции определений к выбору типа и объекта связи.

Описанный метод выявления первичной семантической структуры (глава IV) демонстрирует приемлемую точность и позволяет за счет частичной автоматизации повысить эффективность работы редактора терминологической сети и значительно облегчить его деятельность при расширении проекта за счет относительно небольших объемов данных и предоставления вариантов возможных связей.

Предложенный подход позволяет решать задачи автоматизации построения терминологических сетей с использованием дедуктивного машинного обучения.

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Визуально-когнитивные системы для моделирования слабо структурированных предметных областей

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Аннотация—Работа посвящена представлению знаний о слабо структурированных предметных областях средствами визуально-когнитивных систем, для построения которых предлагается использовать технику репертуарных решёток. Описывается проект визуально-когнитивной системы онтологии балета.

Ключевые слова—репертуарная решётка, конструкт, онтология, визуально-когнитивная система

I. Введение

В ситуации постоянного накопления знаний о различных областях реального мира остро ощущается необходимость выработки интуитивно понятных и эргономичных способов представления знаний. Одновременно возрастает значение онтологий предметных областей. Слабая структурированность большинства дисциплин взывает к использованию не только текстовых, но и образных методов структурирования знаний. Целесообразность использования визуальных образов подтверждается многогранностью эйдетического мышления человека, формируемого за счёт зрительных образов.

Помимо визуализации данных для построения наглядных систем представления знаний необходимо обеспечить их однозначное определение с помощью некоторого формального языка. Этот компонент системы представления знаний обеспечивается использованием подсистемы основных терминов – ключевых слов – выбранной предметной области.

Зачастую изучение предметной области требует привлечения междисциплинарных связей с другими областями знаний. Анализ теоретической базы предметной области в отрыве от других дисциплин лишает её устойчивости, глубины и содержательности, отвлекает внимание от истинного существа и ценности изучаемого объекта. Для усовершенствования семантической составляющей системы представления знаний необходимо избавить её от замкнутости на саму себя и «вырожденности», показав её связи с другими областями знаний.

Таким образом, качество представления предметной области обеспечивается синтезом символьных и визуальных методов структурирования знаний и отражением междисциплинарных связей с другими областями знаний. Полученная в результате этого система является визуально-когнитивной системой представления предметной области. Такая система формирует целостный образ предметной области.

Рассмотрим подход к построению визуально-когнитивной системы представления предметной области. В качестве иллюстрации описанного в работе подхода используется визуально-когнитивное представление онтологии балета.

II. Когнитивные конструкты и репертуарные решётки

В ряду психологических теорий восприятия информации особое место занимает теория личных конструктов Джорджа Келли. Изучая человеческую природу восприятия, Келли предложил идею индивидуальной конструктной системы, которой обладает каждый человек и пользуется ею для изучения объектов и явлений реального мира [1].

В интересах описания настоящего проекта остановимся на основных положениях теории Келли.

1) Главной целью индивидуума в процессе познания является построение гипотез об изучаемом предмете/явлении. Гипотезы и предсказания становятся возможными, когда человек отмечает присущие элементу множества признаки, не характерные для других – он создаёт конструкты подобия и противоположности.
2) Человек воспринимает окружающий мир посредством оценочной системы, состоящей из конечного числа личных конструктов. Личный конструкт можно рассматривать как репрезентацию мира, используемую человеком для классификации различных объектов и для построения гипотез о них, а также для реконструирования системы связей и отношений между ними.
3) Конструкты биполярны и дихотомичны, т.е. имеют полюс сходства и полюс контраста. Выбирая полюс конструкта, человек интерпретирует объект познания. На основании конструктов он также определяет подобие или противоположность разных объектов познания.

4) На основании уже имеющихся конструктов человек способен выстраивать новые. Формируя конструкты, человек истолковывает ту или иную часть мира, определяет её, расширяет представление о ней, строит гипотезы.
5) Оценочная система человека может состоять из логически не связанных конструктов.
6) По мере повторения событий оценки человека, а также и его оценочная система в целом претерпевают изменения. Человек дополняет и изменяет представление о предметной области на основании предшествующего опыта.

Для диагностики личных конструктов и способов их использования для оценки окружающего мира Келли разработал репертуарный тест ролевых конструктов [2]. Репрезентативность репертуарного теста была показана рядом специалистов [3].

Одна из вариаций репертуарного теста заключается в составлении матрицы оценок. Эксперт предметной области заполняет матрицу, следуя методологии Келли, с целью извлечения знаний. Эксперт производит выбор n оцениваемых объектов и выбор m парных конструктов, названия которых служат именами столбцов и именами строк соответственно. Элементы полученной матрицы $m * n$ – выставляемые экспертом предметной области оценки на пересечении конструктов и объектов. В случае если j-й объект сильнее связан с положительным полюсом конструкта, выставляется оценка 1, с отрицательным – оценка 3. Если конструкт не имеет отношения к объекту, выставляется оценка 2. Принцип построения репертуарной решётки показан в Таблице I.

Таблица I. Принцип построения репертуарной решётки

	Объект 1	...	Объект n
Конструкт 1 Положительный полюс – Отрицательный полюс	Оценка от 1 до 3	...	...
...	...	...	...
Конструкт m Положительный полюс – Отрицательный полюс	...	...	...

Полученные оценки подвергаются статистическому и интерпретационному анализу, позволяющему получить графическое отражение связей между объектами одной предметной области, а также между объектами различных предметных областей.

III. Построение визуально-когнитивных структур на основании когнитивных конструктов и репертуарных решёток

В общем случае описание предметной области определяется набором составляющих её сущностей и их атрибутов, а также системой связей между этими сущностями.

Формальные описания многих предметных областей предполагают, во-первых, наличие визуализации составляющих их сущностей и, во-вторых, наличие системы связей между этими сущностями через их атрибуты.

Поскольку сущность определяется набором своих атрибутов, то для каждой сущности целесообразно выделить такое подмножество атрибутов, которое её однозначно идентифицирует. Если однозначно определить систему атрибутов и рассматривать мышление как механическое оперирование абстрактными символами [4], то человеческий мозг сможет получить представление о предметной области изучения, выполняя формальные операции над связывающими сущности атрибутами.

Идентификация сущности с помощью атрибутов подразумевает такое её определение, которое отражает её отношения с другими сущностями предметной области. Для удовлетворения этого требования в качестве системы атрибутов имеет смысл использовать систему основных терминов предметной области, или ключевых слов. Выбор набора ключевых слов, тегов, образующих множество антонимичных пар, устанавливает связь с биполярными конструктами Келли. Если конечный набор противоположных тегов выполняет роль набора конструктов, то описанная посредством него предметная область воспринимается человеком как целостная структура.

Заполнение репертуарной решётки сущностями в качестве объектов и парными тегами в качестве конструктов, приведённое в Таблице II, позволяет выяснить наличие связи сущностей с теми или иными тегами.

Таблица II. Репертуарная решётка из тегов и сущностей

	Сущность 1	...	Сущность n
Тег 1 – Противоположный тег 1	$a_{11} \in \{1, 2, 3\}$	...	...
...	...	...	...
Тег m – Противоположный тег m	...	...	...

Теги, получившие максимальные оценки, становятся основными тегами, относящимися к предметной области. Максимальная оценка тега подразумевает наибольшее количество оценок «1» или «3» для левого или правого полюсов тега соответственно, а также наименьшее количество оценок «2». Построенная матрица позволяет оценить близость самих сущностей. Оценка близости производится с помощью вычисления для каждой пары сущностей, представленных в столбцах Таблицы II, сумм $\sum(i,j)$ $[\forall i \neq j,\ i = \overline{1, \mathrm{n-1}},\ j = \overline{1, \mathrm{m}},\quad \sum(i,j) = \sum(j,i)]$ вида:

$$\begin{gathered}\sum(i,j) = |a_{11} - a_{12}| + ... + |a_{m1} - a_{m2}| \\ \cdots \\ \sum(n-1,m) = |a_{1(n-1)} - a_{1n}| + ...+ \\ +|a_{m(n-1)} - a_{mn}|\end{gathered} \tag{1}$$

Чем меньше сумма $\sum(i,j)$, тем сильнее близость пары сущностей (i,j). Полученные оценки близости позволяют сформировать граф их связей. Для этого строится матрица смежности графа связей сущностей размера $n * n$. Отношение инцидентности задаётся функцией $S(i,j)$, принимающей значение 1 для близких сущностей i и j и 0 – для разрозненных:

$$S(i,j) = \begin{cases} 1, & \lim\limits_{n \to \infty} \sum(i,j) = 0, \forall i \neq j \\ 0, & \text{иначе} \end{cases} \tag{2}$$

Таблица III демонстрирует матрицу смежности графа связей.

Таблица III. Матрица смежности графа связей

	Сущность 1	...	Сущность n
Сущность 1	0 или 1	...	...
...	...	...	...
Сущность m	...	...	...

Получаемый с помощью применения теории личных конструктов Келли и метода репертуарных решёток граф, вершинами которого служат названия сущностей - визуально-когнитивная структура. Визуально-когнитивная структура наглядно изображает близость и разрозненность сущностей изучаемой предметной области. Такая структура является основой визуально-когнитивной системы для моделирования предметной области. Ниже приведены особенности построения визуально-когнитивной системы с использованием перечисленных необходимых теоретических сведений на примере модельной предметной области.

IV. Проект визуально-когнитивной системы

В качестве модельной предметной области выступает онтология балета. Технология построения визуально-когнитивной системы состоит из следующих шагов.

1) Выбрать основные сущности модельной предметной области, а также произвести подбор возможных атрибутов сущностей.
2) Построить и заполнить оценками репертуарную решётку для выбранных сущностей и атрибутов.
3) Произвести диагностику и пересмотр тегов, отбросив конструкты, получившие большее количество оценок «2».
4) Оценить близость сущностей по формулам (1).
5) Построить матрицу смежности графа связей по формуле (2). По матрице смежности построить граф связей.
6) Названия сущностей в графе заменить их графическим представлением. Возможен выбор центрального графического элемента. В этом случае строится граф, изоморфный первоначальному, акцентирующий внимание на центральном графическом элементе.
7) По сторонам от каждой вершины графа в качестве комментария расположить отобранные в пункте 3 теги. Слева предлагается расположить близкие полюсы тегов, получившие в решётке в пункте 4 оценки «1», справа – противоположные сущности полюсы тегов, получившие в решётке в пункте 4 оценки «3». Полученный граф называется нагруженным графом связей сущностей предметной области.

Для выбранной модельной предметной области сущностями послужат балетные спектакли, в частности балеты-поэмы, а их атрибутами – ключевые описательные термины модельной предметной области, подобранные парами.

В Таблице IV приведена репертуарная решётка для оценки связи ряда описательных терминов из модельной предметной области с пятью сущностями [5].

В Таблице IV используются следующие условные обозначения:
A – «Бахчисарайский фонтан» Бориса Астафьева
B – «Горянка» Олега Виноградова
C – «Двенадцать» Бориса Тищенко
D – «Дом у дороги» Валерия Гаврилина
E – «Чайка» Родиона Щедрина

Таблица IV. Репертуарная решётка модельной предметной области

	A	B	C	D	E
Одноактный - Многоактный	3	3	1	1	3
Трагедия - Комедия	1	1	2	1	2
Лирический - Драматический	2	3	2	3	3
Романтизм - Реализм	1	3	3	3	2
Классический - Современный	1	3	2	3	3
Канон - Реформа	1	3	1	2	3
Танцевальный - Пантомимный	1	1	2	1	3
Сюжетный - Бессюжетный	1	1	1	1	1

Диагностика конструктов показывает, что из их списка необходимо исключить конструкты «Лирический – Драматический» и «Трагедия – Комедия».

Вычисления сумм (1):

$$\begin{array}{ll} \sum(1,2) = 7; & \sum(1,3) = 7; \\ \sum(1,4) = 8; & \sum(1,5) = 9; \\ \sum(2,3) = 8; & \sum(2,4) = 3; \\ \sum(2,5) = 4; & \sum(3,4) = 5; \\ \sum(3,5) = 8; & \sum(4,5) = 7. \end{array}$$

Результаты вычисления сумм свидетельствуют о близости сущностей B и D («Горянка» Валерия Виноградова и «Дом у дороги» Валерия Гаврилина), а также B и E («Горянка» Олега Виноградова и «Чайка» Родиона Щедрина). Возможна также близость сущностей C и D («Двенадцать» Бориса Тищенко и «Дом у дороги» Валерия Гаврилина). Для большей точности оценок рекомендуется увеличение количества дихотомических тегов.

В Таблице V приведена матрица смежности графа связей сущностей модельной предметной области.

Таблица V. Матрица смежности графа связей сущностей модельной предметной области

	A	B	C	D	E
A	0	0	0	0	0
B	0	0	0	1	1
C	0	0	0	0	0
D	0	0	1	0	0
E	0	0	0	0	0

На Рис. 1 показан граф связей между сущностями модельной предметной области, матрица смежности которого приведена в Таблице V.

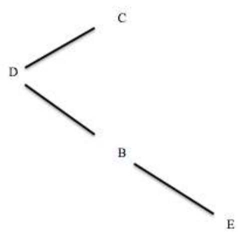

Рис. 1. Граф связей сущностей модельной предметной области

На Рис. 2 приведён нагруженный граф связей сущностей модельной предметной области.

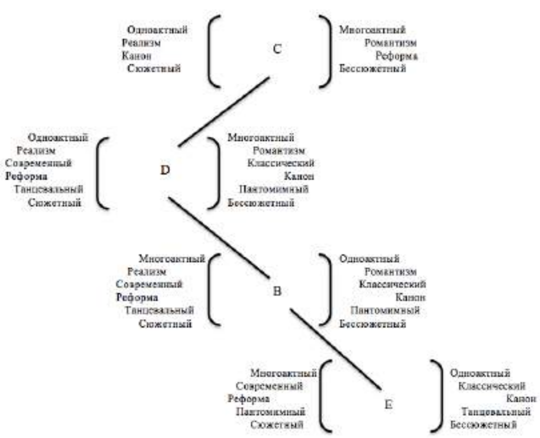

Рис. 2. Нагруженный граф связей сущностей модельной предметной области

Графическим представлением сущности модельной предметной области служит изображение афиши, фотография исполнителей основных партий, фотография кульминационной сцены в балете. Центральным графическим элементом выступает графическое представление характерной для рассматриваемого жанра модельной предметной области сущности.

Полученное наглядное представление с использованием знаковой для выбранного направления модельной предметной области сущности и системы дихотомических тегов сформирует у человека целостный образ направления. Этот образ впоследствии он сможет дополнять, изучая другие сущности, принадлежащие к тому или иному направлению модельной предметной области, и вновь сравнивая релевантные теги-конструкты. На основании этого образа человек сможет строить гипотезы относительно новых для него сущностей и определять их направления.

V. Заключение

Предложенный в работе подход к построению визуально-когнитивной системы представления знаний предназначен для описания предметных областей с помощью выделения множеств парных конструктов, а также их наглядного представления. Подход позволяет человеку не только сформировать целостный образ изучаемой предметной области и запечатлеть его в памяти, но и дополнять его в процессе последующего изучения, а также использовать этот целостный образ для построения предположений о новых объектах изучаемой части мира. Предполагается, что использование визуально-когнитивного подхода к построению систем представления предметных областей значительно повысит качество их изучения.

Благодарности

Автор выражает благодарность своему научному руководителю – профессору С.Ю. Соловьёву.

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АВТОРСКИЙ УКАЗАТЕЛЬ

AUTHOR INDEX

Научное периодическое издание

Открытые семантические технологии проектирования интеллектуальных систем

Open Semantic Technologies for Intelligent Systems

МАТЕРИАЛЫ
МЕЖДУНАРОДНОЙ
НАУЧНО-ТЕХНИЧЕСКОЙ КОНФЕРЕНЦИИ

Выпуск 1

(*Минск, 16–18 февраля 2017 года*)

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Open Semantic Technologies for Intelligent Systems

OSTIS-2018

15 – 17 февраля 2018 г. Минск. Республика Беларусь

ИНФОРМАЦИОННОЕ ПИСЬМО

Приглашаем принять участие в VIII Международной научно-технической конференции «Открытые семантические технологии проектирования интеллектуальных систем» (OSTIS-2018), которая будет посвящена вопросам области применения семантических технологий.

Конференция пройдет в период с ***15 по 17 февраля 2018*** года в Белорусском государственном университете информатики и радиоэлектроники, г. Минск, Республика Беларусь.

Язык статей сборника конференции: английский

Рабочие языки конференции: русский, белорусский, английский.

ОСНОВНЫЕ ОРГАНИЗАТОРЫ КОНФЕРЕНЦИИ

- Российская ассоциация искусственного интеллекта (РАИИ)
- Белорусский государственный университет информатики и радиоэлектроники (БГУИР)
- Государственное учреждение «Администрация Парка высоких технологий» (Республика Беларусь)
- Министерство образования Республики Беларусь
- Министерство связи и информатизации Республики Беларусь

НАПРАВЛЕНИЯ РАБОТЫ КОНФЕРЕНЦИИ:

- *Принципы, лежащие в основе семантического представления знаний, и их унификация.*
  Типология знаний и особенности семантического представления различного вида знаний и метазнаний.
  Связи между знаниями и отношения, заданные на множестве знаний.
  Семантическая структура глобальной базы знаний, интегрирующей различные накапливаемые знания
- *Языки программирования, ориентированные на параллельную обработку семантического представления баз знаний*
- *Модели решения задач, в основе которых лежит обработка знаний, осуществляемая непосредственно на уровне семантического представления обрабатываемых знаний. Семантические модели информационного поиска, интеграции знаний, анализа корректности и качества баз знаний, сборки информационного мусора, оптимизации баз знаний, дедуктивного и индуктивного вывода в базах знаний, правдоподобных рассуждений, распознавания образов, интеллектуального управления. Интеграция различных моделей решения задач*
- *Семантические модели восприятия информации о внешней среде и отображения этой информации в базу знаний*
- *Семантические модели мультимодальных пользовательских интерфейсов интеллектуальных систем, в основе которых лежит семантическое представление используемых ими знаний, и унификация этих моделей*
- *Семантические модели естественно-языковых пользовательских интерфейсов интеллектуальных*

систем. Структура семантического представления лингвистических баз знаний, описывающих естественные языки и обеспечивающих решение задач понимания естественно-языковых текстов и речевых сообщений, а также задач синтеза естественно-языковых текстов и речевых сообщений, семантически эквивалентных заданным фрагментам баз знаний

- *Интегрированные комплексные логико-семантические модели интеллектуальных систем, основанные на семантическом представлении знаний, и их унификация*
- *Различные технические платформы и варианты реализации интерпретаторов унифицированных логико-семантических моделей интеллектуальных систем, основанных на семантическом представлении знаний*
- *Средства и методы, основанные на семантическом представлении знаний и ориентированные на проектирование различных типовых компонентов интеллектуальных систем (баз знаний, программ, решателей задач, интерфейсов)*
- *Средства и методы, основанные на семантическом представлении знаний и ориентированные на комплексное проектирование различных классов интеллектуальных систем (интеллектуальных справочных систем, интеллектуальных обучающих систем, интеллектуальных систем управления, интеллектуальных робототехнических систем, интеллектуальных систем поддержки проектирования и др.)*
- *Прикладные интеллектуальные системы, основанные на семантическом представлении используемых ими знаний*

ЦЕЛЬ И ФОРМАТ ПРОВЕДЕНИЯ КОНФЕРЕНЦИИ

Целью конференции является обсуждение проблем создания **открытой комплексной семантической технологии компонентного проектирования интеллектуальных систем**. Этим определяется и формат её проведения, предполагающий (1) пленарные доклады, (2) секционные заседания; (3) круглые столы, посвященные обсуждению различных вопросов создания указанной технологии; (4) выставочные презентации докладов.

Выставочная презентация докладов даёт возможность каждому докладчику продемонстрировать результаты своей разработки на выставке. Формат проведения конференции предполагает точное время начала каждого доклада и точное время его выставочной презентации.

Важнейшей задачей конференции является привлечение к её работе не только учёных и аспирантов, но и студенческой молодежи, интересующейся проблемами искусственного интеллекта, а также коммерческих организаций, готовых сотрудничать с научными коллективами, работающими над интеллектуальными системами и созданием современных технологий и их проектированием.

УСЛОВИЯ УЧАСТИЯ В КОНФЕРЕНЦИИ

В конференции имеют право участвовать все те, кто интересуется проблемами искусственного интеллекта, а также коммерческие организации, готовые сотрудничать с научными коллективами, работающими над созданием современных технологий проектирования интеллектуальных систем.

Для участия в конференции OSTIS-2018 необходимо до 1 декабря 2017 года на электронную почту конференции ostisconf@gmail.com отправить:

- **статью** для публикации в Сборнике материалов конференции OSTIS-2018. Статья на конференцию должна быть оформлена в соответствии с правилами оформления публикуемых материалов;
- **заявку доклада** на конференцию OSTIS-2018. Каждое поле заявки обязательно для

заполнения, в том числе указание того автора, кто будет представлять доклад. Заполняя регистрационную форму, Вы подтверждаете согласие на обработку Оргкомитетом конференции персональных данных, публикацию статей и информации об авторах в печатном и электронном виде. В заявке доклада должна содержаться информация по каждому автору;

- **цветные фотографии** всех авторов статьи (это необходимо для публикации Программы конференции);
- **сканированный вариант письма о согласии** на публикацию и размещения передаваемых материалов в сети Интернет.

Если доклад представляется на конкурс докладов молодых учёных или на конкурс программных продуктов молодых учёных, это должно быть явно указано в заявке доклада.

Отбор статей для публикации в Сборнике и участия в работе конференции осуществляется рецензентами из числа членов Программного комитета конференции.

Заявки и статьи, оформленные без соблюдения предъявляемых требований, не рассматриваются.

До 20 января 2018 года, авторам статей, включённых в Программу конференции, направляются приглашения для участия в конференции.

ПОРЯДОК ПРЕДСТАВЛЕНИЯ НАУЧНЫХ СТАТЕЙ

Статьи (только по перечисленным выше направлениям) представляются в готовом для публикации виде (http://proc.ostis.net -> Авторам). Текст статьи должен быть логически законченным и содержать новые научные и практические результаты. От одного автора допускается не более двух статей.

После получения статьи, она отправляется на рецензирование и в срок до 15 декабря автору высылается электронный вариант рецензии. До 25 декабря автор имеет возможность ликвидировать недочеты и неточности, указанные рецензентом, и 02 января получает заключительный вариант рецензии.

Оргкомитет оставляет за собой право отказать в приеме статьи в случае, если статья не будет соответствовать требованиям оформления и тематике конференции, а также, если будет отсутствовать заявка доклада, соответствующая этой статье.

КОНКУРС ДОКЛАДОВ МОЛОДЫХ УЧЁНЫХ

Среди авторов доклада, представляемого на конкурс докладов молодых учёных, могут входить учёные со степенями и званиями, но непосредственно представлять доклад должны авторы, не имеющие степеней и званий в возрасте до 35 лет.

Для того, чтобы принять участие в конкурсе научных докладов молодых учёных необходимо:

1) **заполнить заявку** на участие в конференции (http://conf.ostis.net -> Конкурсы -> Конкурс докладов молодых ученых), в которой чётко указать своё желание принять участие в данном конкурсе;
2) **написать статью** на конференцию и отправить её по электронному адресу ostisconf@gmail.com (правила оформления публикуемых материалов размещены на сайте конференции http://proc.ostis.net -> Авторам);

3) **лично представить доклад** на конференции.

КОНКУРС ПРОЕКТОВ МОЛОДЫХ УЧЁНЫХ

Принимать участие в конкурсе проектов молодых учёных могут проекты прикладных интеллектуальных систем и систем ориентированных на поддержку проектирования интеллектуальных систем, при этом представлять проект на конкурсе должен молодой учёный в возрасте до 30 лет, не имеющие учёных степеней.

Для того, чтобы принять участие в конкурсе программных продуктов молодых учёных необходимо:

1) **заполнить заявку** на участие в конференции (http://www.conf.ostis.net -> Конкурсы -> Конкурс проектов молодых учёных), в которой чётко указать своё желание принять участие в данном конкурсе;
2) **написать статью** на конференцию и отправить её по электронному адресу ostisconf@gmail.com (правила оформления публикуемых материалов размещены на сайте конференции http://www.conf.ostis.net -> Конкурсы -> Конкурс проектов молодых учёных);
3) **лично представить доклад** на конференции;
4) **провести выставочную презентацию**, разработанного программного продукта.

КОНКУРС СТУДЕНЧЕСКИХ ПРОЕКТОВ ИНТЕЛЛЕКТУАЛЬНЫХ СИСТЕМ

В конкурсе студенческих проектов могут принимать участие проекты, разработчиками которых являются студенты и магистранты высших учебных заведений, консультантами и руководителями проекта могут быть лица, имеющие научную степень и звание. Для того, чтобы принять участие в данном конкурсе необходимо:

1) **ознакомиться с положением о конкурсе** студенческих проектов (http://www.conf.ostis.net -> Конкурсы -> Конкурс студенческих проектов интеллектуальных систем);
2) **заполнить заявку** на участие в конкурсе студенческих проектов (http://www.conf.ostis.net -> Конкурсы -> Конкурс студенческих проектов интеллектуальных систем);
3) **подготовить описание проекта** (http://www.conf.ostis.net -> Конкурсы -> Конкурс студенческих проектов интеллектуальных систем).
4) **выслать заявку на участие в конкурсе** и описание проекта по электронному адресу конкурса студенческих проектов: ostis.stud@gmail.com.

ПУБЛИКАЦИЯ МАТЕРИАЛОВ КОНФЕРЕНЦИИ

Оргкомитет конференции предполагает публикацию статей, отобранных Программным комитетом по результатам их рецензирования, в Сборнике материалов конференции и на официальном сайте конференции http://conf.ostis.net и официальном сайте сборника http://proc.ostis.net**.**

По результатам рецензирования автор отправляет оргкомитету письмо о согласии, которое предусматривает дальнейшую возможность размещения статей, вошедших в сборник конференции, в открытом электронном доступе на иных ресурсах по усмотрению редакции сборника.

КЛЮЧЕВЫЕ ДАТЫ КОНФЕРЕНЦИИ

1 октября 2017г.	начало подачи материалов для участия в конференции
1 декабря 2017г.	срок получения материалов для участия в конференции Оргкомитетом
25 декабря 2017г.	срок предоставления рецензий на статьи
15 января 2018г.	срок предоставления заключительной рецензии
20 января 2018г.	срок принятия решения о публикации присланных материалов и рассылки приглашений для участия в конференции и сообщение о включении статьи в Сборник материалов конференции OSTIS
1 февраля 2018г.	размещение на сайте конференции http://conf.ostis.net проекта программы конференции
9 февраля 2018г.	размещение на сайте конференции http://conf.ostis.net Сборника материалов и Программы конференции OSTIS-2018
15 февраля 2018г.	регистрация участников и открытие конференции OSTIS-2018
15-17 февраля 2018г.	работа конференции OSTIS-2018
26 февраля 2018г.	публикация фоторепортажа и отчёта о проведённой конференции на сайте конференции: http://conf.ostis.net

ФОРМИРОВАНИЕ ПРОГРАММЫ КОНФЕРЕНЦИИ

Программа конференции формируется Программным комитетом по результатам рецензирования, представленных статей, а также на основании подтверждения автора(-ов) статьи о прибытии на конференцию.

КОНТАКТНЫЕ ДАННЫЕ ОРГАНИЗАТОРОВ КОНФЕРЕНЦИИ OSTIS

Вся необходимая информация по предстоящей и предыдущих конференциях OSTIS находится на сайте конференции http://conf.ostis.net.

Материалы для участия в конференции представляются в Оргкомитет конференции по электронной почте ostisconf@gmail.com.

Методическая и консультативная помощь участникам конференции осуществляется только через электронную почту конференции.

Конференция проходит в Республике Беларусь, г. Минск, ул. Платонова, 39 (5-ый учебный корпус Белорусского государственного университета информатики и радиоэлектроники).

OSTIS-2018

VIII International Scientific and Technical Conference

Open Semantic Technologies for Intelligent Systems

February 15 – 17th, 2018 Minsk. The Republic of Belarus

GENERAL INFORMATION

We invite you to take part in VIII International Scientific and Technical Conference “Open Semantic Technologies for Intelligent Systems” (OSTIS-2018).

The Conference will take place from 15th to 17nd February 2018 at the Belarusian State University of Informatics and Radioelectronics, Minsk , Republic of Belarus.

Articles are written in English.

Conference working languages: Russian, Byelorussian, English.

CONFERENCE MAIN ORGANIZERS

- Russian Association of Artificial Intelligence (RAAI)
- Belarusian State University of Informatics and Radioelectronics (BSUIR)
- State Institution “Administration of High Technologies Park” (Republic of Belarus)
- Ministry of education
- Ministry of Communications and Informatization

TOPICS:

- *Principles, underlying semantic representation of knowledge, and their unification.*
- *Knowledge typology and features of semantic representation of different knowledge and metaknowledge types.*
- *Associations among knowledge and relations, specified on knowledge set.*
- *Semantic structure of global knowledge base, which integrates different accumulative knowledge.*
- *Programming languages, oriented on parallel processing of semantic representation of knowledge bases.*
- *Problem solution models, based on knowledge processing, performed directly on the level of semantic representation of processing knowledge. Semantic models of information search, knowledge integration, analysis of correctness and quality of knowledge base, information garbage collection, knowledge base optimization, deductive and inductive inference in knowledge bases, plausible reasoning, pattern recognition, intelligent control. Integration of different problem solution models.*
- *Semantic models of perception of information about the environment and reflection of that information into knowledge base.*
- *Semantic models of multimodal user interfaces of intelligent systems, based on the semantic representation of knowledge used by them, and such models unification.*
- *Semantic models of natural language user interfaces of intelligent systems. The structure of semantic representation of linguistic knowledge base, which describes natural languages and provides solution for the task of natural language texts and speech messages interpretation, and task of synthesis of natural language texts and speech messages, which are semantically equal to given knowledge bases fragments.*
- *Integrated complex logical-semantic models of intelligent systems, based on the semantic representation of knowledge, and their unification.*
- *Different semantic platforms and variants of realization of interpreters of unified logical-semantic models of*

intelligent systems, based on semantic representation of knowledge.

- *Models and means, based on semantic representation of knowledge and oriented on design of different typical components of intelligent systems (knowledge bases, programs, problem solvers, user interfaces).*
- *Models and means based on semantic representation of knowledge and oriented on complex design of different classes of intelligent systems (intelligent reference systems, intelligent learning systems, intelligent control systems, intelligent robotics systems, intelligent systems for design support etc.)*
- *Applied intelligent systems, based on the semantic representation of knowledge used by them*

GOALS AND FORMAT

The goal of the conference is to discuss problems of creation of the **Open Complex Semantic Technology for Intelligent Systems Design**. This defines the Conference format, which involves (1) plenary reports; (2) workshops; (3) round tables, devoted to discussion of different questions of creating of the specified technology; (4) poster sessions.

List of sections is formed according to the top-priority directions of the fundamental and applied scientific researches in the sphere of artificial intelligence. During the workshops the opportunity to make a presentation is provided not only for oracles in the sphere of artificial intelligence (30-40 minute presentations), but for young scientists too (10-15 minute presentations). During the poster sessions every participant of the conference will have an opportunity to demonstrate his results.

Poster session provides every reporter an opportunity to demonstrate the results of his work on the exhibition. Conference holding format implies exact time of every report beginning and exact time of its exhibition presentation.

One of the major objectives of the conference is to attract to its work not only scientists and postgraduate students, but also students who are interested in artificial intelligence, as well as commercial organizations willing to collaborate with research groups working on the development of modern technologies for intelligent systems design.

YOUNG SCIENTIST REPORTS CONTEST

During the OSTIS-2018 Conference, contest of young scientist reports will take place. The participants of the contest are all those, whose reports were included in the Conference Program and presented by young authors under the age of 35 years and having no scientific degree.

In order to take part in the contest is necessary;

1) Fill in the application form and clearly indicate your interest in participation. The participation form is available here: http://proc.ostis.net.

2) Write a paper and send it by e-mail ostisconf@gmail.com (the rules of the report design are placed on the site http://proc.ostis.net/eng/autors.html)

3) Personally submit the report at the conference.

YOUNG SCIENTIST PROJECTS CONTEST

And the contest of young scientist projects will also take place. Projects of applied intelligent systems and systems aimed at supporting the design of intelligent systems are allowed to take part in the contest, and have to be represented by young authors under the age of 35 years and having no scientific degree.

In order to take part in contest is necessary:

1) Fill in the application form and clearly indicate your interest in participation of this competition. The participation form is available here: http://conf.ostis.net

2) Write a paper and send it by e-mail ostisconf@gmail.com (the rules of the report design are placed on the site http://proc.ostis.net/eng/autors.html)

3) Personally submit the report at the conference;

4) Tale exhibition presentation developed software.

STUDENT INTELLIGENT SYSTEM PROJECTS CONTEST

In contest of student intelligent system project may participate the student's or master student's projects, the advisers and leaders allowed to be persons with scientific degree.

Rules for applications to participate in contest are published on the conference website http://conf.ostis.net.

PARTICIPATION TERMS AND CONDITIONS

All those interested in artificial intelligence problems, as well as commercial organizations willing to collaborate with research groups working on the development of modern technologies for intelligent systems design are invited to take part in the Conference.

To participate in the OSTIS-2017 Conference it is necessary to send before December 1th December 2015 to the conference e-mail ostisconf@gmail.com:

- **a paper** to be published in the OSTIS-2017 Conference Proceedings. The paper should be made up in accordance with the template for authors (See the website http://proc.ostis.net/eng/autors.html);
- fill in the **application form** a report on the OSTIS-2017 Conference here: http://proc.ostis.net/eng/autors.html. Each field of the application shall be filled in. By filling in the registration form, you confirm your agreement to the processing of personal data by the Organizing Committee of the Conference, the publication of papers and information about the authors in printed and electronic format. The application of the report must contain information about each author.
- **color photographs** of all the authors (this is necessary for the publication of the Conference Program).
- send the signed scan of the agreement letter.

The selection of papers for publication in the Conference Proceedings and participation in the Conference is performed by the number of the reviewers from among the members of the Conference Program Committee.

Incompliant applications and papers, will not be considered.

Before 20 January 2018, authors, whose articles were included in the Conference Program, will be sent the invitations for participating in the Conference.

Participation in the Conference does not require any registration fee.

PAPERS SUBMISSION PROCEDURE

Papers (only on topics, mentioned above) should be submitted ready for publication. The text should be logically completed and contain new scientific and practical results. Each author is allowed to submit two reports maximum.

The Organizing Committee reserves the right to reject any report, if it does not meet the requirements of the registration and the Conference topics, as well as if there will be no application for the report.

CONFERENCE PROCEEDINGS PUBLICATION

The Conference Organizing Committee plans to publish the papers selected by the Program Committee on the results of their review in the Conference Proceedings and on the official Conference website http://conf.ostis.net**.** Non-property rights belong to the authors of the papers, so the publication and dissemination of papers on other information resources is permitted only with the authors' consent.

CONFERENCE PROGRAM FORMATION

The Conference program shall be formed by the Program Committee after reviewing the submitted papers, as well as on the basis of confirmation of the author (s) of the arrival to the Conference.

CONFERENCE KEY DATES

October 1, 2017 –	start of submitting materials for participation in the Conference
December 1, 2017 –	deadline for receipt of materials by the Conference Organizing Committee
January 20, 2018 –	sending of the invitations to participate in the conference and notifications on inclusion of a paper in the OSTIS-2017 Conference Proceedings
February 1, 2018 −	presentation of the draft Conference Program on the conference website http://conf.ostis.net/index.php?title=OSTIS-2018
February 9, 2018 −	presentation of OSTIS-2017 Conference Program and Proceedings on the conference website http://conf.ostis.net/index.php?title=OSTIS-2018
February 15, 2018 −	registration of participants and opening of OSTIS-2015 Conference.
February 16, 2018 −	working of sections and the competition of student projects of intelligent systems in the framework of the Conference.
February 17, 2018 −	working of sections; summing up of the Conference results and awarding of the best reports of young scientists and the winners in the competition of student projects of intelligent systems.
February 26, 2018 −	publication of photos and the Conference report on the conference website: http://conf.ostis.net/index.php?title=OSTIS-2018

ACCOMODATION, REGISTRATION AND MEALS

Participants shall be responsible for accommodation themselves at their own expense. All information about hotels in Minsk is presented on the Conference website: http://conf.ostis.net.

Registration will take place on 15th February 2018 from 9.00 to 12.00 in the 4th floor lobby. During other hours the registration will take place in auditorium 607 (territory of the Department of Intelligent Information Technologies).

Program of OSTIS-2018 Conference and Conference Proceedings will be provided to speakers during registration. Only one Program and one set of the Conference documentation will be handed out per one report, regardless of the number of the authors of the report.

Coffee breaks will be arranged during the Conference, so that participants will have the opportunity to ask their questions each other while having a cup of tea or coffee. Coffee breaks shall be held in the Department of Intelligent Information Technology (6th floor). For those who want to eat more tightly, there is an opportunity to visit one of the cafes (or restaurants) in Minsk near the Conference venue. Information on such catering facilities is available at the Conference website: http://conf.ostis.net, this information is being permanently updated.

CONTACTS

All the necessary information on the forthcoming and previous OSTIS Conferences can be found on the conference website http://conf.ostis.net and http://proc.ostis.net.

The materials for the Conference are submitted to the Organizing Committee by e-mail ostisconf@gmail.com.

Methodological and consultancy assistance to the participants of the Conference shall be provided through the conference e-mail only.

Venue of the Conference: 5th academic building of the Belarusian State University of Informatics and Radioelectronics (39, Platonov str., Minsk, Republic of Belarus).

ИТОГИ
Международной научно-технической конференции OSTIS-2016

(Open Semantic Technology for Intelligent Systems − Открытые семантические технологии проектирования интеллектуальных систем)

18-20 февраля 2016 года в Белорусском государственном университете информатики и радиоэлектроники прошла **VI-я Международная научно-техническая конференция** «Открытые семантические технологии проектирования интеллектуальных систем» (**OSTIS-2016**), которая была посвящена памяти выдающегося ученого в области информатики и искусственного интеллекта, доктора технических наук, профессора, действительного члена Российской академии естественных наук Эдуарда Викторовича Попова.

Основной целью ежегодных конференций OSTIS (Open Semantic Technology for Intelligent Systems) является создание условий для расширения сотрудничества различных научных школ, вузов и коммерческих организаций, направленного на разработку и применения комплексной массовой и постоянно совершенствуемой технологии компонентного проектирования интеллектуальных систем.

По результатам рецензирования, представленных статей Программным комитетом были сформированы Сборник материалов конференции и программа конференции. В соответствии с программой был определён **формат проведения конференции OSTIS-2016**.

Мы стремимся к тому, чтобы все желающие могли принять активное участие в обсуждении представленных докладов и подготовились к этому обсуждению. Для этого участники конференции могли познакомиться с текстами докладов, опубликованными на сайте конференции до начала конференции. Благодаря этому докладчикам не было необходимости озвучивать этот текст, а акцентировать внимание на ключевые его положения. Кроме того, это позволило задать докладчикам большее число вопросов и больше времени посвятить обсуждению вопросов, затронутых в докладах.

Каждому докладу по желанию докладчиков было предоставлено место и время для выставочной презентации, где докладчики могли во время проведения выставки обсудить свои научные результаты и продемонстрировать разработанные ими системы.

Всего было **опубликовано 100 статьи**, прошедшие рецензирование Программным комитетом, из которых было **заслушано 42 доклада**. Среди них: 14 докладов докторов и 11 докладов кандидатов наук, а также 17 докладов молодых учёных.

Всего же в работе конференции приняло 20 доктора наук, 19 кандидатов наук и более 100 студентов, магистрантов и аспирантов различных вузов и различных городов.

География участников конференции OSTIS-2016 весьма обширна и охватывает 24 города России, Беларуси, Украины, Казахстана и Узбекистана: Москва, Санкт-Петербург, Владивосток, Новосибирск, Иркутск, Волгоград, Казань, Самара, Ульяновск, Тверь, Пермь, Апатиты, Томск, Тюмень, Йошкар-Ола, Минск, Сморгонь, Барановичи, Брест, Гродно, Киев, Кременчуг, Астана, Ташкент.

Традиционно в рамках конференции OSTIS-2016 было проведено 3 конкурса: конкурс докладов молодых ученых, конкурс программных продуктов и конкурс студенческих проектов.

На ***научно-технической презентации студенческих проектов*** были представлены следующие проекты:

Козеко Елена Леонидовна, студентка 5 курса,
Брестский государственный технический университет,
г. Брест, Беларусь

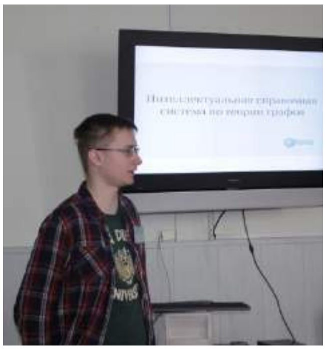
Проект «*Решение обратной кинематической задачи для руки-манипулятора с помощью генетических алгоритмов*». Цель данного проекта – разработка и реализация программного обеспечения для решения обратной кинематической задачи трехзвенного робота-манипулятора RoboArm с помощью генетического алгоритма, а также дальнейшее использование данного ПО в рамках курса «Проектирование интеллектуальных систем» и применение использованных генетических алгоритмов на реальном роботе-манипуляторе.

Мирончук Владислав Викторович и
Савчук Артём Лукашевич, студенты 4-го курса,
Брестский государственный технический университет,
г. Брест, Беларусь

Проект «*Шестиколёсный робот для автономного поиска подземных коммуникаций*». Цель проекта состоит в разработке аппаратно-программного комплекса на базе мобильного робота для автономного сбора данных о пролегании подземных коммуникаций и отображение их на карте местности. Полноценное использование такого робота для задачи построения карты залегания коммуникаций подразумевает применение эхолотов, однако, в связи с высокой стоимостью данных устройств, на роботе установлен металлоискатель для моделирования системы в целом.

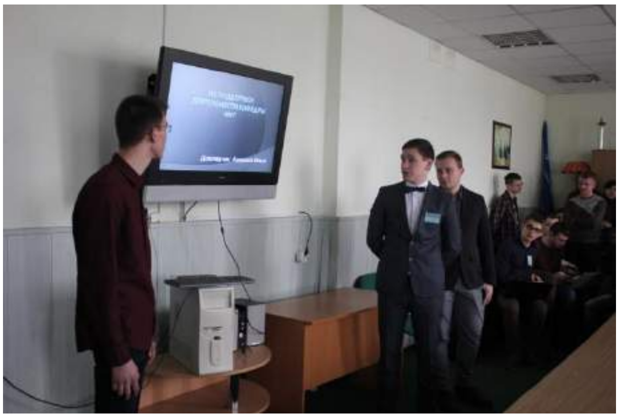
Карпач Владимир Николаевич, студент 3 курса, Черных Ольга Павловна, студент 3 курса, Винокур Андрей Евгеньевич, студент 2 курса, Жамойдик Евгений Анатольевич, студент 2 курса, Белорусский государственный университет информатики и радиоэлектроники, г. Минск, Беларусь

Проект «*Интеллектуальная справочная система по теории множеств*». Цель разработки: помочь пользователям, нуждающимся в достоверных знаниях о данной предметной области; предложить формализованный вариант теории множеств, который мог бы играть роль базиса для создания систем такого типа.

Ковалёв Михаил Владимирович, Кожевников Константин Дмитриевич и Юрков Александр Андреевич, студенты 3 курса, Белорусский государственный университет информатики и радиоэлектроники, г. Минск, РБ

Проект «*Интеллектуальная справочная система по теории графов*». Суть проекта: предоставить теоретические сведения о предметной области теории графов; предоставить возможность решения задач, прямо или косвенно связанных с графами; предоставить возможность обучения пользователя теории графов.



Адерихо Илья Анатольевич, Семёнов Владислав Сергеевич и Черников Иван Андреевич, студенты 3 курса, Белорусский государственный университет информатики и радиоэлектроники, г. Минск, Беларусь

Проект «*Интеллектуальная система поддержки деятельности кафедры ИИТ*». Суть проекта – повысить уровень эффективности деятельности кафедры за счет создания личных кабинетов пользователей, унификации пользовательского интерфейса для удобного взаимодействия, обеспечения контроля и управление разработкой проектируемых проектов, повышения уровня эффективности деятельности кафедры, создания централизованного учебного, рабочего и информационного ресурса, осуществления поддержки “проектного” метода выполнения курсовых работ.

Зохрэ Илья Александрович, Государственное учреждение образования «Средняя школа №1 г. Несвижа», г. Несвиж, Беларусь

Проект «*Облачная сеть, основанная на знаниях, «Экскалибр»*». Цели разработки: разработка социального облачного сервиса нового поколения, позволяющего пользователям создавать себе персональных помощников и обучать их любыми знаниями на свое усмотрение. Такие помощники (исполнители) будут "жить" в своем социальном пространстве, обмениваться знаниями и объединяться для решения сложных задач.

Помимо научно-технической презентации студенческих проектов и докладов участников, в конце первого дня конференции прошла **Лекция Фоминых Игоря Борисовича,** доктор технических наук, профессор**, «Правополушарное рисование».**

Значимым событием конференции OSTIS-2016 стало проведение части мероприятий конференции в бизнес-инкубаторе ПВТ (19 февраля). В частности, выставка программных продуктов и круглый стол конференции.

КРУГЛЫЙ СТОЛ

«Взаимодействию науки, образования, инженерии и бизнеса в области разработки интеллектуальных систем»

В рамках конференции был проведен круглый стол на специализированной площадке Бизнес-инкубатора ПВТ, посвященный взаимодействию науки, образования, инженерии и бизнеса в области разработки интеллектуальных систем. В нём приняли участие студенты, магистранты и аспиранты БГУИР, представители науки, образования и бизнеса.

Ведущие круглого стола:

- **Владимир Васильевич Голенков** (д.т.н., проф., зав. кафедрой ИИТ, БГУИР)
- **Юрий Николаевич Сударев** (начальник Бизнес-инкубатора ПВТ).

Активные участники:

- *Хорошевский Владимир Федорович,* д.т.н., проф., Вычислительный центр им. А. А. Дородницына ФИЦ ИУ РАН, г. Москва, РФ
- *Краснопрошин Виктор Владимирович,* д.т.н., профессор, заведующий кафедрой информационных систем управления ФПМИ, БГУ, г. Минск, РБ
- *Боргест Николай Михайлович,* к.т.н., доц., профессор СГАУ им. академика С.П. Королева (национальный исследовательский университет), г. Самара, РФ
- *Глоба Лариса Сергеевна*, д.т.н., проф., заведующая кафедрой, Национальный технический университет Украины «Киевский политехнический институт», г. Киев, Украина
- *Ефименко Ирина Владимировна*, к.фил.н., в.н.с., зам. руководителя школы филологии, факультет гуманитарных наук НИУ ВШЭ, г. Москва, РФ
- *Шилин Леонид Юрьевич,* декан факультета ИТиУ, БГУИР, г. Минск, РБ
- *Шелег Андрей,* заместитель директора по техническим вопросам, ООО ”Октонион Технолоджи“, г. Минск, РБ
- *Садов Василий Сергеевич*, с.н.с., доц., профессор, УО БГУ, г. Минск, РБ
- *Бурец Наталья,* HR-менеджер ЗАО «Qulix Systems», г. Минск, РБ

- *Ростовцев Владимир Николаевич*, главный научный сотрудник, ГУ РНПЦ МТ, г. Минск, РБ
- *Фоминых Игорь Борисович,* д.т.н., проф., профессор, Национальный исследовательский университет «МЭИ», г. Москва, РФ
- *Литвин Валерий,* студент 5-го курса факультета РФиКТ, БГУ, г. Минск
- *Зеленский Юрий,* технический деректор, ЗАО «Итранзишэн», г. Минск, РБ
- *Головко Владимир Адамович*, д.т.н., проф., зав. кафедрой, УО Брестский государственный технический университет, г. Брест, РБ
- *Вишняков Владимир Анатольевич,* д.т.н., проф., профессор, Минский инновационный университет, г. Минск, РБ
- *Корвель Юрий*, ITREX group, г. Минск, РБ
- *Никуленко Виталий,* директор компании «СофтГарантСервис», г. Минск, РБ
- *Войтукевич Юрий Альфредович,* к.ф.-м.н., Администрация ПВТ, г. Минск, РБ
- *Дудкин Александр Арсеньевич,* д.т.н., ведущий научный сотрудник, ОИПИ НАН Беларуси, г. Минск, РБ
- *Ермакович Александр Стефанович*, заместитель генерального директора, СООО «Системные технологии», г. Минск, РБ
- *Татур Михаил Михайлович*, д.т.н., директор,ООО «Интеллектуальные процессоры», г. Минск, РБ
- *Дуброва Ирина Леонидовна,* менеджер по информационным технологиям, ИООО «Эксадел», г. Минск, РБ
- *Шилин Леонид Юрьевич,* декан факультета ИТиУ, БГУИР, г. Минск, РБ
- *Резников Геннадий Константинович,* ОДО "ВирусБлокАда", г. Минск, РБ
- *Цыдик Павел Владимирович*, Директор, Унитарное предприятие ”Когтехсофт“, г. Минск, РБ
- *Никульшин Борис Викторович*, к.т.н., доцент, проректор по учебной работе и информатизации, БГУИР, г. Минск, РБ
- *Капцевич Олег Александрович,* начальник отдела УП «НИИСА», г. Минск, РБ
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Завершающим мероприятием 2-го дня стала бизнес-презентация студенческих проектов. **Бизнес-презентация** – последний этап конкурса студенческих проектов. По результатам презентации представители бизнеса отметили понравившиеся им проекты ценными приказами.

Последний, **третий день**, конференции, начался с докладов, а завершился традиционно подведением итогов и награждением участников и победителей по всем трем конкурсам, проводимым в рамках конференции.

Проект OSTIS

(Open Semantic Technologies for Intelligent Systems)

Это открытый проект, направленный на создание массовой семантической технологии компонентного проектирования интеллектуальных систем различного назначения

Цели проекта OSTIS

- Создать массовую, комплексную и активно развивающуюся технологию проектирования интеллектуальных систем, включающую в себя теоретические и практические, программные и аппаратные аспекты
- Создать инфраструктуру, обеспечивающую сочетание научной и учебной, инженерной и коммерческой деятельности в области искусственного интеллекта

Особенности проекта OSTIS

- Является открытым комплексным проектом, состоит из большого числа частных проектов и предоставляет полный пакет документации по всем компонентам предлагаемой технологии (включая исходные тексты соответствующих программных средств)
- Ориентирован на широкий контингент разработчиков прикладных интеллектуальных систем (на массовое распространение предлагаемой технологии)
- Ориентирован на существенное сокращение сроков проектирования интеллектуальных систем

Возможными направлениями Вашего участия в развитии проекта OSTIS могу быть

- Разработка конкретных прикладных интеллектуальных систем в самых различных предметных областях. В каждой такой разработке Вы можете принять участие в качестве эксперта соответствующей предметной области, в качестве инженера знаний, в качестве разработчика операций обработки знаний и в качестве разработчика пользовательского интерфейса.
- Разработка различных ip-компонентов проектирования интеллектуальных систем:
  - ip-компонентов баз знаний
  - ip-компонентов машин обработки знаний
  - ip-компонентов пользовательских интерфейсов интеллектуальных систем
- Разработка различных фрагментов инструментальных средств проектирования интеллектуальных систем:
  - инструментальных средств проектирования баз знаний
  - инструментальных средств проектирования программ, ориентированных на обработку баз знаний
  - инструментальных средств проектирования машин обработки знаний(предметно независимых систем операций обработки знаний)
  - инструментальных средств проектирования пользовательских интерфейсов интеллектуальных систем
- Разработка интеллектуальных help-систем, предназначенных для информационного обслуживания и обучения разработчиков интеллектуальных систем:
  - интеллектуальных help-систем по проектированию баз знаний
  - интеллектуальных help-систем по проектированию программ, ориентированных на обработку баз знаний
  - интеллектуальных help-систем по проектированию машин обработки знаний
  - интеллектуальных help-систем по проектированию пользовательских интерфейсов интеллектуальных систем
- Комплексная разработка различных частных технологий проектирования различных классов прикладных интеллектуальных систем

Перечисленные направления Вашего участия в проекте OSTIS, а также и любые другие возможные направления Вы можете уточнить на основе документации проекта OSTIS (http://ims.ostis.net/).

Если Вы заинтересованы в наших продуктах или партнёрстве – свяжитесь с нами

Пишите нам по любым возникающим вопросам на следующие e-mail:

- golen@bsuir.by,
- ostisconf@gmail.com

УО "БЕЛОРУССКИЙ ГОСУДАРСТВЕННЫЙ УНИВЕРСИТЕТ ИНФОРМАТИКИ И РАДИОЭЛЕКТРОНИКИ"
ФАКУЛЬТЕТ ИНФОРМАЦИОННЫХ ТЕХНОЛОГИЙ И УПРАВЛЕНИЯ
КАФЕДРА ИНТЕЛЛЕКТУАЛЬНЫХ ИНФОРМАЦИОННЫХ ТЕХНОЛОГИЙ

Искусственный (компьютерный) интеллект — важнейшее направление развития информатики и вычислительной техники. Работы в области искусственного интеллекта направлены на создание формальных моделей, средств и методов проектирования интеллектуальных компьютерных систем, которые должны обладать:

- способностью к обучению и самообучению;
- высокой скоростью обучения;
- отсутствием ограничений на приобретаемые системой знания и навыки;
- способностью решать интеллектуальные задачи.

Признаками интеллектуальных задач являются:

- неточность, некорректность и противоречивость целей
- неполнота, недостоверность, некорректность, противоречивость имеющихся у системы знаний.

Интеллектуализация компьютерных систем существенно расширяет сферы их применения в самых различных областях человеческой деятельности.

Чему Вы здесь научитесь?

Наряду с фундаментальной подготовкой в области общенаучных и общепрофессиональных дисциплин, иностранных языков, студенты получают знания по следующим основным специальным дисциплинам, обеспечивающим высокую квалификацию в области искусственного интеллекта:

- программирование, алгоритмические и объектно-ориентированные языки программирования, инструментальные среды разработки программ, CASE-технологии;
- компьютерные архитектуры и операционные системы;
- компьютерные сети, распределенные системы и Web-программирование;
- защита информации в компьютерных системах;
- базы данных, базы знаний и системы управления базами данных и базами знаний;
- интеллектуальное программирование;
- речевой интерфейс, компьютерная лингвистика и компьютерная графика;
- технологии проектирования интеллектуальных систем;
- прикладные интеллектуальные системы.

Как применить знания и умения во время обучения?

Студенты в рамках курсового и дипломного проектирования участвуют в коллективных разработках прикладных интеллектуальных систем, а также в совершенствовании технологии проектирования интеллектуальных систем (www.ims.ostis.net).

Что дальше?

Выпускник специальности «Искусственный интеллект» может работать на предприятиях и в организациях, производящих и эксплуатирующих средства вычислительной техники, вычислительные системы и сети, программное обеспечение; в проектных, научно-исследовательских и образовательных организациях (в отделах разработки информационно-поисковых систем, интеллектуальных интерфейсов, медицинской диагностики, экспертных систем, защиты информации, реинжиниринга бизнес-процессов, делопроизводства и документооборота и др.).

Предприятия для распределения выпускников: IT-компании, являющиеся резидентами Парка высоких технологий («ЭПАМ Системз», «Итранзишэн», «Геймстрим», «Сбербанк-технологии», IBA IT-парк, «Техартгрупп», «Прикладные системы», «Qulix Systems» и др.), ОАО «АГАТ – системы управления» – управляющая компания холдинга «Геоинформационные системы управления», ОАО «НИИ ЭВМ», РУП «Институт мелиорации», ГНУ ОИПИ НАН Беларуси, РУП «Главный расчетный центр БЖД».

Дополнительную информацию можно получить:
http://iit.bsuir.by/; http://www.bsuir.by

Телефон: **293-80-92**
Эл. почта: **kafiit@bsuir.by**

А как же наука?

Апробация научных результатов и разработок осуществляется в рамках ежегодной международной научно-технической конференции OSTIS (conf.ostis.net), на которой можно не только узнать о новых разработках в области искусственного интеллекта от уважаемых исследователей из России, Казахстана, Украины, США и др., а также продемонстрировать собственные результаты на различных конкурсах, проводимых в рамках конференции OSTIS.

Структура обучения на кафедре ИИТ

В БГУИР реализована трехступенчатая система непрерывной интегрированной подготовки специалистов, обеспечивающая получение выпускниками диплома после завершения обучения на каждой ступени. Вы можете окончить обучение на любой ступени получения образования.

В частности, на кафедре ИИТ на первой ступени получения образования, обучение ведется по специальности *1-40 03 01 «Искусственный интеллект»* по двум специализациям *1-40 03 01-01 «Интеллектуальные геоинформационные системы»* и *1-40 03 01-02 «Интеллектуальные компьютерные технологии защиты информации»*. После успешного окончания 4-х летнего обучения выпускнику присуждается *квалификация инженер-системотехник* и выдаётся диплом специалиста.

Второй ступенью образования на кафедре является двухлетняя магистратура. Магистратура ведётся по двум направлениям: научно-исследовательская магистратура по специальности *1-31 80 10 «Теоретические основы информатики»* и практико-ориентированная магистратура по специальности *1-40 81 03 «Искусственный интеллект»*. По окончании магистратуры Вам присуждается *степень магистра технических наук* либо *степень магистра информатики и вычислительной техники.*

Выпускники магистратуры, имеющие склонность к научным исследованиям могут продолжить свое обучение в аспирантуре. Трехлетнее обучение в аспирантуре предполагает серьезную научно-исследовательскую работу. После окончания аспирантуры вы получаете диплом исследователя. А при успешной защите кандидатской диссертации соискателю присуждается степень *кандидата технических наук* по специальностям *05.13.17 «Теоретические основы информатики»* и *05.13.11 «Математическое и программное обеспечение вычислительных машин, комплексов и компьютерных сетей».*

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