Usage of Ontology-Based Semantic Analysis of Complex Information Objects in Virtual Research Environments

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Abstract

Ontology-based method of recognition and analyzing of complex information objects through the virtual research environments is proposed. The main features of this method are demonstrated on example of student's qualification monitoring for e-learning courses. Software realization of this approach in multiagent M(e)L system that provides creation and matchmaking of course ontologies is described.

Keywords: *knowledge management, domain ontology,ontology matching, intelligent e-learning, virtual research environment*

1. Introduction

Now semantic search of complex information objects is a difficult and actual problem. The main feature of semantic search is an employment of knowledge in retrieval process. Different approaches use knowledge about users that need some information, about *information objects* (IO) that they try to find and about *information resources* (IR) accessible in some information environment – the Web, local network, virtual research environments etc. Users have only some part of information about structure and properties of IO and the search results have to provide them the rest. For the task of examining of student skills and qualification in e-learning such IO is a domain model that student forms as a result of learning.

Knowledge management is a big challenge especially in large organizations such as the big modern universities that provide traditional and distant forms of learning. The most interesting problems in this sphere deal with recognition and matching of such IO as qualification level, specialization and skills of learners. The search provided in *virtual research environments* (VRE) becomes more specific because VRE provide the additional means for intelligent knowledge-based interaction of students, tutors and domain-specific IR. This task in general can be considered as a particular case of pattern recognition problem where the recognized IO is a qualification or particular skills of students. Ontological approach is widely used for solving of these tasks.

In this work we propose to use *the reference domain ontology* as an instrument of knowledge representation about student qualification and examining skills: student ontology of course is compared with the reference one with the set of different concept and relation ratings.

Student has to form an ontological domain model of his course knowledge (directly or automatically by analysis of student's answers) and then we match this ontology with reference domain model built by expert or tutor. Student ontology reflects all his beliefs and knowledge about main concepts, connections and taxonomies about learned domain. For domain modeling we propose to use ontologies with fixed number of terms and relations.

The article consists of such parts:

- The state-of-the-art in ontology-based semantic search
- Virtual research environments for e-learning projects
- Use of ontologies and Semantic Web technologies in e-learning
- Domain ontology as an object of examining
- Knowledge acquisition from natural language documents
- Software realization of domain ontologies matching for semantic control of e-learning results
- Summary and conclusion

2. Ontology-based semantic search

Now the Web provides a lot of different IR. Efficient informational retrieval becomes an important and complex problem though it has to be semantically oriented and based on knowledge of some subject domain. Such retrieval procedures use the formulized knowledge model of domain of user interests (e.g., as ontology) that links all information resources IR with some subject domains.

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 process of defining and instantiating a knowledge base is referred to as knowledge markup or ontology population, whereas (semi-)automatic support in ontology development is usually referred to as ontology learning.

Ontologies have been broadly used in knowledge management applications, with a recent upsurge around Semantic Web applications and research. In recent years, ontologies have regained interest also within the NLP community, specifically in the context of such applications as information extraction, text mining, and question answering. However, as ontology development is a tedious and costly process there has been an equally growing interest in the automatic learning or extraction of ontologies. Much of this work has been directed towards extraction from textual data as human language is a primary mode of knowledge transfer.

In this way, textual data provides both resources for the ontology learning process as well as an application medium for developed ontologies.

Knowledge reuse and access is one of the leading motivations for the Semantic Web. Driven by those intentions an increasing amount of ontologies can be found nowadays on the Web distributed among personal or institutional web pages.

Another problem is that domain ontologies are often too big to be reused efficiently. These ontologies try to capture the complete domain knowledge but ontology engineers usually need to reuse only certain parts for their ontology. Modular ontologies can facilitate their reusability but developers are not able to find them efficiently.

3. Virtual research environments for e-learning projects

We analyze here only the VRE functionality on top of real use cases, so making it possible to take due account for privacy aspects. The VRE platform is conceptually defined on a set of underlying e-infrastructures. It can re-use existing theme-relevant knowledge and solutions (e.g., tools and services from existing infrastructures and projects) at both European and national levels. Standardized software building blocks and workflows, well-documented APIs and interoperable software components are used for designing and implementing the VRE.

The VRE platform functionality will be built on top of real use cases, so making it possible to offer two general kinds of services in the long term: generic services (to be delivered by e-infrastructures) and domain specific services [1].

The VRE platform manages data in such a way that the following requirements will be met their corresponding metadata semantics will be formally defined in a machine-understandable and interoperable manner. They will support proof of concept, prototyping and deployment of advanced data services and environments, and access to top-of-the-range connectivity and computing.

The following main groups of research and innovation activities, which come from a variety of research topics, considering the trans-disciplinary nature of the VRE above mentioned, will be connected to the problem solving.

The current e-infrastructure services related to HPC, Grid and Cloud, which have been funded by national or European funding agencies (like FP7 PRACE for HPC, EGI-Inspire for Grid, BonFIRE for Cloud services), are focused on computational intensive services, rather on data processing. Offering HPC services to various research communities is and was subject of multiple e-infrastructure projects funded by EC. The most remarkable example is the communities around PRACE initiative. UVT team has offered HPC services in multiple EC projects (starting with the early FP6-Infra SCIEnce, for symbolic computing community until the latest FP7-eInfra HP-SEE, for computation physics, computational chemistry and life sciences).

Since specialized data services are becoming complex and expensive to maintain in data centers, a recent trend is their deployment in Private or Public Clouds. The migration and deployment is nowadays not straightforward and requires specific knowledge and manual intervention [2].

Co-sharing based networks conception often highlight the importance of such networks in primarily fostering forms of shared information thanks to the engagement of agents and resources improving participatory approaches and direct involvement. They are also critical tools in enforcing and materializing the interrelations between innovation and processes of change whose role have been widely acknowledged and studied in literature. Besides, dynamics and impacts of collaborative systems may highly vary according to the action of varieties of well-known pathologies in social systems creating specific peculiarities of these networks. The potential capability of these pathologies to create profound effects in inhibiting link formation, to turn positive links into ineffective or negative ones and to enhance the non-linear system behavior and results deeply influence the quality of the interactions among network agents.

The possibility to provide a correct diagnosis of these network pathologies could provide useful contributions in alerting about actual and potential possibility of their occurring and in preventing a system collapse caused by deterioration in the link value and in the eventual link losses.

Open Science and Open Innovation are also key concepts, which have become very popular in the last years [3,4]. Open Science refers to dynamic systems of knowledge production characterized by a more or less high degree of accessibility of information and knowledge by researchers and scientists. These systems also act as dynamos, generators and stimulators of knowledge for future investigators. This implies the creation of effective networks based on collaborative-shared resources through technical tools able to distribute this information. The collaborative technologies, both in terms of infrastructure and specific technical tools, within these networks, are aimed at facilitating the distribution also of those resources that involve the issue of protected data (proprietary data and materials, trade secrets, legal protections, intellectual property rights, patents, copyright, etc.).

The Open Innovation concept is one of the central aspects of the processes of diffusion of innovation and technology transfer. This concept involves many disciplines including economics, psychology, sociology, cultural anthropology and management. In general, Open Innovation can be defined as the result of the use of purposive inflows and outflows of knowledge to accelerate internal innovation, and to expand the markets for external use of innovation. In literature, several international case studies are cited from which it is possible to understand the concrete operation of these processes and to identify the most important factors involved.

The correct management of research data is a fundamental part of the research process. This management involves making decisions and actions before the creation of the data during its creation and use and throughout it’s life cycle, so that a proper management of data should involve: 1. plan of data management as part of the budgets of the organization that anticipates management challenges and propose solutions to them; 2. treat appropriate ethical and legal issues relating to sensitive personal data, copyright and license to access and use of data; 3. the organization and documentation of data according to disciplinary and international standards that allows to know the nature of the data and how the data was created, to be reused; 4. appropriate storage, back-up and security mechanisms to ensure the confidentiality, integrity and availability of information; 5. share the data to be cited using standard and so give credit to the creators thereof; 6. archive a final copy of the data in specialized services, taking the necessary measures for its preservation and dissemination. All these steps will be realised in the data management policy, which will be adopted in this proposal.

Another analytic perspective of data management comes from their conceptual dimension. Conceptual systems, which are typically represented by concepts and categories, can be modeled by universal constraints independently of cultural variations, in which case the quality of the categorizations is positively correlated with the level of simplicity of these categorizations. Ontologies, which are commonly conceived as explicit formalizations of shared conceptual systems [5, 6], are the most widely used approach to represent knowledge, due to their intrinsic properties of structure, reuse, sharing and formalization, among others. All these properties enable them even for the automatic integration of knowledge once this has been represented. Ontologies provide a common vocabulary of an area and define – with different levels of formality – the meaning of the terms and the relations between them. Knowledge in ontologies is mainly formalized using classes, relations, functions, axioms and instances.

4. Ontologies and Semantic Web technologies in e-learning

Ontologies form the backbone on which to build the future Web, namely, the Semantic Web [7], and are part, together with reasoning techniques, of the subject of several research lines, leading to the achievement of a more intelligent Web [8] or the automation of science. The purpose of the Semantic Web (SW) is to add semantics to the data on the Web (for example, establish the meaning of the data using metadata), so that machines can process these data like humans can do. In order to achieve this aim, ontologies are expected to be used to provide structured vocabularies that describe the relationships between different concepts, allowing computers (and humans) to interpret their meaning flexibly yet unambiguously. Although there are several ontological languages, OWL [9] is the de facto SW standard ontology language.

Most of the techniques and inference engines developed for SW data are focusing either on reasoning over instances of an ontology with rules support (e.g. rule-based approaches) or on reasoning over ontology schemas (DL reasoning). Reasoning over instances of an ontology, for example, can derive a certain value for an attribute applied to an object, while reasoning over concepts of an ontology can automatically derive the correct hierarchical location of a new concept in a given concept hierarchy. Nowadays, the integration of rule and DL-based reasoning approaches has also gained a lot of attention and several ontology reasoners are currently available, including non-licensed versions like Hermit.

On the other hand, the multi-agent systems and intelligent agents area has received increasing attention by researchers since the end of last century and is currently very SW-relevant. An „Agent" could be defined as a computer system situated in some environment and capable of autonomous action in this environment in order to meet its design objectives [10]. Agents having reactivity (i.e. the ability to perceive its environment and respond to changes to it in a timely fashion), pro-activeness (i.e. the ability to exhibit goal-directed behavior by taking the initiative), and social ability (i.e. the ability to interact with other agents) have been called as the weak notion of agency.

Intelligent agents can exhibit some other properties such as temporal continuity (i.e. an agent functions continuously and unceasingly), reasoning (i.e., decision-making mechanism, by which an agent decides to act on the basis of the information it receives, and in accordance with its own objectives to achieve its goals), rationality (i.e. an agent`s mental property that attract it to maximize its achievement and to try to achieve its goals successfully), veracity (i.e. mental property that prevents an agent from knowingly communicating false information), mobility (i.e. the ability for a software agent to migrate from one machine to another), etc. In particular, one property that is often attached to the agent is the learning ability, that is, the capacity to adapt or modify its behavior by means of learning processes. Agents can be useful as standalone entities that are delegated particular tasks on behalf of a user. However, in the majority of cases, agents exist in environments that contain other agents, constituting Multi-agent Systems (MASs). MAS can be seen as a group of agents that can potentially interact with each other. MASs present several advantages over isolated agents, such as reliability and robustness, modularity and scalability, adaptively, concurrency and parallelism, and dynamism. Efforts toward the standardization of agent technologies have taken place. Organizations such as FIPA (http://www.fipa.org/) and OMG Agent PSIG (http://agent.omg.org/) are leading this process.

In particular, FIPA has become an IEEE Computer Society standards organization aimed at producing standards for the interoperation of heterogeneous software agents FIPA has developed some specifications with a group of normative rules that permit an agent society to operate among themselves. This model identifies some necessary agent's roles for the platform and agent management: the AMS (Agent Management System) and the DF (Directory Facilitator), which should act as white and yellow pages respectively, and the MTS (Message Transport System), which manages the interoperability among agent platforms. There exist different FIPA compliant agent platform implementations, like FIPA-Open Source, JADE and ZEUS are the most popular. With all, the agent community is facing the problem of integrating agent technology with Semantic Web Services.

We will do research to define the features of an agent platform organization specific to the needs of the problem, including flexibility and adaptation to changes imposed by the VRE management-related knowledge available in the implementation in each moment of time. The agents will have to deal also with various ontologies, due to their evolution in time. Learning should also be a fundamental capability as a way to keep track of the changes in VRE users preferences [1]. Argumentation has been gaining increasing importance, mainly as a vehicle for facilitating rationally justifiable decision making when handling incomplete and potentially inconsistent information.

As the Web grows in size and diversity, there is an increased need to automate aspects of Web Services such as discovery, execution, selection, composition (that comprises both choreography, which concerns the interactions of services with their users, and orchestration, which defines the sequence and conditions in which one Web Service invokes other Web Services in order to realize some useful function) and interoperation. The problem is that current technology around UDDI, WSDL and SOAP provide limited support for all that [11, 12].

The joint application of Semantic Web and Web Services in order to create intelligent Web Services is referred to as Semantic Web Services (SWS). SWS consist of describing Web Services with semantic content so that service discovery, composition and invocation can be done automatically. The W3C has examined various approaches with the purpose of reaching a standard for the Semantic Web Services technology, including OWL-S, WSMO, SWSF, WSDL-S, and the proposed as W3C recommendation, SAWSDL. The first three approaches propose an ontology that semantically describes all relevant aspects of Web Services.OWL-S is an ontological model that use the semantic approach to Web services [13]. On the other hand, WSDL-S and SAWSDL identify some WSDL and XML Schema extension attributes that support the semantic description of WSDL components. (OWL) Ontologies, agents and SWS will constitute one of the central pillars of the technological research and development activities to be carried

E-learning is an alternative concept to the traditional tutoring system. The course tutor in a software tutoring system controls learners relatively weaker than in the traditional one where it is the tutor who is charge the contents and sequence of instructions. Therefore, in order to obtain better tutoring outcomes, a software tutoring system should emphasize engaging students in the learning process and be adaptive to each individual learner. E-learning offers new possibilities: student has immediate feedback, learning paths are individualized, etc. It is a growing business: the number of e-learning tools and courses with varying functionality are available now by the Web [14].

Now e-learning applications are oriented on usage of the Semantic Web technologies for intelligent and personalized learning (Fig.1).

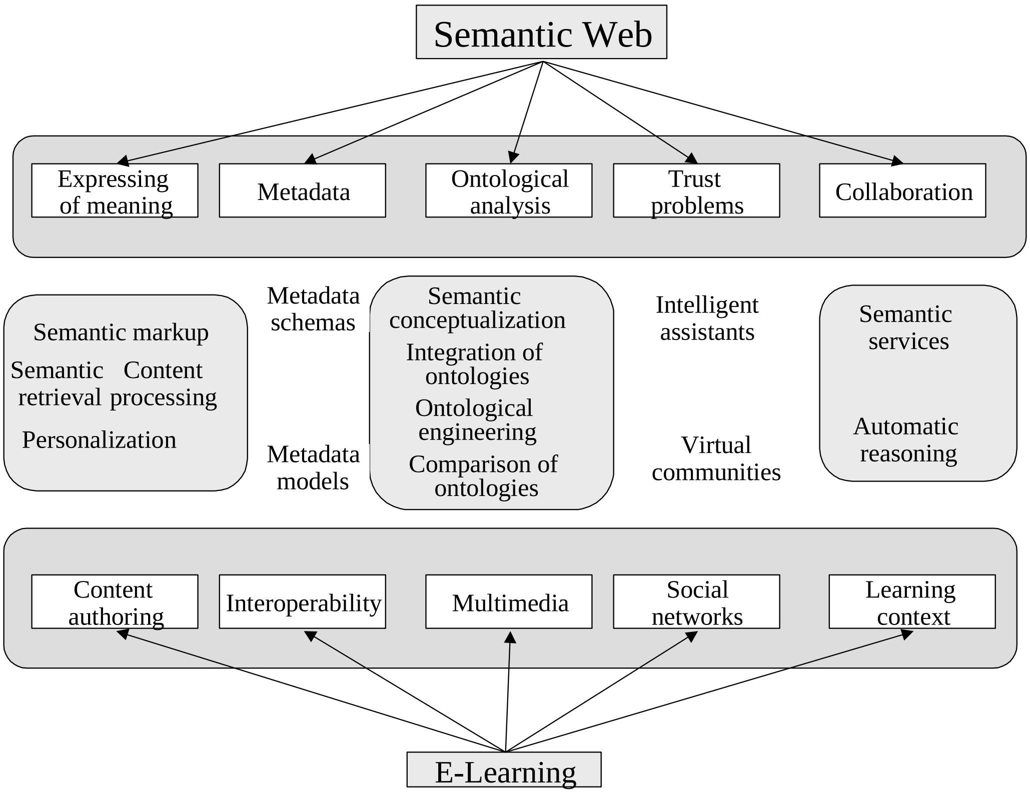

Figure 1. The relations between Semantic Web technologies and e-learning.

A structured information representing is required and ontologies (machine processable representations containing the semantic information of a domain) can be very useful. The ontology systems serve as a flexible and extendable platform for knowledge management. The inspiring idea to develop reusable atomic learning components and to capture their characteristics in widely-accepted, formal metadata descriptions will most probably attract learning object providers to annotate their products with the accepted standards. An important component of e-learning is testing of student's qualification, skills and knowledge.

For example, in [15] the expediency of computer ontologies use as a transparency tool of European and national qualification frameworks is reasoned. Qualifications are described by triads of professional qualities – knowledge, skills and competencies. Model orientated on training results helps to compare qualifications and simplifies the procedure for their acceptance. Tools facilitating the correlation of European and national qualification frameworks levels are proposed.

One of the main problems arising during creation of testing systems is an interoperability of created tests – opportunity to reuse these tests in different testing systems. To organize test exchange between various systems it is necessary to create some universal format of tests preservation and their processing instructions. And an important condition for this format should be its independence from the platform. Standardization of educational technologies and, in particular formats of test data preservation is working out all over the world. Now Ministry of Education and Science of Ukraine realize the Program of On-line Education Development.

According to these activities the development of projects of standards for systems, methods and technologies standards of on-line education in educational institutions taking into account international standards was provided. But different test formats such as Instructional Management Systems (IMS) Question and Test Interoperability (QTI) of Global Learning Consortium are not adequate for representation of all domain relations.

The more serious problems are caused by the semantic testing. Many authors use the ontology's semantic data to improve the analyses of information in unstructured documents. The domain ontology plays central role as a resource structuring the learning content. One of the key challenges of the course construction process is to identify the abstract domain of information within which this course will exist. Tutor has to describe the main terms and concepts from which a course is to be constructed.

5. Domain ontology as an object of examining

Computer technologies have been significantly changing the content and practice of education. The consequent applications of multimedia, simulation, computer-mediated communication and communities, and internet-based support for individual and distance learning have the significant potential for revolutionary improvements in education [16].

E-learning provides an alternative to the traditional tutoring system. The course tutor in a software tutoring system controls learners relatively weaker than in the traditional one where the tutor is charge the contents and sequence of instructions. Therefore, in order to obtain better tutoring outcomes, a software tutoring system should emphasize engaging students in the learning process and be adaptive to each individual learner.

The goal of the today e-learning systems is not only to an efficient access to knowledge for the individual learners but to give to the learner an individual control over the learning process [17]. Learning control needs the comparison means of learner's knowledge base that forms (and modifies) in learning process with the course domain knowledge base. It requires the powerful and interoperable tools of knowledge representation and analysis [18].

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In recent years, e-learning has been widespread, especially since standardizing initiatives for learning technologies have begun. For distant learning where the tutor works with many students without direct contacts it is very important to provide the objectivity and atomization of knowledge examination.

The main idea of our approach is that the *domain ontology* is not only the instrument of learning but an object of examining and forms by students [19]. We propose for students to build the domain ontology of examine discipline and then compare it with reference one. Results of this comparison show the mistakenly understood parts of domain knowledge and help tutor in improvement of distant course. Realized experiments demonstrate that this approach is much more efficient then usual tests where some mistakes can be involved by ambiguous formulation of questions and misprints, but correct answers can be obtained intuitively or by accident and don't reflect the real student concept about domain.

Ontological analysis is accomplished by examining the vocabulary that is used to discuss the characteristic objects and processes that compose the domain, developing rigorous definitions of the basic terms in that vocabulary, and characterizing the logical connections among those terms. The product of this analysis, *an ontology*, is a domain vocabulary complete with a set of precise definitions, that constrain the meanings of the terms sufficiently to enable consistent interpretation of the data that use that vocabulary [20].

An ontology includes a catalog of terms used in a domain, the rules governing how those terms can be combined to make valid statements about situations in that domain, and the sanctioned inferences that can be made when such statements are used in that domain. In the context of ontology, a relation is a definite descriptor referring to an association in the real world; a term is a definite descriptor that refers to an object or situation-like thing in the real world.

Formal model of ontology O is ordered triple of finite sets O = < T, R, F > , where T – the domain terms of which is described by ontology O; R – finite set of the relations between terms of domain; F – the domain interpretation functions on the terms and the relations of ontology O. In process of ontology building students use relations from the fixed set that contains the most widely used relations: R={"is a subclass of", "is a part of", "is a synonym", "has attributes", "has elements"}. It simplifies the ontology building and analyses processes [21].

The students (as well as the tutor) have to execute five main steps to design the ontology of domain:

1. define the main classes and terms of domain and describe their meaning: the set of class names T; the set of relation names R; For every class name define the set of attribute names At; for every attribute name $a \in A_t, t \in T$ define it type – INT, STRING, NUMBER etc. or other class of ontology;
2. Construct the taxonomy of domain terms:

$$< t_1, t_2 >, t_1 \in T, t_2 \in T, r(t_1, t_2) -> t_1 \text{"IS\_A\_Subclass\_Of"} t_2, r \in R;$$

3. Define synonymy and other relations:

$< t_1, t_2 >, t_1 \in T, t_2 \in T, r(t_1, t_2) -> t_1 "IS\_Synonyme\_Of" t_2, r \in R$;

$< t_1, t_2 >, t_1 \in T, t_2 \in T, r(t_1, t_2) -> t_1 "Related\_With" t_2, r \in R$;

4. Describe the instances of constructed classes $\forall a \in t, t \in T$.

We compare the student ontology Os with reference ontology Oe made by tutor: 1. Define the sets of ontology terms Ts and Te; 2. Classify terms from Ts on three disjoint categories: Tn, Tu and Tw. $T_s = T_n \cup T_u \cup T_w$ where correctly defined terms $T_n \subseteq T_e$; not accurately defined terms $T_u \not\subset T_e$ but $\forall t_i \in T_n \exists t_{j1} \in T_e, ..., t_{jm} \in T_e, t_{jk} \in T_e, m = \overline{1,k}$, and incorrectly defined terms $T_u \not\subset T_e$ and $\forall t_i \notin T_n \neg \exists t_j \in T_e$; 3. Define the sets of ontology relations R_s and R_e; 4. Classify relations from R_s on three disjoint categories: R_n, R_u and R_w. $R_s = R_n \cup R_u \cup R_w$ where correctly defined terms $R_n \subseteq R_e$, not accurately defined terms $R_u \not\subset R_e$ but $\forall r_i \in R_n \exists r_{j_1} \in R_e, ..., r_{j_m} \in R_e, r_{j_k} \in R_e, m = \overline{1,k}$, and incorrectly defined terms $R_u \not\subset R_e$ and $\forall r_i \notin R_n \neg \exists r_j \in R_e$;

5. Analyze the use of ontology terms and relations.

We don't consider the use of terms from T_W and relations from R_W. It`s very important to take into account the type of relations – hierarchical or improper: Mistake of use "is a part" relation instead of "is a subclass" is much less principle then use "is a synonym" relation instead of "is a subclass" one.

6. Knowledge acquisition from natural language documents

If student don't build the domain ontology we need to do it automatically. As a knowledge source we can use all natural language texts generated by this student – written tests, reports etc.

On the base of reference domain ontology the lexical ontology that connects domain ontology terms and relations with fragments of natural language text is built. This lexical ontology is used for semantic markup of student's texts. Then we can automatically analyze what the domain relations student believe between the domain concepts and instances [22].

The method of constructing ontology is based on the natural language document and relevant glossary.

The structure of the domain ontology is based on reference domain ontology.

Therefore, it contains:

- Terms that are specific to a given domain;
- some commonly used terms required to uniquely identification of the use context of domain terms (for example, "month", "year", "sum", "percentage"), which can be determined either directly or by reference to external ontology – the top level ontology or specialized ontology;
- hierarchical relations between domain ontology terms - different mereological types of relations "part-whole", "class-subclass", "class-instance";
- synonymy relations that can increase the terminological dictionary;

- specific for domain relations that (their semantics can be described by the analysis of relevant articles of glossary).

Thus, domain is represented by the "lightweight" ontology containing no axioms. This greatly simplifies its use and provides faster performance algorithms analysis.

At the first stage the set of terms is exported from the reference ontology.

Lexical ontology is built on base of reference ontology set of terms. Every ontology term is connected with the set of corresponding natural text fragments.

These rules of markup are used for student texts. If two fragments from one sentence are marked up by concepts of reference ontology A and B and some fragment is marked by relations X from the reference ontology then we can check the semantics of this sentence.

If reference ontology contains this relation X between concepts A and B, $X(A,B) \in O_{reference}$, then we can assume that student correctly understands this regularity.

If reference ontology contains other relation Y (or have no relations) between concepts A and B then we analyze the type of X and Y relations. If X and Y are incompatible, $Y(A,B) \in O_{reference} \Rightarrow X(A,B) \notin O_{reference}$ then we can assume that student incorrectly understands this regularity.

Else we analyze relations of subclasses and superclasses of A and B. If some of them has relation X, $\exists X\left(A^{`} \in subclass(A) \cup superclass(A), B^{`} \in subclass(B) \cup superclass(B)\right) \in O_{reference}$

then we can assume that student understands this regularity but with some mistakes.

This algorithm can mark up not only classes bat individuals as well. In natural language the equivalents of individuals are named entities (names, titles etc.). If reference ontology includes individuals we can analyse the relations of concepts and their individuals.

7. Ontology-based matching of domain ontologies in e-learning: the implementation of the prototype

Ontological representation of student domain skills can be automatically processed by intelligent software agents and multi-agent systems (MAS). It is appropriate to use software agents for e-learning because they work efficiently in dynamic heterogeneous distributed environment. Now a lot of researchers use MAS for e-learning and e-coaching tasks [23].

M(e)L prototype is a multiagent ontology-based e-learning system that produces automatically semantic control of student learned course beliefs. This system provides such functions:

– Tools of building of reference domain ontology by tutor (with automated generation of the set of concepts, the set of relations and the lexical ontology);
– Tools of building of domain ontology by student on base of the set of concepts and the set of relations;
– Tool for generation of domain ontology from natural language texts (on base of their semantic markup by terms from the set of concepts and the set of relations of reference domain ontology – with the help of lexical ontology);
– Ontology matching tool (for ontologies with equivalent sets of concepts and relations);

General architecture of this system is proposed in fig.2:

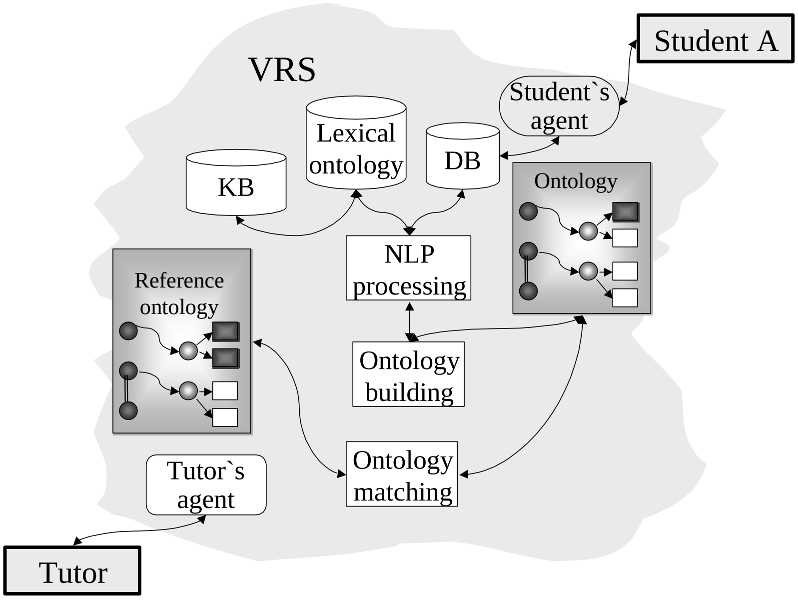

Figure.2. Ontology building process as a result of learning

For example, tutor builds the reference domain ontology O with the set of concepts T={A,B,C}, the set of individuals $I = \{a_1 \in A, a_2 \in A, b_1 \in B, b_2 \in B, c_1 \in C\}$ and the set of relations (object properties) R={x,y}. Ontology O contains information that A is a subclass of B, $x(a_1, c_1)$, $y(b_2, c_1)$.

Student use the sets T, I (without classification) and R for building of ontology O` on base of his beliefs about domain that he forms during e-learning process. O` contains such facts: $a_1 \in B, a_2 \in C, b_1 \in B, b_2 \in B, c_1 \in C$, B is a subclass of A and $x(a_2, c_1)$. The tool of ontology matching compare O` with O and shows mistakes with different significance: wrong class hierarchy of A and B and wrong relations between individuals more significant for understanding of domain than wrong classification of individuals for subclass or superclass.

The focus of ontology analysis is on knowledge structuring (of main domain terms and their relations). We use ontologies to describe learning materials and to represent student belief about course domain (fig.3).

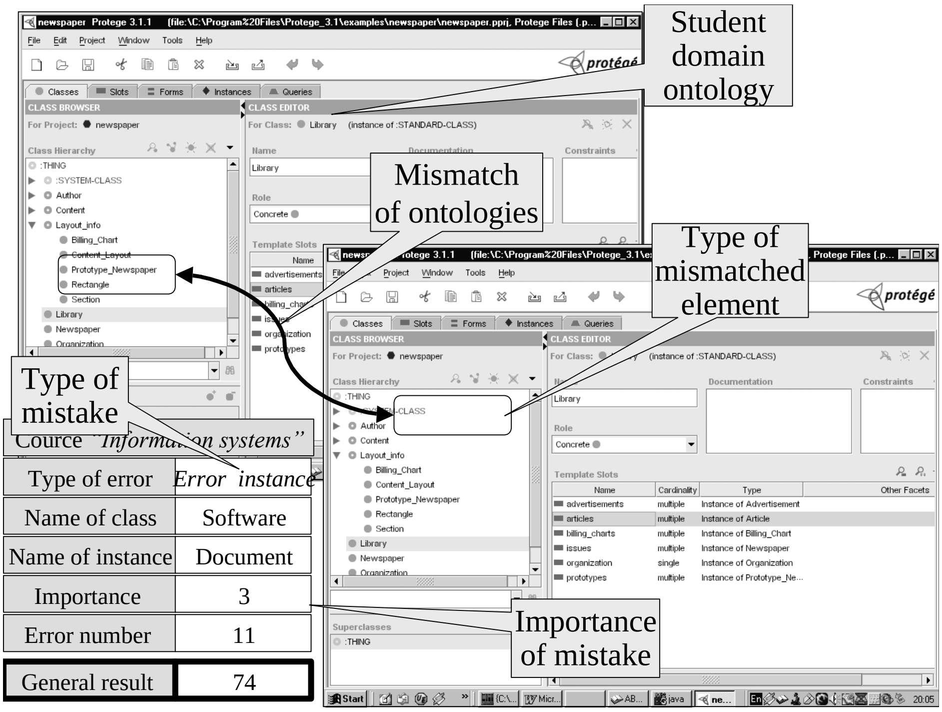

Figure 3. Domain ontology matching with reference one in M(e)L

M(e)L shows all disagreements of O and O` with the weight of every mistake and generates the result mark. System demonstrates to student and tutor general number of mistakes, their type (for example, false classification of individuals, false relation between individuals, false class taxonomy) and weight. This information helps them in correction of errors and in more correct and comprehensible modelling of domain. If students in many cases make the same mistake then tutor has to change or increase the explanation of corresponding matherials.

8. Summary and conclusion

The main features of our approach to analysis of complex information objects are based on their ontological modeling and matching of these models with reference one. For example, if an analyzed object is a student competence in e-learning process then student himself or the analyzing system (by linguistic processing of the student natural language texts) build the ontological model of the learning domain and then match it with the reference domain ontology built by the tutor.

In this work we propose an algorithm of matching and the evaluation of it's results where ontological relations between domain concepts are differ on hierarchical, synonymic and domain specific.

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