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Ontology-based knowledge recognition in service-oriented virtual research environments

Case: application in e-learning

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***Abstract*—In the paper some methods of ontology-based knowledge recognition in service-oriented virtual research environment are proposed. These methods are about export of knowledge, qualification level and study domain of students, and about automatic evaluation of their skills. The research is situated in different disciplines. Using domain ontology as an instrument for student skills evaluation is set forward. Web services and ontologies provide reuse of these methods in other applications. A prototype automatic tutor has been developed to support e-learning.**

Keywords—knowledge management, intelligent e-learning, ontology, virtual research environment, knowledge recognition

I. INTRODUCTION

Virtual Research Environments are providing a lot of possibilities for distributed knowledge management to be applied in different study domains. Implementing knowledge management in modern universities is a challenge when they are providing a mix of traditional and on distance education. Knowledge management process can be organised in different ways. The following steps are often identified: acquisition, creation, storage, validation, and utilisation of knowledge. These steps can be found in e-learning projects setup to increase the learning process effectiveness.

Knowledge acquisition about the qualification level and the learners' skills is a main problem. This problem can be seen as a particular case of pattern recognition. The information object describes the qualification and the skills of the learners. An approach based on ontologies is widely used for solving these problems. In our research we are proposing a method of reference domain ontology to be used as an instrument to evaluate students' qualification and skills. The students- or course-ontology is compared with the reference one based on a set of different concepts and relation ratings.

II. VIRTUAL RESEARCH ENVIRONMENTS

We believe that more research about generating new knowledge and cost-effective technologies , mainly based on a number of ICT-related disciplines, will offer a number of possibilities, which have not been exploited yet in Virtual Research Environments (VREs) supported by e-infrastructures. In particular, state-of-the-art methods and technologies in fields like the Semantic Web, Computing, Networks, Artificial Intelligence, among others, will be integrated into the SMART-VRE solution.

We are analyzing in this research only the VRE functionality on top of real use cases, and by the way make it possible to take into account the privacy aspects. the communication and dissemination strategy of the VRE have a

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key role into the accomplishment of its main technical objectives by: (1) reporting to Universities and Research Institutes, to the general public and to the media; (2) exploiting the VRE outcomes and results in order to help reinforcing the EU industrial base in the domain of e-infrastructures; (3) communicating about SMART-VRE benefits in VRE's so as to ensure the exploitation.

In table 1 we present an overview of the challenges faced by the implementation of a virtual research environment.

TABLE I. CHALLENGE FACING

Challenge	Way(s) to be faced
Integrate resources across all layers of the e-infrastructure (networking, computing, data, software, user interfaces)	-Adopting open data (fulfilling privacy requirements), open science and open innovation as main principles and implementing an advanced dedicated software application to facilitate e-infrastructure networking resources integration. -Encompassing several physical e-infrastructures and computing models, including HPC, grid and cloud computing models. -Performing semantic annotation of data for further semantic integration into ontologies using standardized ontological languages. - Using semantic web services and intelligent agents for integrating software applications. -Adopting a bottom-up approach in user interfaces integration, so achieving High-Fidelity prototypes of user interfaces that will reflect the scalability features used in the previous stage (Low-Fidelity prototypes)
Foster cross-disciplinary data interoperability	-Data will be semantically annotated so that these can be interoperated amongst VRE (web) services and users overcoming possible disciplinary-related terminological discrepancies. - Semantic web services will be utilized so that VRE-provided services and resources are decoupled with respect to both the data provided by such services and the (user) services requested
Provide functions allowing data citation and promoting data sharing and trust	Metadata will be semantically annotated for each data for those ones further processing so that they will include features like authorship and source of publication
Provide functions promoting data sharing	Maximizing the use of ontologies and semantic web services in carrying out the (services, networking and joint research) activities in the VRE platform
VREs should provide functions promoting trust	- We will seek endorsement of the SMART-VRE privacy concepts by consumer stakeholders and propose an European privacy standard for VRE solutions. - The developed software modules integrating the VRE platform in the project will be continually tested and user-evaluated. - The VRE platform will encompass security mechanisms and protocols against external attacks.

The overall aim of the VRE is the generation, validation, communication and exploitation of the VRE platform for ageing. In particular, the VRE platform will be conceived in such a way that: (1) it will be conceptually defined on a set of underlying ageing-relevant e-infrastructures; (2) it will re-use existing project theme-relevant knowledge and solutions (e.g., tools and services from existing infrastructures and projects) at both European and national levels; (3) standardized software building blocks and workflows, well-documented APIs and interoperable software components will be used for designing and implementing the VRE; (4) at least 1.000 potential users will be targeted.

The VRE platform manages data in such a way that 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.

III. RESEARCH AND INNOVATION ACTIVITIES OF THE VRE

The following main types of research- and innovation-activities, covering a variety of research topics about the trans-disciplinary nature of the VRE, have been linked to the problem and the resulting solution.

A. Computer networks

1. High Performance Computation

High Performance Computation (HPC) is set forward. 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 than on data processing [1], [7].

As underlined in the PRACE report ("The scientific case for high-performance computing in Europe 2012-2020"), handling large data volumes generated by research is a major challenge and opportunity for future HPC systems and integrated environments for computing and data management. SMART-VRE intends to provide a showcase of an integrated environment that can serve a specific community, the one engaged in ageing research. Offering HPC services to various research communities is and was subject of multiple e-infrastructure projects funded by EC. The most remarkable ones are the communities around the PRACE initiative. The 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). SMART-VRE is offering the opportunity to show how a particular health community can benefit from the availability of HPC resources.

Since specialized data services are becoming complex and expensive to maintain by datacenter management, 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. [8],[9]

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2. Networking.

Networking, or co-sharing computing services [10], is fostering forms of shared information thanks to the engagement of agents and resources improving participatory approaches and direct involvement. Networking is also critical to enforce and materialize the interrelations between innovation and processes of change whose role have been widely acknowledged and studied in literature. Dynamics and impacts of collaborative systems may also highly vary according to the action of varieties of well-known pathologies in social systems creating specific peculiarities of these networks. These pathologies have the potential capability of creating profound effects in inhibiting link formation, to turn positive links into ineffective or negative ones and to enhance the non-linear system behavior. And as a result these pathologies are deeply influencing the quality of the interactions among network agents. The possibility of providing a correct diagnosis of these network pathologies can alert about actual and potential possibility of the occurrence of a system collapse caused by deterioration in the link value and in the eventual link losses. It can also support in preventing a system collapse.

B. Data management

1. Open Science and Open Innovation.

Open Science and Open Innovation are key concepts, which have become very popular in the last years [11],[12].

Open Science refers to dynamic systems of knowledge production, characterized by a more or less high degree of accessibility of information and by knowledge of researchers and scientists. These systems act as dynamos, generators and stimulators of knowledge for future research. Open Science implies the creation of effective networks based on shared collaborative resources using technical tools that are able to distribute the information. The collaborative technologies are facilitating also the distribution resources including 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.

Both concepts of open innovation and of open science will guide the high-level strategy to carry out the networking activities in SMART-VRE (fig.1).

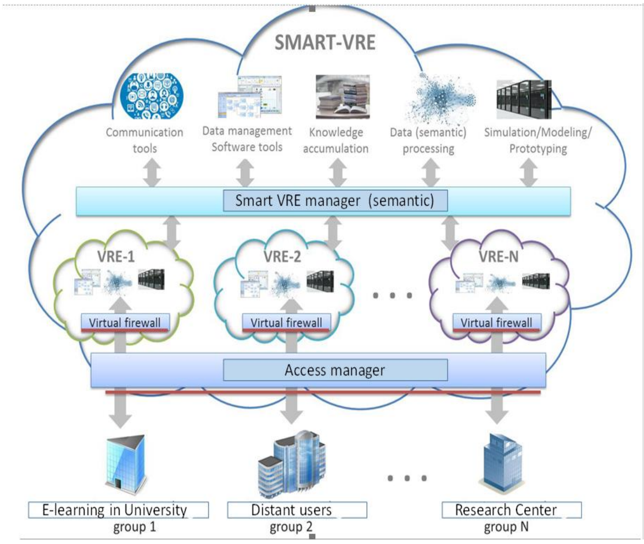

Fig. 1. The VRE Framework

2. Data management and Semantic Web technologies

To ensure the exploitation of data, data must be available and accessible in a network environment. However, the nature of data (research, administrative, academic) is variable and dependent of the scientific discipline, the application scope and the life cycle. A critical point in data management is the metadata representation of datasets catalogs [13] for which the vocabulary DCAT [14] is used. From a technical point of view, an open dataset has a life cycle that includes data extraction, storage, review, interconnection with other open data, classification and maintenance [15].

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 its life cycle. Management of data should involve 5 actions.

1. plan of data management, as part of the budgets of the organization, that anticipates management challenges and that proposes solutions to them;

2. treat of appropriate ethical and legal issues relating to sensitive personal data, to copyright and to license about 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 and how it can be reused;

4. the appropriate storage, back-up and security mechanisms to ensure the confidentiality, integrity and availability of information;

5. standards about sharing the data when cited

6. archiving of a final copy of the data in specialized services, taking the necessary measures for its preservation and dissemination.

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All these steps will be realized in a data management policy, which will be adopted in this proposal.

3. Ontologies.

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 independent of cultural variations [7], in which case the quality of the categorizations is positively correlated with the level of simplicity of these categorizations [9, 16].

Ontologies, which are commonly conceived as explicit formalizations of shared conceptual systems [17], are the most widely used approach to represent knowledge, due to their intrinsic properties of structure, reuse, sharing and formalization. All these properties enable them even for the automatic integration of knowledge once this has been represented [18]. 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 [19].

C. Semantic Web

1. Ontologies to add semantics to the data on the web

Ontologies form the backbone on which to build the future Web, namely, the Semantic Web [20],[21].

Ontologies and reasoning techniques are leading to the achievement of a more intelligent Web [9] or to the automation of science [13]. 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 in a flexible way and unambiguously. Although there are several ontological languages, OWL [18] is the de facto SW standard ontology language.

2. Semantic Web (SW).

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 reasoning systems are currently available, including non-licensed versions like Hermit.

3. Multi-agent systems and intelligent agents

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 to action autonomously in this environment in order to meet its design objectives. 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.

4. Learning ability of an intelligent agent and of a multi-agent system (MAS)

In particular, one main characteristic of an agent is the learning ability, that is, the capacity to adapt or modify its behavior based on learning experiences. 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.

5. Standardization and integration of agent technology with semantic web services

Efforts toward the standardization of agent technologies have been taken. 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

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interoperability among agent platforms. There exist different FIPA compliant agent platform implementations, like FIPA-Open Source, JADE and ZEUS are the most popular. The agent community is facing the problem of integrating agent technology with Semantic Web Services.

6. Our research about the agent platform required by our VRE.

We are doing research in defining the features of an agent platform organization, tailored to the needs of the problem. It is including flexibility and adaptation to changes as 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 [22]. 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 and interoperation.

Composition 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.

The problem is that current technology around UDDI, WSDL and SOAP provide limited support for all that.

7. Intelligent Web Services thanks to Semantic Web and Web Services.

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 consists 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. 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

IV. E-LEARNING WITH THE VRE

E-tutor, supporting learners of an e-learning course, 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 in charge of the support of learning content and fulfilling the assignments. 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 for the learner. The learner can get immediate feedback on his solved problems, can have individualized learning paths, etc.

E-learning services business is growing. The number of organizations working on E-learning and delivering e-learning tools with varying functionality is growing. The number of e-learning courses on the Internet is increasing rapidly [23].

A. Ontologies in E-learning

A structured information representing is required and ontologies (machine process representation containing the semantic information of a domain) can be very useful. The ontology systems serve as a flexible and extendable platform for e-learning 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 [24] 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. A model oriented training 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

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and Test Interoperability (QTI) of Global Learning Consortium are not adequate for the 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 a central role in resource structuring of 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. The tutor has to describe the main terms and concepts from which a course is to be constructed.

B. Domain ontology an object of evaluation

The main idea of our approach is that the *domain ontology* is not only the instrument of learning but an object of evaluation of students. We propose for students to build the domain ontology of the study domain and then compare it with the reference one. Results of this comparison show the parts of the domain knowledge which were wrong understood by the student and will help the tutor to improve the e-learning 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 understanding of the concept about the domain.

Ontological analysis is accomplished by examining the vocabulary that is used to discuss the characteristic objects and processes that are composing the domain, that are developing rigorous definitions of the basic terms in that vocabulary, and that are characterizing the logical connections among those terms. The product of this analysis, *an ontology*, is a domain vocabulary completed 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 [25].

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 and 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 > [15], 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 the 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 [26].

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

1.define the main classes and terms of the 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 its type – INT, STRING, NUMBER ets. or other class of ontology;

2. Construct the taxonomy of domain terms:

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

3. Define synonymy and other relations:

$$<t_1,t_2>, t_1 \in T, t_2 \in T, r(t_1,t_2) -> t_1 "IS\_Synonyme\_Of" t_2, r \in R;$$
$$<t_1,t_2>, t_1 \in T, t_2 \in T, r(t_1,t_2) -> t_1 "\mathrm{Re}lated\_With" t_2, r \in R;$$

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 $\forall t_i \in T_n \exists t_{j_1} \in T_e,..., t_{j_m} \in T_e, t_{j_k} \in T_e, m = \overline{1,k}$, 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 sncorrectly 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. Iit`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 sinonime" relation instead of "is a subclass" one.

C. The implementation of the prototype.

Ontological representation of student domain skills can be automatically processed by intelligent software agents. It is appropriate to use software agents for e-learning because they work efficiently in dynamic heterogeneous distributed environment. One of the main properties of an intelligent agent is sociability. Agents are able to communicate between themselves, using some kind of agent communication language, in order to exchange any kind of information. In that way they can engage in complex dialogues, in which they can negotiate, coordinate their actions and collaborate in the

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solution of a problem. A set of agents that communicate among themselves to solve problems by using cooperation, coordination and negotiation techniques compose a multi-agent system (MAS). A lot of researchers use MAS for e-learning and e-coaching tasks [27].

M(e)L prototype is a multi-agent ontology-based e-learning system that produces automatic semantic control of student learnt course beliefs. 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's belief about the course domain (fig.2).

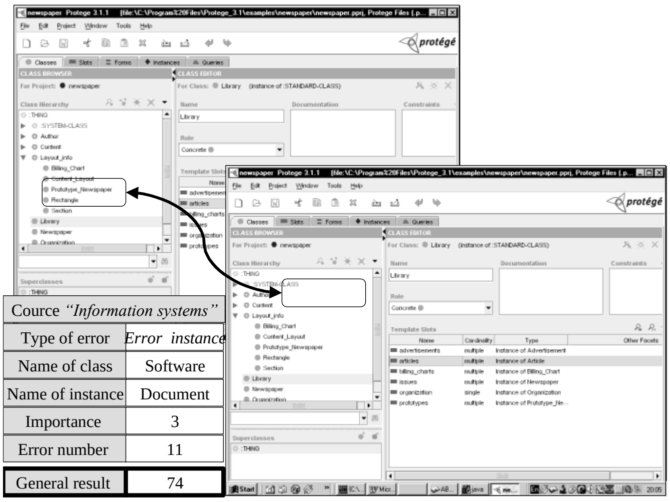

Fig. 2 Domain ontology matching with reference one in M(e)L

V. SUMMARY AND CONCLUSION

A prototype was developed to replace the human tutor intervention. Ontological representation of student domain skills can be automatically processed by intelligent software agents.

The main features of our approach to knowledge control are the following: all results are analysed automatically without human tutor, the results are analysed objectively, students can work with knowledge base, a structuring of domain knowledge simplifies the learning process and tutors can exchange their knowledge based on reference ontologies.

VI. ACKNOWLEDGMENT

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