TECHNOLOGICAL AND ECONOMIC DEVELOPMENT OF ECONOMY
Baltic Journal on Sustainability
2009
15(2): 229–244

MULTI-LAYERED KNOWLEDGE-BASED ARCHITECTURE OF THE ADAPTABLE DISTANCE LEARNING SYSTEM

Dalė Dzemydienė[1], Lina Tankelevičienė[2]

[1] *Mykolas Romeris University, Ateities g. 20, LT-08303 Vilnius, Lithuania*
E-mail: daledz@mruni.lt

[2] *Software Engineering Department, Institute of Mathematics and Informatics, Akademijos g. 4, LT-08663 Vilnius, Lithuania, e-mail: linat@splius.lt*

Received 5 November 2008; accepted 4 May 2009

Abstract. The quality of the distance learning courses is largely influenced by competently prepared educational resources and an effective study support system. One of the possible ways to improve distance learning infrastructure and increase its effectiveness is to extend the architecture of present e-learning systems by the components for adaptable and sustainable learning. This research work is devoted to developing the service-oriented distance learning environment adaptable to the user's needs. The proposed adaptable communication environment of distance learning is constructed by integration of new components of communication scenarios generation, adaptable for student's goals, multilayered domain ontology of learning subject and forming intelligent agents' framework possible. The paper presents the knowledge-based component architecture of the distance learning system, which enables a better adaptation of learning resources to students. The paper analyses the possibilities of integrating ontology into the e-learning system. The issues of decomposing ontology into different levels of understanding are discussed in order to adapt to learner's tasks and goals. A conceptual approach is proposed for extending the existing distance learning system architecture by intelligent and deeper knowledge layers.

Keywords: distance learning environment, adaptable e-learning, decision support system, ontology, intelligent agents, knowledge-based architecture.

Reference to this paper should be made as follows: Dzemydienė, D.; Tankelevičienė, L. 2009. Multi-layered knowledge-based architecture of the adaptable distance learning system, *Technological and Economic Development of Economy* 15(2): 229–244.

ISSN 1392-8619 print/ISSN 1822-3613 online
doi: 10.3846/1392-8619.2009.15.229-244
http://www.tede.vgtu.lt

1. Introduction

Software engineering methods offer new semantic e-service technologies, ontology management possibilities, and intelligent agents' integration techniques. Synchronous, asynchronous, and blended study models are applicable and widely described in the e-learning process realizations (Karampiperis and Sampson 2005; Zavadskas *et al.* 2008; Kaklauskas *et al.* 2007a). However, personalised learning with the use of distributed information and a dynamic and heterogeneous learning environment is still problematic. Therefore, intellectualization of the distance learning system, using software agents, is important in order to support student's activities and the distance learning process, as well as instructor's activities. Our research aims at using domain ontology in order to acquire a general/particular understanding of the learning domain between users and software agents.

The educational virtual environments are being developed by the means of emerging new technologies enforcing us to reflect once again the theoretical background of how people learn and try to find innovative ways of adaptable learning realizations (Kaklauskas *et al.* 2007b; Stukalina 2008). The use of Learning Management System (LMS) is a common practice and it is widely analysed, but information seeking as a process may require new skills and strategies from the e-learner. On the other hand, a lot of extensions of functionality of LMS are oriented towards increasing the support, provided of a system to the e-learner.

Semantic web technologies, such as ontologies, agents, web services, can help in these cases and intensive research is carried out in the field (Stojanovic *et al.* 2001; Allert *et al.* 2006; Alsultanny 2006). Student's modelling and adaptation processes, based on ontologies are analysed in (Muñoz and Oliveira 2004; Dolog *et al.* 2004; Cristea 2004; Karampiperis and Sampson 2005). Domain ontology plays an important role in approaches, presented for e-learning systems (Angelova *et al.* 2004; Deline *et al.* 2007), but the examples showing their usability are concerning more primitive domains.

Traditional distance study courses usually have predicted by lecturer sequence of learning resources and activities (Mockus 2008). This fact sometimes does not correlate with pedagogical strategy used, where free exploration is preferred. Despite of knowledge receiving or exploring method used (e.g. reading topics coherently, starting from different point and deepening the knowledge or looking all around, browsing in order to acquire the overall view of a material), students need to understand the structure of the information space, in order to better navigate through it and achieve their goals. In this case, the meta-cognitive support can be employed. Meta-cognition deals with understanding, managing, planning the own learning process. Specific methodologies and tools are proposed for seeking to support knowledge building, e. g. meta-cognitive maps (Lee and Baylor 2006), Did@browser System, which poses meta-cognitive questions during browsing (Chiazzese *et al.* 2006). The difference of our framework is the automation of the resource linking process at run time. However, developing ontology and resources, and mapping ontology concepts with resources remains manual work.

The goal of this research is to develop distance learning environment by improving the architecture of the traditional learning management system (LMS) while integrating domain ontology by generating scenarios with the reasoning components in adaptable learning process. The aim of the paper is to analyze application of reasoning mechanisms in the domain ontology, and to propose a framework for conceptual linking of educational resources.

2. The architecture of the distance learning management system for adaptable purposes

The multi-layer architecture of the e-learning system integrates the components of the usual learning management system (LMS) and extends it with intelligent components. The proposed architecture of an adaptive learning management system shows the structure of the main components and packages integrated for supporting the main functional organizational tasks (Dzemydiene *et al.* 2006):

- Subsystem of development of distance courses, intended for course planning, material creation or importing, integrating activities;
- Subsystem of supporting a study process, intended for process organization, users' activities control, communication, and assessment organization;
- Subsystem for organizing realization and control which identifies the registered users, analyses their rights, offers access to the objects of the environment, and ensures the safety of the data used;
- Subsystem of logistics meant for planning the personnel, resources, finances, equipment, and information of the institution.

In essence, we extend the existing LMS with 2 layers. One layer – intelligent decision support components – should act as a mediator between the core LMS elements and user interface. We prefer software agents as independent components. However, the previous intelligent learning systems were oriented towards the behavioural learning model.

Besides the main databases (data on users, courses, and users' activities within courses), we propose deeper knowledge layer. We give the top priority to domain ontology integration. The layer of intelligent decision support components (2) has to act as a mediator between the elements of LMS (3) and different types of user interfaces (1). This layer plays the role of interaction regulations. We prefer software agents in the implementation stage. The schema of agents' relationships with the other components of e-learning system is presented in Fig. 1.

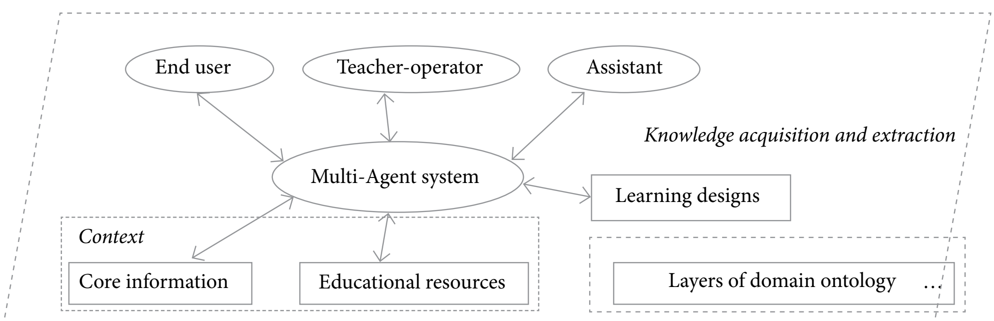

Fig. 1. Agents' relationships with the other components of the distance learning system

Agents must transfer right knowledge within the right context. Therefore agents must not only use knowledge, but also they need relevant, real time information, the so-called context. Context-related information (data on users, courses, and users' activities within courses) is stored in the core information component of databases. If we are aware of the subject domain ontology and information about goals of a student, we can adapt educational resources to students with different levels of e-learning progress (Fig. 2).

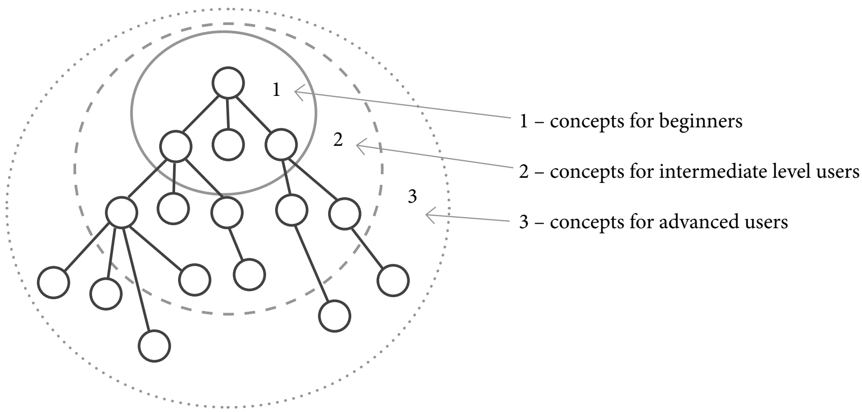

Fig. 2. An example of division/extraction of abstract subject areas (in line with ontology levels provided by the lecturer)

The goals are formulated by the teacher, who has subject domain ontology and information about student's goals. The learner does not reach the educational resources directly, but through the interacting with multi-agent system, which works on the intelligent level (Fig. 2). The example of division/extraction of abstract subject areas according to ontology levels by lecturers to become the agents later on. Scenarios for personalized learning path generation have to be specified and introduced into the intellectual layer. Due to language compatibilities with different platforms, such as Java-based, agents can be integrated with each form of the distance learning system used.

In order to gain more benefit from automating some processes, we have to find some exclusive tasks which are important in the aspect of being automated. In (Becks 2001) a task is regarded to be important if it is:

– typical, i.e. it occurs frequently;
– difficult to perform and thus can benefit from suitable support;
– valuable for the user to solve it;
– information technology can possibly support the problem solving process.

Typical users of e-learning system and their functions are listed in Table 1.

Table 1. Users and their functions

User type	Functions
System administrator	Controls the system, users, courses, defines users' rights, adapts system to separate computer or informs users, how to adapt computer to system (what to install, what values of parameters to change).
Author	Creates new courses, while using previously accumulates materials and forming new learning content, renews content, provide learning scenarios.
Instructor	Observes learning process, analyzes students' achievements, consults students, direct students to the proper direct, evaluates tasks. Usually authors become instructors of the course.
Student	Picks the course according to his/her goals, seeks for realisation of defined goals, connects to the system using user name and password, studies material, evaluates progress, completes tasks, collaborates with others, etc.

More precisely students' activities can be formulated ranging them by learning methods used:

- information transfer: lecture, studying learning material, instruction, illustration, analysis of case studies and examples;
- practical-operational: exercise, task, coursework;
- creative: working with scientific-technical literature, search for information and analysis of results, group work.

Simplified model of learning, as the process of acquiring experience, can be depicted as the sequence of 3 steps: 1) Absorb knowledge; 2) Do practice; 3) Connect to a life or work. In other words, these steps can be described as: 1) Introduce; 2) Apply; 3) Summarise. We don't consider here further use of acquired knowledge and abilities, therefore, we analyse only the first 2 steps.

In the modern society it is postulated that absorbing knowledge happens using different sources: lecturers, colleagues, virtual communities, libraries, internet, etc. Also the role of learner is emphasized. In the same time the role of the lecturer transforms into the collection of the following: consultant, expert, facilitator, mentor, etc. But despite of that we as academic staff must support learning processes and, if it possible, we try to employ intelligent systems in this support. Students' support concerns guidance and encouragement of the students both from the instructional material and from the communication channels in all steps of learning processes.

We present particular users', i.e. learners, tasks, typical tasks and ontology-based activities in Table 2.

The interpretation of data is as follows: for example, we would like to support browsing process in order to develop meta-cognition skills. We must realize typical tasks: details-on-demand, relate, history. Details-on-demand requires the following ontology-based activities: getting (picking) class (from name), inferring about properties and upper properties, retrieval of instances.

Analysis shows that tasks of the type *absorb knowledge* require all mentioned ontology-based activities except for checking equivalence and consistency check. On the other hand, these activities are useful in automating practice processes.

Table 2. Important users' tasks in distance learning

Task type	Users task	Type of task	Ontology-based activities

Absorb knowledge (receive and explore)	– Gaining information about all the course
	– Reading topics:
	  – Coherently
	    – Main sequence
	    – According to different levels of learning progress
	    – From different starting point
	  – Deepening from a different starting point
	  – All around from a different starting point
	– Browsing
	  – Meta-cognitive support
		Overview
		Zoom & Filtering
		Details-On-Demand
		Relate
		History
		Extract
			Property level:
			– Inferring about super-properties
			– List of all properties
			– Adding and removing properties
			
			Class level:
			– Creating class
			– Getting (picking) class (from name)
			– Getting class name
			– Checking for sub-classing
			– Checking for super-classing
			– Listing all subclasses
			– Constructing a class hierarchy
			– Checking equivalency

Practice	Taking quizzes Writing essays Task of the type concept mapping Task of the type development of topics map Analysis of meta-cognition (matching concept maps) Posting to forum		Individual level: – Creating instance – Consistency check; – Realization (finding class) – Retrieval of instances

3. Conceptual linking of educational resources in e-learning space

The overall structure of learning process from e-learner perspective can be described as a part of the conceptual model of IMS Learning Design (IMS-LD) (Fig. 3).

Learning process happens in virtual environment, face-to-face activities are also incorporated in blended studies. In "step-by-step" methodology learning circle is quite short, e.g. one academic hour. But if we seek the competences of a higher level, sometimes we cannot project our proposed sequence for studying learning material. Some order or hierarchy is provided to the learner, but it is not compulsory to follow. In this case, it is more useful to support free exploration better, and here the problem of linking resources arises.

We distinguish several important types of linking educational resources according to the technology used.

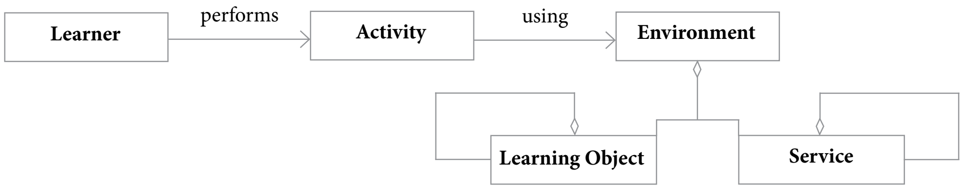

Fig. 3. The simplified view on learning process in virtual environment

Manual linking. All educational resources and links to external resources are compiled by human, lecturer. Typical web server/web client architecture is used. By clicking hyperlink user requests some data. Application from Server side renders it for the user. This model invokes problems of social type: a) developing of learning resources and linking them to each other is time consuming; b) links to external resources must be often revisited in order to guarantee their availability.

Automatic linking. Technically this model of linking is usually implemented by analyzing possible resources or their metadata in a syntactical level. In this case the problem of relevance, quality and trust arises, because all resources found are treated as of the same quality.

Conceptual linking. The main problem of automatic linking is that semantics usually is ignored. Semantics concerns the relation of signs to real world entities they represent. Concept is an abstraction, formed in mind. It corresponds to the real world entities and is designated by signs (e.g. word). For example, in Cognitive Linguistics theory (Hoek 1999) it is stated, that "the meaning of an expression is the concepts that are activated in the speaker or hearer's mind. In this view, meaning is characterized as involving a relationship between words and the mind, not directly between words and the world". Here subjectivism is emphasized, and it means that we are dealing with conceptualization – abstract representation of domain.

Therefore, in order to implement conceptual linking of educational resources, the humans (and the computer, if we want to automate and/or support some tasks) must accept a) common vocabulary of some domain, and b) the meanings of syntactical elements.

Ontology concept has various meanings in different sources. Some of the definitions, used in computer science field, are presented in (Guizzardi 2005). We assume the following definition of ontology: „Ontology is a conceptual specification that describes knowledge about a domain in a manner that is independent of epistemic states and state of affairs"(Guizzardi 2007). This definition emphasizes that ontology are universal models of domains or models of known knowledge in a domain.

Therefore, we adopt a formal definition of ontology from (Guizzardi 2005), derived from logic and set theory. Ontology is a 4-tuple $<C, R, I, A>$, where C is a set of classes (concepts), R is a set of relations, I is a set of instances, and A is a set of axioms. *Classes* (other synonymous terms: concepts, categories, types) represent important concepts of the domain. Classes in the ontology are usually organized in taxonomies, where generalizationspecification mechanisms are applied. *Relations* (properties, slots, attributes, roles) represent associations between the concepts of a domain. Most often *is-a* and *consist-of* relationships are used. However, the taxonomical structure is not the only one possible. Ontology usually contains binary relations. The attributes are sometimes distinguished from relations. *Instances* (individuals) represent individuals in ontology. Instances can be defined in ontology or in database of factual data. *Formal axioms* are used for expressing propositions that are always true, e.g. in the *eLearning* course the same person cannot perform the role of a lecturer and student at the same time. Formal axioms are used to infer new knowledge. If axioms are not included into ontology itself, reasoning mechanisms must be implemented in program part of the system (in the code).

Domain ontology can be used in the 2 main processes of the eLearning life cycle: development and delivery, as shown in Table 3.

Table 3. Two main types of processes, where domain ontology can be used in distance learning system

Entitlement	Description
Development of learning materials/activities using subject domain and instructional ontology (optional).	Constitutes of 2 different parts: 1) Content and services discovery and assembly; 2) Development of their own materials and/or activities. Tasks that can be realized: verifying completeness, timeliness, compatibility, linking of learning materials.
Teaching/learning process.	Includes adaptive course delivery, adaptive sequencing, adaptive presentation, adaptive interaction, and adaptive support. For example: 1) Adapting educational resources for students with different levels of learning progress; 2) Different starting point. Concepts belong to overlapped groups, which are important differently to different students; 3) Concept mapping, development of topics map (as evaluated task); 4) Free exploration of content, based on conceptual linking.

4. Scenarios generation using reasoning over domain ontology in adaptable distance learning system

One of the commonly used reasoning definitions is as follows: *"Reasoning is computing the implied relations"* (Brusse and Pokraev 2007). We restrict ourselves with reasoning using knowledge, represented by the means of ontology. Differently from traditional AI systems, reasoning over ontology tends to be deductive, not inductive. It is a limitation, because deductive reasoning does not allow us to learn something new. However, the purpose of domain ontology is to represent domain and support retrieval of data. Therefore, the use of ontology unconsciously provides better capabilities and ontology driven information system differs qualitatively.

Usually the reasoning must be conducted over 2 elements: the ontology itself (which contains terminology) and the knowledge base, in which instances described (and contains assertions).

Two main reasoning techniques are used in the Semantic Web: a) Query languages; and b) Logic-based formalisms (Walton 2007). Query-based reasoning comes from popularity and wide spreading of Relational Data Base Management Systems (RDBMS). It employs the main idea used in RDBMS: the use of structured query language in order to extract data, which matches a given pattern. The last standard for querying ontology is SPARQL – Simple Protocol and RDF Query Language.

Logic-based reasoning is performed, after ontology has been translated into a description logic representation. The last standard for implementing logic-based reasoning is compliance with DIG (shortened: DL Implementation Group).

The categorization of reasoning over ontology can also be conducted considering formalisms used. The types of reasoning according to (Brusse and Pokraev 2007) are listed as follows:

1. Property level reasoning. Means inferring implied triples (subject, predicate, and object) from the stated ones.
2. Class level reasoning. For example, it concerns checking whether a class *B* is a subclass of class *A*. A separate case is classification – constructing a class hierarchy.
3. Individual level reasoning. For example, it oncerns checking if an individual can exist in some model (consistency check). Two distinguishable cases are: 1) Realisation is finding the classes of which an individual is a member; and 2) Instance retrieval is finding all the known instances from the class.

The list of the main reasoning tasks as: class membership, equivalence of classes, consistency, and classification is analysed by (Antoniou 2007).

Summarising the analysed literature, we can state:

– The query-based reasoning is simpler, more efficient and easier to use. Logic-based reasoning provides more possibilities, it is more powerful, but it is harder to implement.
– Since our solution is oriented towards extending present LMS, which already uses current web technologies, including Relational Databases, we choose the query-based reasoning for further use.

We distinguish between lightweight and heavyweight ontologies. Lightweight ontologies include concepts with properties and taxonomies, but do not include axioms. Heavyweight ontologies are richer in expressiveness, but they are harder to manage. Since the lightweight ontologies are less restrictive, they are usually acceptable wider, which is very important for knowledge sharing and reuse. The less expressiveness the language provides, the better reasoning mechanisms are implemented. This is very important in the context of immediate feedback generation and increasing the efficiency of a system in common and simple tasks.

Emphasizing the importance of using formal semantics, we allow humans and systems to reason about the knowledge (Antoniou 2007). Reasoning support is usually provided by system components. The reasoning mechanisms can be realized, for example, based on Description Logic (RACER, FaCT++, Pellet) or rule-based (Jena, Bossam). Reasoning is necessary because the ontology is static in its essence. According to our proposed architecture (Dzemydiene and Tankeleviciene 2006), reasoning processes are planned to realize an intelligent layer, intended for active components that automatically perform functions previously performed by the lecturer.

4.1. Framework for conceptual linking of educational resources

In our proposed knowledge-based architecture of the adaptable distance learning system, we use a framework for conceptual linking of educational resources. This framework supports our foreseen improvement of the architecture of the traditional LMS (Dzemydiene and Tankeleviciene 2008; Tankeleviciene and Dzemydiene 2009), while integrating domain ontology by generating scenarios with the reasoning components in adaptable learning process.

The goal of our framework is automated support in eLearning activities, based on pedagogical background. We follow these instructional requirements:

- Provide learners with the learning material and guidance towards the accomplishment of their goals;
- Stimulate learners for active participation in learning and to take control over learning results;
- Support adaptability, personalization and information retrieval.

Often adaptability is analysed in the context of learning, and is oriented towards knowledge transfer. For example: "The main goal of adaptation in educational systems is to guide the students through the course material in order to improve the effectiveness of the learning process" (Gaudioso and Montero 2005). It means that the constructive view is not taken into account. On the other hand, we can consider adaptability and personalization as "guiding students" rather than forced intervention, but also support in simple and time consuming tasks, and provision of learners with alternative ways of learning.

Educational resources represent knowledge to the learner in the form suitable for learning. Therefore, in the static view, we can distinguish 2 levels (Fig. 4):

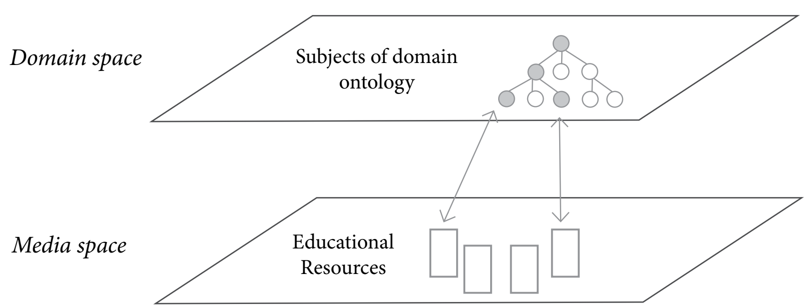

Fig. 4. Separation of domain and media spaces

– Domain level, which concerns the domain knowledge, is called Domain space.
– Course level, which concerns the practical implementation of e-learning. The course consists of a set of educational resources, including both teaching/learning materials and activities. This level is called Media space.

Therefore, subject domain ontology can be developed despite the educational resources and services, which may vary at different moments. Obviously, some design/development processes must be performed beside typical processes, such as development of educational resources or definition of distance study course structure. These additional processes are presented in Fig. 5.

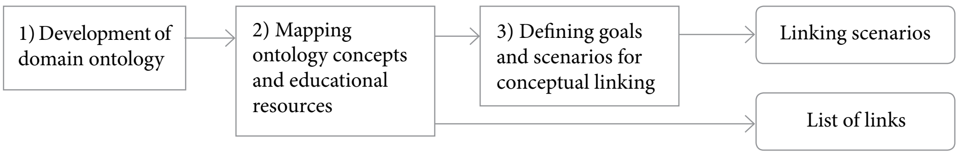

Fig. 5. Workflow of processes at design/development of ontology and linking scenarios

Mapping of ontology concepts and educational resources allow us to perform only elementary operations: to get class from its name, to get resource identifier from class name. Therefore, in step 3 further scenarios for reasoning over ontology must be defined. The scenarios that can be developed depend on pedagogical goal, ontology structure, and technology of reasoning used.

4.2. Workflow representation for providing studying scenarios

The workflow of run-time processes is presented in Fig. 6.

Instructional engineering in general and our framework in particular try to focus on 2 important processes (Paquette 2004): knowledge extraction and knowledge dissemination.

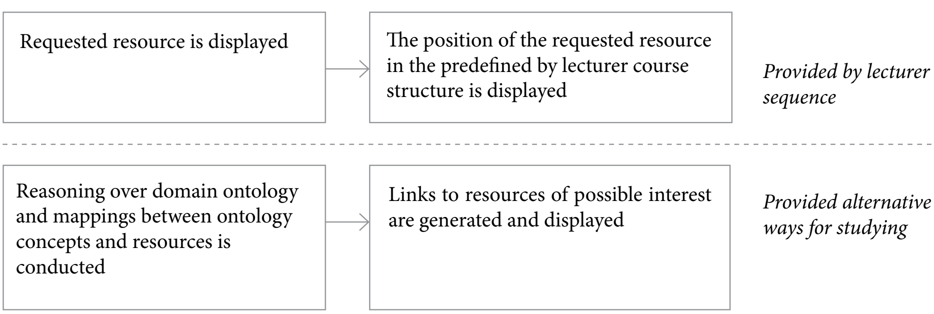

Fig. 6. Workflow of processes at run time

In order to realize ontology-based conceptual linking, the experimental domain ontology was developed, pedagogical goal was formulated and scenario was designed. E-learning tools were chosen for implementation, in order to implement the ontology and the framework, while working with distance study course "E-learning technologies". The course is implemented using Moodle: an open source e-course management system. Therefore, we already have learning material, which shall be further linked to the concepts from domain ontology. The main general concepts in our domain are: *Software_Product*, *Manufacturer*, *Purpose*, *Curriculum_Level*. The more specific concepts are: *Multimedia_Processing_Tool*, *LMS, Web_Browser*, etc. The example of description of part of taxonomical hierarchy from general concept *Software_Product* is presented in Fig. 7.

Also we employ a *whole-part* relationship in order to represent aggregation. The most general concepts are associated with relationships *provides*, isProvided, *isSuitableFor*, *canBeAchievedWith*.

An approach to choosing a tool suggests several steps of filtering, beginning from all possible alternatives. We may begin our analysis with defining a manufacturer, if we use some other its products; we can restrict ourselves only to the free tools or easy to use tools, if our competencies are on a quite low level. The possible scenario is presented in Fig. 8.

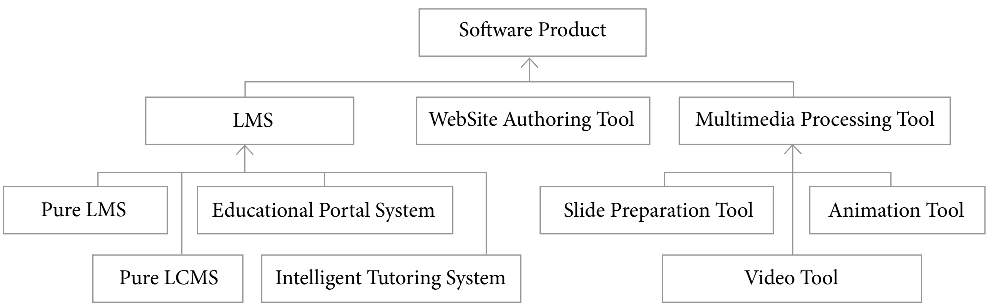

Fig. 7. The part of taxonomical structure

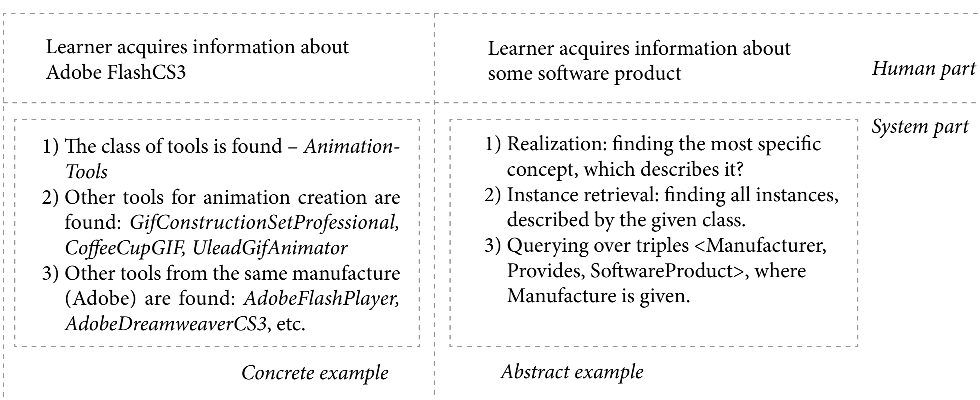

Fig. 8. Description of steps of scenario for automated linking of educational resources

The scenarios for automated linking of educational resources are described by means of sequence diagrams of UML (Fig. 9) at run-time.

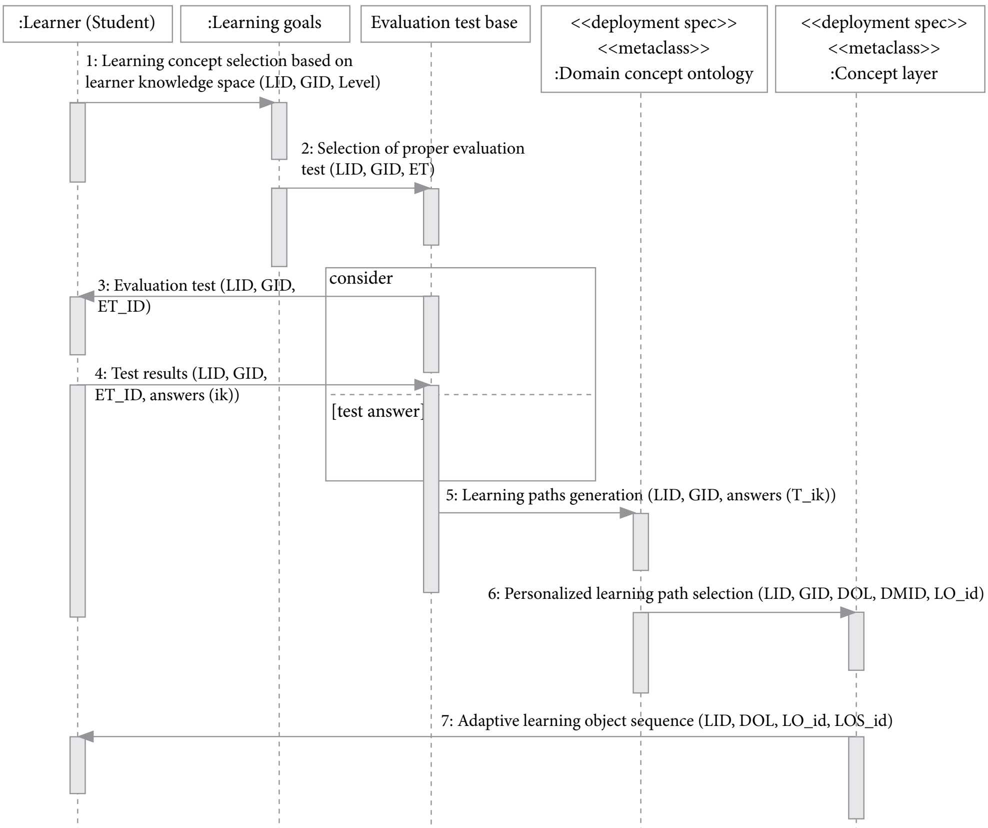

Fig. 9. An example of description of scenario for automated linking of educational resources

5. Conclusions

Development of multi-layered architecture for adaptable distance learning system offers some advantages including the use of scenarios which help in personalisation and individualisation of learning processes. Ontology has a great potential in distance learning systems, but the methodologies, describing how to do that, are developed from the instructional design viewpoint. The query-based reasoning over ontology is simpler and more efficient than logic-based reasoning; therefore, it is suitable in hybrid information systems, where current web technologies and ontology engineering are combined. The reasoning component must be designed, which provides API for integration with external parts of the system.

Despite of increased attention of researchers towards instructional ontologies and design of learning scenarios, design and development of domain ontology remain an actual problem, because domain ontology and learning resources, developed based on it, imply realisations of the mentioned learning scenarios. The approach to using domain ontology in the development and delivery of educational resources enables automating these processes, increasing effectiveness, interactivity, adaptivity and users' satisfaction.

List of important tasks, possible and worth to automate using ontology-based reasoning, have been made. It lets to gain more effectiveness from e-learning system.

Conceptual linking of educational resources and displaying different ways of achieving the learning goal provide us with a better trade-off between control and self-responsibility. There is enough to apply simpler reasoning mechanisms over domain ontology in order to support learner in simple tasks.

The proposed framework for the conceptual linking of educational resources is based on reasoning over structural parts of ontology: classes, instances and properties. We have demonstrated the applicability of this framework in a case study, where the field of *E-learning tools* was chosen as a problem domain, and supporting browsing and searching for the most suitable tools for realising project work were considered as a pedagogical goal. The same framework can be reused in other context for realizing other pedagogical goals.

The social impact of the proposed solution can be identified as supporting knowledge building process. From the managerial point of view on e-learning, it increases interactivity on student–study-material level and decreases the amount of workload of academic staff.

The analysis of the domain, the proposed framework, and practical experiments have allowed us to formulate a set of research problems: there is the need for collaboration of experts in instructional design and ontology engineering fields, because the design of scenarios must be based on sound pedagogic strategies. Compatibility of the traditional Learning management system (e.g. Moodle) with the ontology development tools and reasoning component over ontology is problematic due to interoperability problems between ontology and current web technologies. These problems shall be a subject of our further research.

References

Allert, H.; Markannen, H.; Richter, C. 2006. Rethinking the use of ontologies in learning, in Memmel, M.; Burgos, D. (Eds). *Proceedings of the 2nd International Workshop on Learner-Oriented Knowledge Management and KM-Oriented Learning (LOKMOL 06)*, 115–125.

Alsultanny, Y. A. 2006. e-Learning System Overview based on Semantic Web, *Electronics Journal of e-Learning* 4(2): 111–118.

Angelova, G.; Kalaydjiev, O.; Strupchanska, A. 2004. Domain ontology as a resource providing adaptivity in elearning, in *Proceedings "On the Move to Meaningful Internet Systems 2004"*, Springer, LNCS 3292, 700–712.

Antoniou, G. 2007. Web ontology languages, in Cardoso, J. (Ed.). *Semantic Web Services: Theory, Tools and Applications*, IGI Global.

Becks, A. 2001. *Visual knowledge management with adaptable document maps*. PhD thesis.

Brusse, R.; Pokraev, S. 2007. Reasoning on the semantic web, in Cardoso, J. (Ed.). *Semantic Web Services: Theory, Tools and Applications*. IGI Global.

Chiazzese, G.; Ottaviano, S.; Merlo, G.; Chifari, A.; Allegra, M.; Seta, L. ; Todaro, G. 2006. Metacognition in web-based learning activities, in Mittermeir, R. T. (Ed.). *Informatics Education – The Bridge between Using and Understanding Computers*, Springer, LNCS 4226, 290–298.

Cristea, A. I. 2004. What can the semantic web do for adaptive educational hypermedia? *Educational Technology & Society* 7(4): 40–58.

Deline, G.; Lin, F.; Wen, D.; Gasevic, D. 2007. Ontology-driven development of intelligent educational systems, in *IEEE Pacific Rim Conference on Communications, Computers and Signal Processing*, 34–37.

Dolog, P.; Henze, N.; Nejdl, W.; Sintek, M. 2004. Personalization in distributed e-learning environments, in *Proceedings of WWW2004 – The Thirteen International WWW Conference*, New York, 170–179.

Dzemydiene, D.; Tankeleviciene, L. 2006. Enhancing creation and delivery of educational resources by using ontologies, in Dagiene, V.; Mittermeir, R. (Eds.). *Proceedings of Second International Conference "Informatics in Secondary Schools: Evolution and Perspectives"*, Vilnius, Lithuania, 111–119.

Dzemydiene, D.; Tankeleviciene, L. 2008. Conceptual linking of educational resources based on reasoning over domain ontology, in Haav, H.-M; Kalja, A. (Eds.). *Proceedings of 8th Int. Baltic Conference on Databases and Information Systems*, Tallinn University of Technology Press, Tallinn, 241–252.

Dzemydiene, D.; Tankeleviciene, L.; Servetka, R. 2006. An approach of developing the component-based multi-layer knowledge management architecture for distance learning system, in Vasilecas, O. *et al.* (Eds.). *Databases and Information Systems, Proceedings of the Seventh International Baltic Conference on Databases and Information Systems, Communications, Materials of Doctoral Consortium*. Vilnius, Lithuania, 164–174.

Guizzardi, G. 2005. *Ontological foundations for structural conceptual models.* PhD with Cum Laude, Telematica Instituut Fundamental Research Series, vol. 015, Enschede, the Netherlands.

Guizzardi, G. 2007. On ontology, ontologies, conceptualizations, modeling languages, and (meta)models, in Vasilecas, O.; Edler, J., Caplinskas, A. (Eds.). *Frontiers in Artificial Intelligence and Applications, Databases and Information Systems IV*, IOS Press, Amsterdam.

Gaudioso, E.; Montero, M. 2005. Adaptable and adaptive web-based educational systems, in Ghaoui, C. (Ed.). *Encyclopedia of human computer interaction*, IGI Global, 8–11.

Hoek, K. 1999. Cognitive linguistics, in Wilson, R. A.; Keil, F. C. (Eds.). *MIT Encyclopedia of the Cognitive Sciences*, The MIT Press, Massachusetts Institute of Technology, London, 134–135.

IMS-LD: IMS Learning Design Information Model. Available from Internet: <*http://www.imsglobal.org/learningdesign /ldv1p0/imsld_infov1p0.html*>.

Kaklauskas, A.; Gulbinas, A.; Krutinis, M.; Naimavičienė, J.; Šatkauskas, G. 2007a. Methods for multivariant analysis of optional modules used in teaching process, *Technological and Economic Development of Economy* 13(3): 253–258.

Kaklauskas, A.; Zavadskas, E. K; Babenskas, E.; Seniut, M.; Vlasenko, A.; Plakys, V. 2007b. Intelligent library and tutoring system for Brita in the PuBs project. Luo, Y. (Ed.). CDVE 2007, *LNCS* 4674: 157–166.

Karampiperis, P.; Sampson, D. 2005. Adaptive learning resources sequencing in educational hypermedia systems, *Educational Technology & Society* 8(4): 128–147.

Lee, M.; Baylor, A. L. 2006. Designing metacognitive maps for web-based learning, *Educational Technology & Society* 9(1): 344–348.

Mockus, J. 2008. Investigation of examples of e-education environment for scientific collaboration and distance graduate studies, Part 1, *Informatica* 17(2): 259–278.

Muñoz, L. S.; Oliveira, J. P. M. 2004. Applying semantic web technologies to achieve personalization and reuse of content in educational adaptive hypermedia systems, in *Proceedings of the SWEL Workshop at Adaptive Hypermedia*, 348–353.

Paquette, G. 2004. *Instructional engineering in networked environments*. Pfeiffer, San Francisco.

Stojanovic, L.; Staab, S.; Studer, R. 2001. eLearning based on the semantic web, in *Proceedings WebNet2001 – World Conference on the WWW and Internet.*

Stukalina, Y. 2008. How to prepare students for productive and satisfying careers in the knowledge-based economy: creating a more efficient educational environment, *Technological and Economic Development of Economy* 14(2): 197–207.

Tankeleviciene, L.; Dzemydiene, D. 2009. Domain ontology-based support to navigation in distance study course structure, in Hele-Mai Haav; Ahto Kalja (Eds.). *Frontiers in Artificial Intelligence and Applications, Vol. 184, Databases and Information Systems V – Selected Papers from the Eighth International Baltic Conference*. IOS Press, 53–64.

Walton, C. D. 2007. *Agency and the semantic web*. Oxford University Press, Oxford, New York.

Zavadskas, E. K.; Kaklauskas, A.; Vlasenko, A. 2008. Web-based VSA analyzer decision support system for e-examination, Computational Intelligence in Decision and Control. Book Series: *World Scientific Proceedings Series on Computer Engineering and Information Science* 1: 1153–1158.

DAUGIASLUOKSNĖ, ŽINIOMIS GRINDŽIAMA ADAPTYVAUS NUOTOLINIO MOKYMO SISTEMOS ARCHITEKTŪRA

D. Dzemydienė, L. Tankelevičienė

Santrauka

Nuotolinių studijų kokybė daugiausia priklauso nuo kompetentingai parengtų mokomųjų priemonių ir veiksmingai veikiančios studijų paramos sistemos. Ieškant priemonių, kaip pagerinti nuotolinių studijų sistemos infrastruktūrą ir padidinti jos darbo efektyvumą, nagrinėjamos galimybės praplėsti tradicinės nuotolinio mokymo sistemos architektūrą komponentėmis, kurios leistų išplėtoti adaptuotą ir darnų mokymosi procesą. Šio tyrimo uždaviniai skirti paslaugoms, skirtoms išvystyti nuotolinio mokymo aplinką. Siekiant sukurti tinkamą kompiuterizuotą bendradarbiavimo aplinką, lanksčiai prisitaikoma prie kintančių vartotojo poreikių studijų procese. Architektūra projektuojama integruojant naujas komponentes bendravimo scenarijams generuoti, daugelio lygių dalykinės srities ontologijai naudoti ir sudarant sąlygas automatizuotam intelektinių agentų bendravimui. Straipsnyje nagrinėjamos galimybės integruoti dalykinės srities ontologiją į tradicinės nuotolinio mokymo sistemos aplinką. Ontologijos detalizavimo pagal studento supratimo lygmenis klausimai nagrinėjami siekiant pateikti koncepcinį tokios nuotolinės adaptuotos sistemos darbo modelį.

Reikšminiai žodžiai: nuotolinio mokymo aplinka, adaptuotas elektroninis mokymas, sprendimų priėmimo sistema, ontologija, intelektualūs agentai, žiniomis grindžiama architektūra.

Dalė DZEMYDIENĖ. Professor, Doctor, Head of the Department of Informatics and Software Systems of Social Informatics faculty of the Mykolas Romeris University (Lithuania). She holds a diploma with honour of applied mathematics in specialization of software engineering in 1980, Dr. in mathematics-informatics in 1995, Habilitation Doctor procedure in the field of social sciences of management and administration in 2004, and long time works at the Department of Software Engineering (the Institute of Mathematics and Informatics). She has published about 100 research articles, 3 manual books and one monography. An organizer of international conferences in the area of information systems and database development. A head of the Legal informatics section of Lithuanian Computer Society (LIKS), member of European Coordinating Committee for Artificial Intelligence (ECCAI) and member of Lithuanian Operation Research Association. Her research interests include: artificial intelligence methods, knowledge representation and decision support systems, evaluation of sustainable development processes.

Lina TANKELEVIČIENĖ. Doctoral student at the Software Development Department of the Institute of Mathematics and Informatics under the supervision of Prof. D. Dzemydienė; she works as lecturer at the Distance Learning Department of Šiauliai University. Her research interests include: knowledge representation methods, ontology description methodologies, distance learning systems.