Ontologies for eLearning

B.Polakowski and K.Amborski

Institute of Control and Industrial Electronics, Warsaw University of Technology.
Warsaw, Poland
e-mail: polakpl@yahoo.com, ambor@isep.pw.edu.pl

Abstract

Learning is one of these activities that differ from one person to another. However most of the eLearning systems do not include any mechanisms that could support pedagogical diversity. The individual aspects of the students and their needs are ignored what reflects in worse quality of learning. In this paper, we present the architecture and features of the present eLearning systems and show the newest trends in this field, directed on dynamic knowledge acquisition, and personalization of presentation. The key role in this solution is use of ontologies as methods for knowledge representation. We present how an ontology can be used in a learning environment in order to give the student the content that will fit his needs and support him during the learning process.

Keywords

Ontology, personalization, feedback, eLearning, LMS, Web 3.0

1. Introduction to Learning Management Systems

E-learning would not be so successful without some kind of platform that allows control over the whole learning process, its parts and participants. In the past the e-courses were scattered all over the Web or companies intranet (btw such solutions can still be found). The learners were let on their own what brought nothing except lost money. In most cases users were not interested in using these resources, because learners could not find them and tutors could not monitor learners' progress. The solution came with first learning platforms.

Learning management system (LMS) or a Virtual Learning Environment (VLE) is a "software system designed to help teachers by facilitating the management of educational courses for their students, especially by helping teachers and learners with course administration" (Wikipedia, 2008). In other words it's a computer program that facilitates a computerized learning by organizing, mapping and delivering content and managing different types of users (i.e. learners, instructors, administrators) and their interactions. It allows easy management of the learning materials and tracking of user's learning progress and results. LMS is typically a large system that includes many features such as: access control, personalized working spaces, assessment tools, searching facility, content creation tools, information distribution mechanisms (i.e. Calendar, News announcements), or communication and collaboration functions (i.e. email, chat, discussion forum) .

We can divide them into three groups depending on the type of user and functionality he is offered. (Culley, 2006)

Features available for all users:

- Authentication (including login, name and password)
- Individualized working place (home page) based on user's settings and preferences.
- Support (help pages and quick links)
- Authoring tools for different types of content
- Information tools (i.e. Calendar, News & Course announcements).
- Synchronous and asynchronous communication and collaboration functions (i.e. email, discussion boards, chats).

Features offered to the tutor:

- Users access control
- System management tools
- Ability to track student progress.
- Assessment tools.
- Student Assignment Management,
- Administrative applications.

Features offered to the student:

- Personalized access to learning resources
- Learning management tools.
- Online support (feedback from system or other users)
- Self assessment (i.e. online quizzes)

A generic LMS architecture is presented in Figure 1.

A common architecture is very simple and includes four main components. Web server (i.e. Apache) is the central component that stores content repository (course web pages) and the whole application layer including all mentioned before mechanisms such as authentication or communication tools. All data about users, system configuration, and information about available courses is stored in database (typically MySQL) in database layer. There is no need to install any special client software other than standard browser, because learning content can be provided in any web-deliverable format.

One of the most popular and the best Learning Management System - Moodle (Moodle, 2007) is based on such architecture. A study called "An Evaluation of Open Source E-Learning Platforms Stressing Adaptation Issues" found that Moodle outperforms all other platforms and also obtained the best rating in the adaptation category. It is a modular object-oriented dynamic learning environment which can be customized to any need with new ready or self written modules.

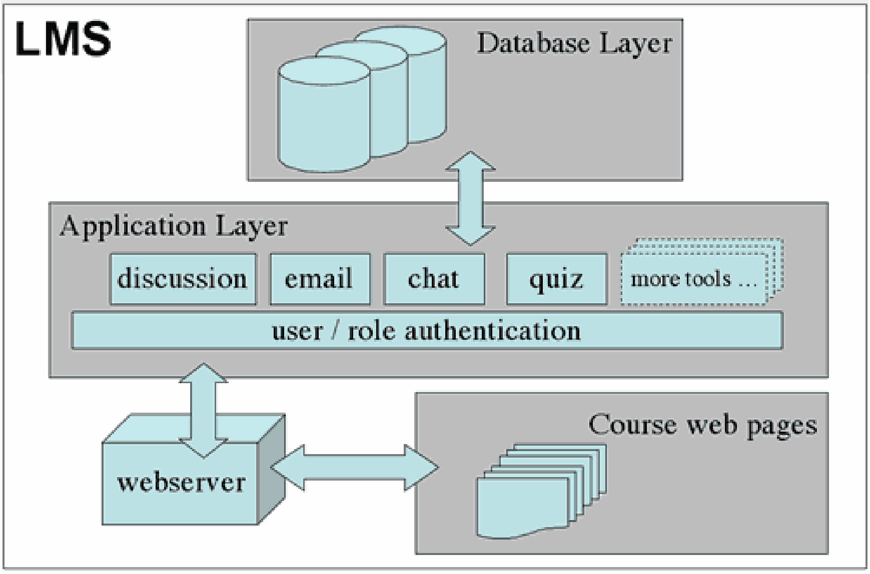

Figure 1: Generic LMS architecture (Wise, 2005)

In large companies LMS is often integrated with other large systems such as Content Management or Human Resources. All subsystems share an interface in a form of custom portal. Because of the large number of users there must be also LDAP Directory service. Figure 2 presents enterprise architecture with LMS included.

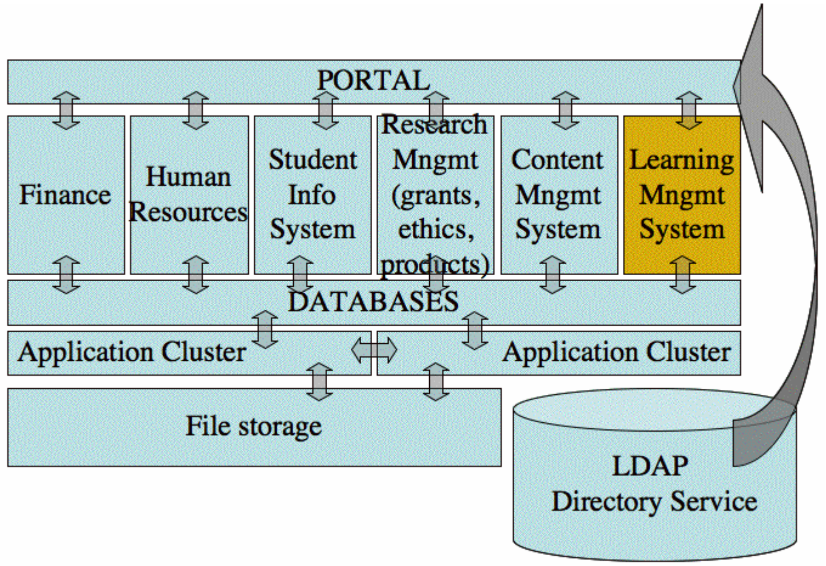

Figure 2: Enterprise architecture (Wise, 2005)

Such solutions have been already successfully implemented at thousands of universities and companies. However present learning management systems should follow the newest trends in information technologies and e-learning in order to offer more effective methods of learning. Web 2.0 brought more creativity, collaboration, and sharing possibilities to the users. Such things as blogs, wikis, podcasts, RSS feeds , and social software are to find in all professional LMSs. These technologies gave learners possibilities to become active participants in the learning process. They are no longer passive "receivers" of knowledge, but actively take part in their creation.

The time has come for another big step. The next generation of World Wide Web called Web 3.0 has already begun. Web 3.0 technologies, such as intelligent software that utilize semantic data, have been already implemented and used by multiple companies. It was caused by the growing interest to bring semantic web technologies to the general public. E-learning authoring tools vendors have already given possibilities to create metadata for content in order to allow it's recognition and reasoning in incoming Web (Reload, 2007). The e-learning systems are unprepared for such change so far. Present researches of key players in this field go in the direction of workflow and document management systems (DMS). However the progress of semantic Web technologies is unavoidable. On a few universities there are already trail versions of new e-learning systems. They exploit ontologies that in our opinion are the future of knowledge representation. These platforms offer a new feature to the user – personalization of content. With this functionality the learning process will become more similar to ideal one to one learning with teacher. Normally it is unprofitable or even impossible to accurately and instantly give the best feedback or learning materials to the user. Systems based on ontologies keep the profile of each user and thanks to the ontologies are able to find best fitting content.

2. Introduction to Ontologies

Ontology can be described as a formal description of knowledge from some domain. It can be understood as a whole knowledge used in a computer system or just as a class model of one domain. One of the most popular definitions of an ontology comes from (Gruber, 1993) and it says *"ontology is a description (like a formal specification of a program) of the concepts and relationships that can exist for an agent or a community of agents"*. He used the term ontology to mean a *"specification of a conceptualization"*. The weak points of this statement related to different understanding of the same words in different countries have been pointed out by (Bassara, 2004). However for our needs we will use the definition from Gruber.

The growing interest in the idea of the Semantic Web (Berners-Lee et al., 2001), reflects on ontologies which are seen as mechanism that will allow the interoperability of web resources. The research in this field brought a standard ontology language based on XML, Resource Description Language (RDF), RDF Schema (RDFS), and the Web Ontology Language (OWL). (Bechhofer et al., 2004)

The eLearning community discovered the great potential of ontologies and the Semantic Web (Sampson et al., 2004) (Lytras et al., 2003) and started researches that have an aim to make use this of this mechanism within eLearning. According to the work of (Stojanovic et al., 2001) we can distinguish three different dimensions in eLearning that can be described using ontologies: content, context which defines the way in which the content is presented and the structure of the learning material within a course. The most advanced researches have been made in direction of the first group what have resulted in such systems as Edutella which is a peer to peer network for searching semantic web metadata. (Edutella, 2007)

In our work we have concentrated on different approaches to use ontologies within eLearning environments. We have recognized main streams in this direction, described them and showed their implementation. The first one is personalization of content, which enables the system to respond differently according to the user characteristics, performance and current knowledge. The second is improvement of learning resources search, which will helps to get data from external repositories that is topically connected with our current activity and properties. Last but not least important topics are ontologies within architecture of feedback systems which provide support for both students during learning and teachers during authoring.

3. Using ontologies for content personalization

Personalization is a very important issue in the evolution of the modern eLearning systems. There are several learner types that require different kind (in different form i.e text, pictures and videos) of learning materials for more effective learning. (Bleimann, 2004) Every learner has different knowledge and competences. This forces eLearning systems to know the profile of each student, monitor his progress, and choose always content that will exactly fit his needs. An interesting approach to this problem was presented by (Gomes et al, 2005). It is based on a student model which defines all data about student and is built incrementally by the system using several data sources (i.e. student enrolment form, data from interaction with system, teacher). The collected data can be divided into two groups: static, which is an aggregation of student characteristics that are not changed during a learning process (i.e. name, qualifications), and dynamic which gathers information about the student's current performance in the course, and describes student's knowledge and competences relevant for the current course. The whole information is the basis for the personalization model. (Gomes et al, 2005) distinguish two models. The off-line model (Figure 3) allows content developers to change course content according to analysed data (using data mining tools) from student system interactions.

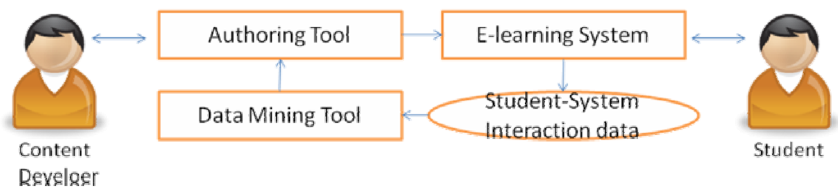

Figure 3: Architecture of off-line information model (Gomes et al, 2005)

The on-line model monitors interaction between student and system and tries to adapt the content according to the student model. The architecture of this solution is presented in Figure 4.

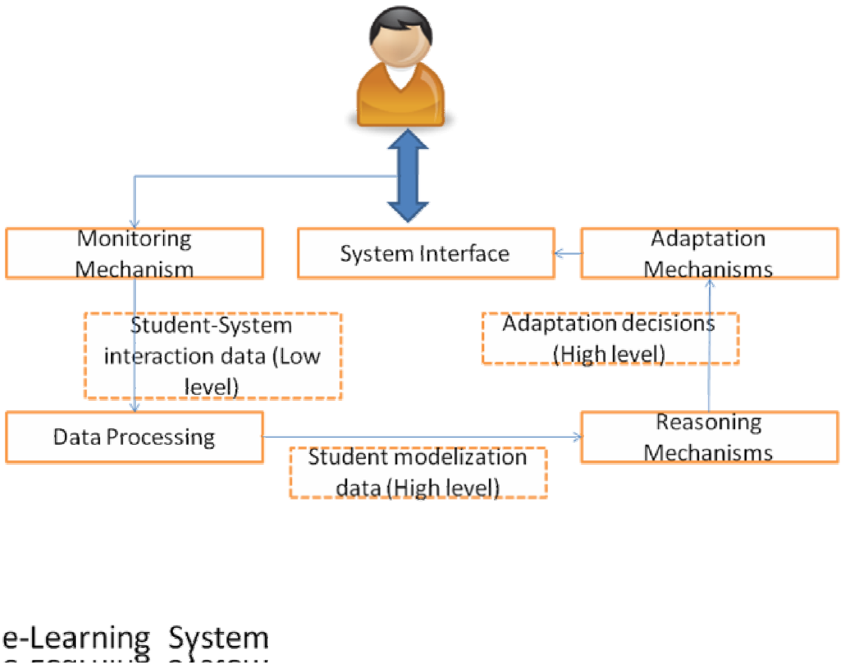

Figure 4: Architecture of on-line information model (Gomes et al, 2005)

To decide what content should be presented to the student, there must be a reference between the dynamic model and course concepts organized in an ontology. The ontology represents the domain knowledge and is the formalization of its concepts. In (Gomes et al, 2005) model, the taxonomic structure is built from classes which represent the concepts and generalization relations between them. With some course modules, objectives and interactions there are associated concepts. The system can trace their status during the session and so determine the student's knowledge. It allows computing the learning progress of a student. Each concept in the ontology has associated parameters and an associated state. The parameters define the number of correct and wrong answers as well as the number of completed SCOs by the student. The state is based on these parameters, and it stores information if and how good the concept was learned. The data about student is updated in the domain ontology which enables to trace his knowledge and progress at any time.

4. Ontology based feedback generation

Feedback can be described as a process that have an aim to inform a user (in our case a student) about the accuracy of his response to some instructions. It can inform not only about answers correctness but also about precision, timeliness, learning guidance, motivational messages, background materials, learning focus and others (Mory 2003). Feedback is a crucial element in every user oriented system. In the eLearning environments it is particularly important because it is one of the main issues that defines the quality of learning. In the current generation of eLearning systems, feedback is often reduced to the email communication with a tutor, which is very time consuming and ineffective, or to automatically produced, hard coded support, which is often invaluable. There is one exception in environments based on social constructivism where learners and teachers solve problems through social negotiations (Duffy, 1996). Semantically rich feedback can be only found in a specialized design environment.

There are already eLearning systems that are based on ontologies (Aroyo, 2002 (1) (2)), (Jin, 1999). The eLearning community carries out researches in order to develop a mechanism, based on ontologies which would supply valuable feedback both during the learning process and authoring phase. It has to be generic, domain and task independent and produce semantically rich feedback. Such an approach was presented by (Passier et al, 2003). They developed a feedback mechanism where ontologies are used as arguments of the feedback engine and mechanism which enables the authors to define a domain or task specific feedback. Both things can be reused for different ontologies what saves a lot of time and developers work. Such a system gives student a possibility for example to compare the completeness and correctness of his solution with education ontology, which describes the learning task and was created by the author. The learner can be asked to list some concepts and their relations or choose and relate concrete instantiations. On the other hand an author can analyse the domain ontology and get feedback about the concepts. For example some of them can be used but never defined or they can be used before their definition. Such system must by ready to solve problems with synonyms or homonyms between concepts.

The system that delivers such generic feedback mechanism (see Figure 3) naturally contains several types of knowledge which is represented using ontologies (Passier et al, 2003).

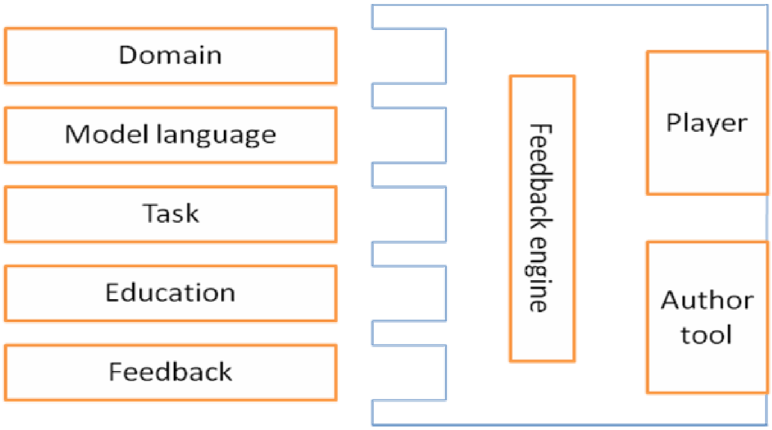

Figure 5: Architecture of an eLearning system with generic feedback generation (Passier et al, 2003)

The main architecture contains three main components: a player where the learner can learn concepts, construct artefacts and solve problems, an authoring tool where an author can develop courses and course related materials (i.e. ontologies, examples, feedback patterns) and a feedback engine, which uses ontologies as parameters and automatically generates feedback. It can be generic, that means independent of ontologies (applicable to all design activities) or specific, which is defined by the author and can be task, domain or, course specific.

To construct feedback the presented engine needs five ontologies as arguments, which can be freely exchanged (Passier et al, 2003).

5. Ontology for improving learning resource search

The common problem in the development of distributed eLearning environments is a lack of the interoperability between the systems that are based on different ontologies. One of the main issues is connected with the learning materials. Since a few years there are special digital libraries (i.e ACM Portal) and community-based learning repositories (i.e. Merlot) that allow the exchange of such materials. However, researches showed that authors have difficulty of making annotations of their learning material using subject taxonomies (Greenberg et al., 2002). This results in lower effectiveness of searching across multiple object collections. The resources are not interconnected into the Web, so there is no context where they can be defined.

The main aim of current research is to develop a mechanism that will allow users to find resources that are most relevant in their current learning context.

The solution looks simple. There are already web based courses whose structure can be considered as ontology.

The learning resources that form them are directly related to their structure and annotated with the course ontology. (Gaševic et. al, 2005) proposed a course structure that is similar to the SCORM standard. On the left hand side of the screen user sees a structure of the course and on the right hand side the appropriate content. The bottom part contains a search mechanism that allows context sensitive search for the ACM Digital Library (ACM DL, 2005). What makes this solution different from traditional text search engines is that the search request is collected together with annotation of the current page within the course ontology. Than it is sent to the ontology mapping system, which maps the course ontology to the ACM CCS (classification in the domain of computer science) ontology and sends an expended query to ACM DL. (Gaševic et. al, 2005) pointed out two areas in the context of their work that need further research.

The first thing is annotation of learning objects with Domain Ontologies. The ontological levels of learning object and domain ontologies are different so the learning object metadata which is an instance of learning object metadata schema is enriched with keywords defined in the ontology (Figure 4). In the schema there are keywords that are defined as classes. If we refer to them, we annotate the metadata (i.e. metadata instances) with ontology classes (i.e. schema). Using classes as concepts complicates reasoning, but there is a solution in a form of specialized ontologies for defining domain taxonomies with a rich set of properties for defining concept hierarchies. Another issue is mapping between multiple domain ontologies.

There are many ontology mapping techniques. (Gaševic et. al, 2005) system uses a mapping ontology that expresses relations between two ontologies. (Figure 5)

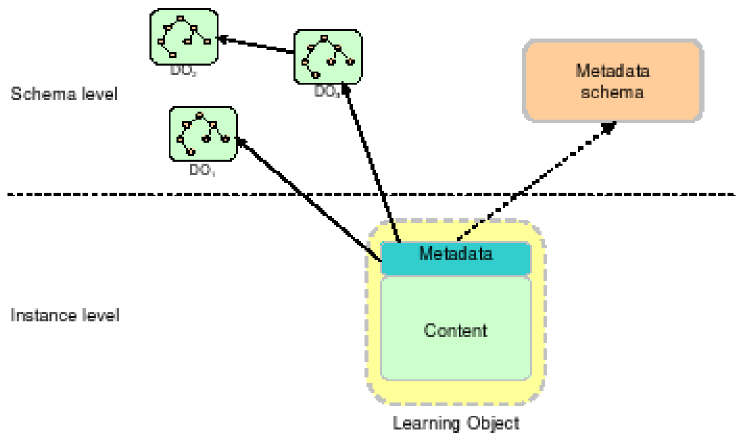

Figure 6: Ontological levels of learning object and domain ontology (Passier et al, 2003)

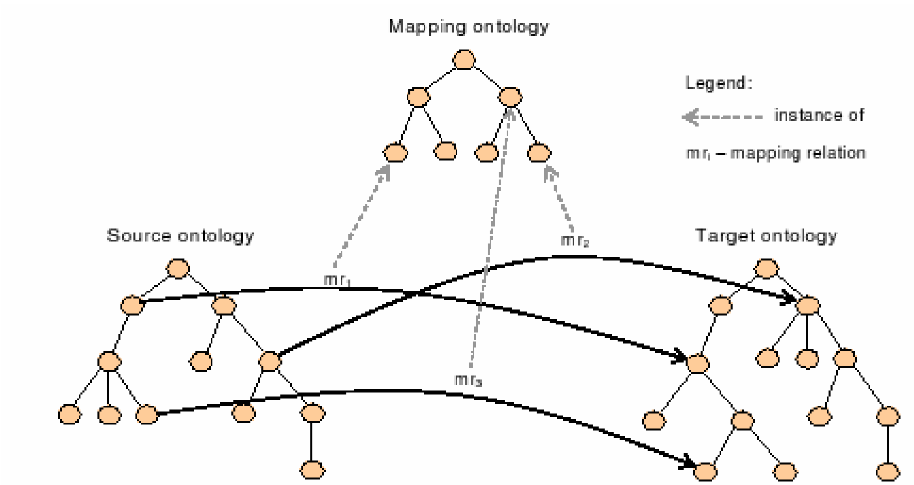

Figure 7: Mapping ontology (Gaševic et. al, 2005)

The two problems mentioned above can be solved using currently developed Simple Knowledge Organization System (SKOS) (Miles and Brickley, 2005). It allows defining different types of ontologies (i.e. taxonomy, thesaurus) and mapping of concepts from different domain ontologies, using special RDF vocabularies. These vocabularies provide a model for expressing the basic structure and content of concept schemas, and describing mappings between concept schemes. The mappings specify the mapping relations between concepts using set of properties like broadMatch, narrowMatch, ExactMatch etc. which reflect weight of mapping. This facilitates the later ranking of search results. In the case of (Gaševic et. al, 2005), the defined mappings enabled the user to improve searching in the remote ACM DL, using local context in the form of course ontology. What is more, not all mappings have to be defined, because a special algorithm allows extrapolation of missing mappings using the structure of both ontologies. It takes concepts of the source ontology as input arguments and concepts of the target ontology as the results of the mapping algorithms. Than SKOS Mappings are used to define mapping relations between concepts from both ontologies. The search results are ranked according to different types of SKOS Mappings properties. The algorithm uses also all the "children" (sub-nodes) of matched concepts in the target ontology. The weight factor is used to determine ranks of matched concepts and their children in the results. It is calculated according to the type of mapping relation connecting the matched concept with the source ontology concepts. The researches showed that the use of ontologies reduces the number of found objects during the search activities, what helped learners to find resources that better fit their current learning activities (Gaševic et. al, 2005).

6. Conclusion

This paper presents the advantages of ontology based mechanism within modern eLearning systems. We have presented three main directions in current researches in this area and give concrete examples of implementation.

The main aspect of our work was to provide the reader with the idea about the current state of eLearning technologies and to show further research area.

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