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Learning Ontology Design for Supporting Adaptive Learning in e-Learning Environment

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Abstract. Ontology has an important role in conceptualizing knowledge of multiple phases, e.g. curriculum, syllabus, texts, in e-Learning environment. Our e-learning project aims to make of creation, integration and interfacing of multiple ontologies on different layers, i.e. *Curriculum ontology*, *Syllabus ontology*, and *Subject ontology*. The primary objective is to develop ontology-based e-learning support system which allows learners to build adaptive learning paths according to understanding curriculum, syllabuses, and subjects of courses deeply. In this paper, we introduce our ontology model and propose an effective method for enhancing learning effect of students through construction of subject ontology. The subject ontology of a certain course is composed of an ontology made by a teacher and many ontologies made by students.

Keywords: e-learning, ontology, learning path, curriculum, syllabus

1. Introduction

Until now, many previous researches performed in order to apply Semantic Web technologies including ontology engineering to intelligent e-learning system development[10]. The researches applying ontology technology to education field are classified into curriculum or syllabus ontology creation[2,3], ontology-based learning object organization, and ontology-based learning contents retrieval. The studies for education ontology creation include curriculum ontology creation[9] and personal subject ontology creation[1].

ACM Computing Curricula 2005(CC2005) is representative of curriculum ontology research. CC2005 defines the standard curricula of computer science undergraduate course to be referred to other computer-related educational institutions or universities. CC2005 classifies curricula of computer science into introductory course, intermediate course and advanced course. In addition, CC2005 defines computer-related knowledge as 14 areas, 132 units and 950 topics.

Personal learning ontology conceptualizes and organizes knowledge of learned by a person. A person can extend, modify, or retrieve his/her learning ontology using an ontology management system. In this paper, we propose an extended version of person learning ontology to include teachers and students in classes. The goal of our learning ontology is improvement of learning outcomes of students, active communication among teachers and students and self-initiative learning of students.

Mizoguchi[5,6] proposed a ontology-based solution to solve several problems caused by intelligent instructional systems. Another works defined metadata of learning objects and learning path including curriculum based on ontology engineering technology[4,7]. These works concentrated on management of learning objects and materials and performance enhancement of instructional systems. Ontology technology, however, can be used to make the knowledge structure, which improves the interaction among teachers and students and enables spontaneous learning of students, of teaching contents and learning materials of students based on semantic information[8].

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Our e-learning project aims to make of creation, integration and interfacing of multiple ontologies on different layers, i.e. *Curriculum ontology*, *Syllabus ontology*, and *Subject ontology*. The primary objective of our project is to develop ontology-based e-learning support system which allows learners to build adaptive learning paths through understanding curriculum, syllabuses, and subjects of courses deeply. In this paper, we introduce our ontology model and propose an effective method for enhancing learning effect of students through constructing learner-based ontologies in which knowledge discovered by students is conceptualized and organized. Learner-based ontologies can be merged into teacher-based ontologies which conceptualize teaching contents in classes. Thus, our subject ontology is composed of teacher-based ontologies and learner-based ontologies. Teachers and students share and understand knowledge of learning materials based on learning ontologies.

2. System Architecture

Our system is composed of several components in order to support semantic-based syllabus and subjects search and adaptive outcome-based learning path creation. Figure 1 shows the architecture of our system conceptually in which these core components are represented. The core components are designed to provide the following functionalities.

- Understanding the user's request and invocation of appropriate handlers.
- Translating the user's query formed as a list of keywords or template into *SPARQL* or *TMQL*.
- Creating instances of ontologies through collecting, parsing, and classifying resources, i.e. syllabus webpages, course description webpages, and so on.
- Identifying and managing learning outcomes in terms of individual courses and academic areas.
- Semi-automatic creating adaptive learning paths according to user's learning purposes.

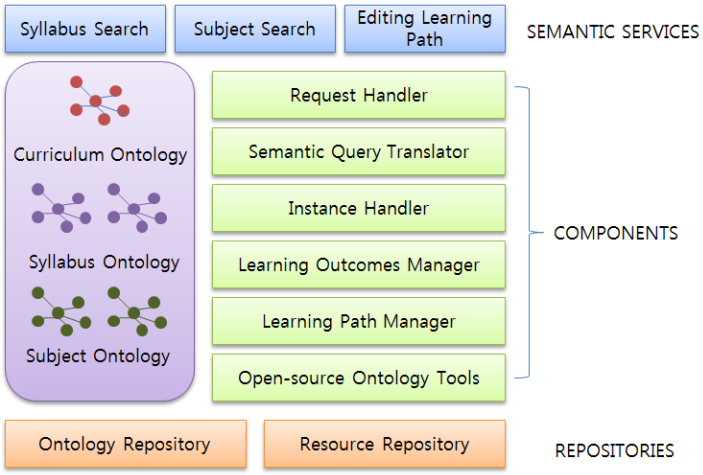

Fig. 1: The System Architecture of our ontology-based learning support system.

In our view, a curriculum can be recognized as a set of courses and a syllabus, which is part of the curriculum and a skeleton of a course, can be represented as a collection of different resources related to a certain course. We design the curriculum ontology in order to organize various semantic relationships, which include *hasSubtype*, *prerequisiteOf*, *basicOf*, *advancedOf*, *combinedOf*, and so on, between individual courses in the Computer Science or Engineering field. Curriculum ontology conceptualizes the knowledge of curricula concepts, i.e. *ProgramOfStudy*, *Course*, *KeyConcept*, *AttainmentGoal*, *AttainmentLevel*, and establishes direct connections with one or more syllabus ontologies.

Syllabus ontology conceptualizes the internal and external structures of courses identified in curriculum ontology. Our syllabus ontology defines the unified vocabulary of syllabus to help compromise the different vocabularies used by different instructors. A *syllabus* class, which is the core concept of syllabus ontology, has 9 data type properties, i.e. *titleOfCourse*, *description*, *gradingPolicy*, *goalOfCourse*, and 12 object type properties, i.e. *oldVersionOf*, *hasInstructor*, *hasMaterial*, *hasSchedule*, *hasLectureRoom*, to describe semantic knowledge extracted from traditional syllabuses.

Figure 2 shows the relationships between syllabus ontology and each of other ontologies, top-level ontology, curriculum ontology, and subject ontology. Syllabus ontology has one or more subject ontologies because a conventional syllabus represents multiple concepts taught during a school semester. The *subject* class is top level concept in subject ontology. The subject class has responsibilities to collect lower level topics and link to syllabus ontology. Following section 3 and 4 describe the structure of subject ontology and a case study for evaluating of the usefulness of subject ontology.

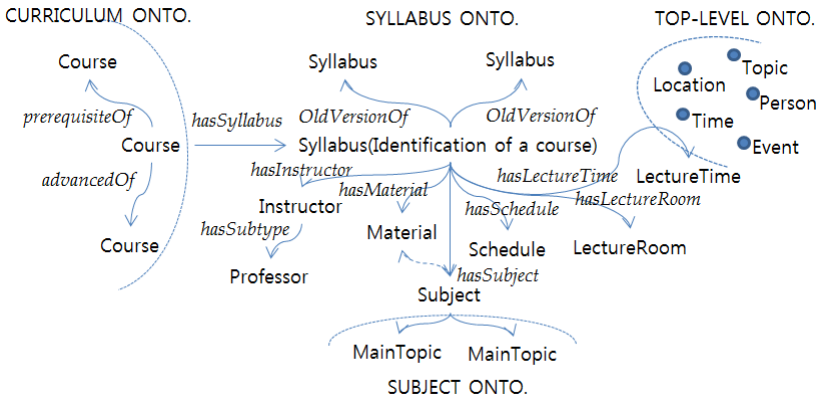

Fig. 2: The Relationship among Top-level ontology, Curriculum ontology, Syllabus ontology, and Subject Ontology.

3. Subject Ontology Model

The hierarchical structure of subject ontology is depicted in figure 3. Subject ontology is composed of one or more of teacher-based ontology, several learner-based ontologies and learning materials. Teacher-based ontology contains learning concepts and knowledge structure to teach in a class. Learner-based ontology contains concepts and knowledge structure created by students.

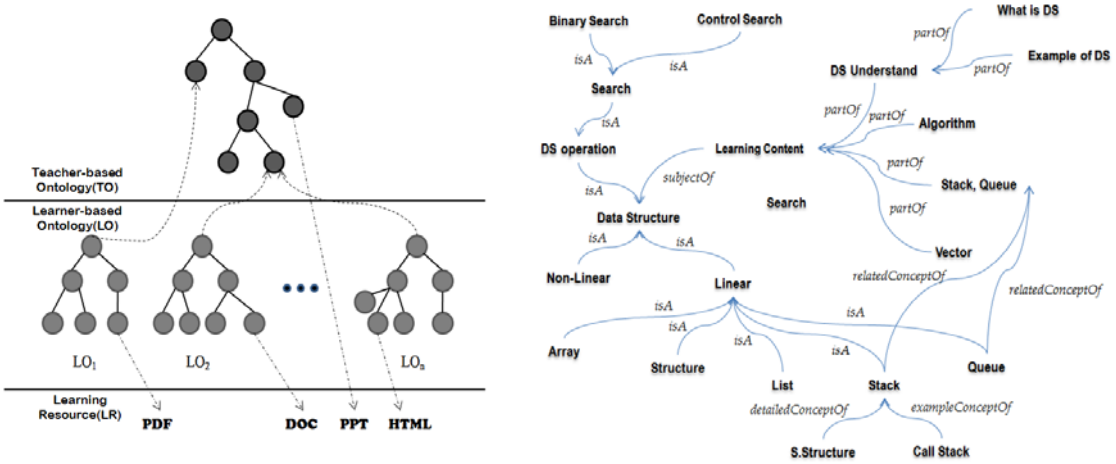

Fig. 3: The Structure of Subject Ontology(left) and an example of subject ontology describing 'Data Structure'(right).

Subject ontology is described as following 5-tuples, $<C, P, I, R_H, R_C>$. The symbol C, P, I, R_H and R_C represent *class*, *property*, *instance*, *hierarchy* relation between classes and *association* between classes individually. We explain the structure of teacher-based ontology and learner-based ontology based on above 5-tuples in following some paragraphs.

Entities of teacher-based ontology are classified into following 3 categories:

1) Learning Concept – Main topics will be described in a class for a semester. This category includes fundamental concepts, advanced concepts, related concepts, examples and exercises.
2) Learning Structure – Learning concepts organized as a semantic network to describe knowledge structure of topics. In addition, learning path and schedule represented in syllabus added to the learning structure.

3) Learning Material – Teacher collects useful resources like web pages, images, audios, and videos and creates lecture notes using the resources. These lecture notes have connections to relevant concepts.

4. Experiment

We applied our method to a certain class, *Understanding Data Structure*, to evaluate the effectiveness of subject ontology-based education in spring semester, 2011. We collect and analyze two kinds of experimental data like feedbacks from students and test data such as midterm exam, final exam, quiz, homework, and so on. Feedbacks of students are acquired by the interview with students. Table 2 shows the result of feedbacks of students.

Table 2. The feedback from students about subject ontology-based education

Question	①	②	③	④	⑤
1) Students have good understanding of ontology-related technologies.	●				
2) Student can extract meaningful concepts from learning materials, essays created by themselves, or textbooks.		●			
3) Students can define new concepts in learning ontologies.		●			
4) Students can relate new concepts with other existing concepts based on semantic relation types.			●		
5) Students identify and describe competency questions easily.			●		
6) Students familiar with discussion and presentation based on subject ontology.	●				
7) Students can understand the meaning of concepts defined by other students.		●			
8) Students can understand the knowledge structure of subject ontology.		●			
9) Learning ontologies are useful for representing and sharing of knowledge owned by students.		●			
10) Student can connect between multiple concepts according to their semantic correspondences and relatedness.	●				

In table 1, numbers like ①, ②, ③, ④, and ⑤ represent the level of agreement. ① means extremely agreement but ⑤ means extremely disagreement. 5 questions from 1) to 5) survey the feedbacks from students about the difficulties in creating learning ontologies. The other 5 questions from 6) to 10) survey the effectives of learning ontologies during presentation and discussion of learning knowledge in classes. From analysis of the feedbacks of students we know that students understand the fundamental concept of ontologies and the way of applying ontologies to learning. However, creating of subject ontology is somewhat difficult work but it is useful to present, discuss, and share of studied subjects of students.

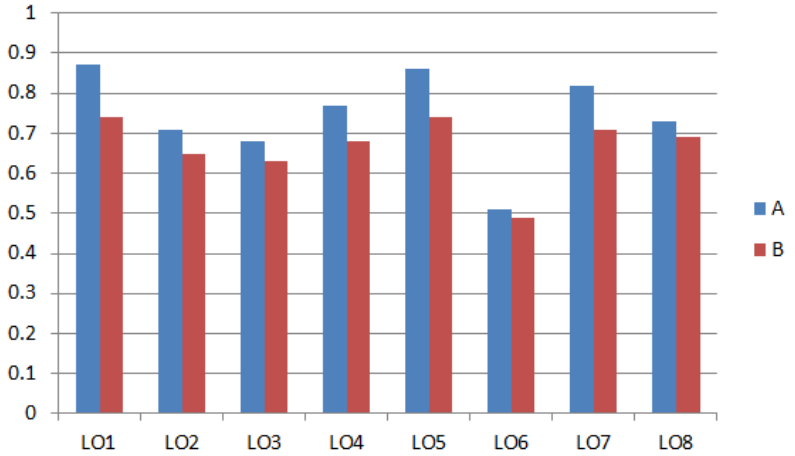

Fig. 4: Learning outcomes before and after applying subject ontology to class.

The graph depicted in figure 4 shows the values of learning outcomes before(*symbol B*) and after(*symbol A*) applying learning ontologies to class. We compute the values of learning outcomes of students through evaluating of quiz, exams, homework, and so on. We define learning outcomes as follows:

LO1 – Understand fundamental concepts of learning subjects
LO2 – Understand semantic relationship between concepts of learning subjects
LO3 – Problem understanding and solving ability
LO4 – Knowledge structure identifying ability
LO5 – Knowledge representing and sharing ability
LO6 – Critical thinking ability
LO7 – Semantic Representation ability
LO8 – Discussion and presentation ability

5. Conclusion

In this paper, we introduce our ontology model and propose an effective method for enhancing learning effect of students through constructing learner-based ontologies in which knowledge discovered by students is conceptualized and organized. Our method includes creation of subject ontology, discovery and sharing of knowledge based on subject ontology. The subject ontology is composed of teacher-based ontologies and learner-based ontologies.

We applied our method to a certain class, Understanding Data Structure, to evaluate the effectiveness of subject ontology-based education. We found that subject ontology-based teaching and learning enhances the learning outcomes of students through interviewing from students, defining specific outcomes, and comparing outcomes of students before and after applying subject ontology to the class.

6. Acknowledgements

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