Design of Structured Syllabus and Subject Ontology for Adaptive Learning

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Abstract - *In this paper, we introduce our e-learning project that 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 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. It is used in discussion, visual presentation, and knowledge sharing between instructor and students. We used the subject ontology in two lectures in practice and found that the subject ontology enhances learning effect of students in according to the analysis of feedbacks of students.*

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

1 Introduction

Until now, ontology engineering has been applied in order to conceptualize knowledge of many different domains including education. Recently, lots of researches performed in order to apply Semantic Web technologies including ontology engineering to intelligent e-learning system development[1]. 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[4] and personal subject ontology creation[5].

Mizoguchi[6],[7] 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[8],[9]. 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[10].

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.

This paper is structured as follows. Section 2 provides an overview of the layered structure of our learning ontologies. Section 3 represents the revised syllabus structure for supporting adaptive learning of students. We describe the hierarchical structure of subject ontology in Section 4. Section 5 shows the experimental result and in the end the paper presents our conclusion in Section 6.

2 The structure of learning ontologies

Commonly, a curriculum can be represented as a set of description of courses and syllabuses. A syllabus, which is identification and skeleton of a course, can be represented as a collection of several kinds of 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, existing between individual. The curriculum ontology conceptualizes the knowledge of curricula concepts, i.e. *ProgramOfStudy*, *Course*, *KeyConcept*, *AttainmentGoal*, *AttainmentLevel*, and includes the direct semantic connections between courses and their syllabus ontologies.

The syllabus ontology conceptualizes the internal and external structures of syllabuses. 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 the contents and relationships extracted from traditional textual syllabus templates.

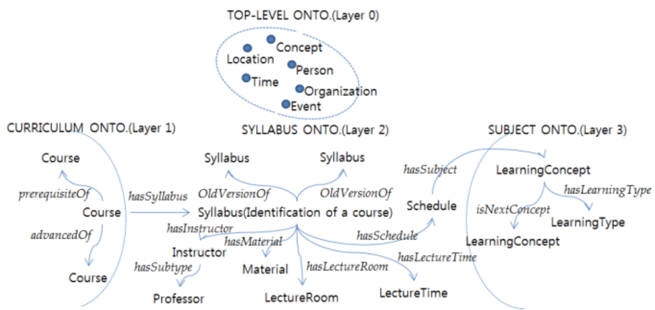

Figure 1. The layered structure of Top-level ontology, Curriculum ontology, Syllabus ontology, and Subject Ontology.

Figure 1 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 to be taught during a school semester. The *LearningConcept* class is top level concept in the subject ontology. The *LearningConcept* class has responsibilities to collect lower level topics and link to syllabus ontology. Following section 3 and 4 describe the detailed structure of the syllabus ontology and subject ontology.

3 Syllabus conceptualization

Adaptive learning path generation refers to the organization of learning objects in a proper order so that students can effectively study a subject area. In a learning graph a node denotes a learning object or learning element. However, effective assessment for learning activities of students is required in order to support adaptive learning of students. In other words, a node in a learning graph should be composed of lectures, learning goals, learning activities and assessment.

Thus, we have considered a syllabus as a node in a learning graph because it includes course description, learning goals, lectures, activities, and learning materials also. Figure 2 shows the syllabus-based learning graph in which learning graphs can be generated in two levels, i.e. course-level and concept-level. In this chapter, we define systematic models of learning goal, learning activity and assessment of a syllabus based on Bloom's taxonomy[11] which classifies behaviors of students to six cognitive levels of complexity. Table 1 shows cognitive, attitude, and skill domains of Bloom's taxonomy.

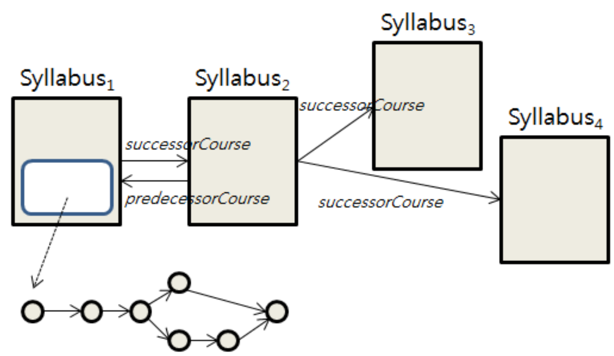

Figure. 2. The syllabus-based learning graph.

Table 1. Bloom's taxonomy

Levels	Cognitive	Attitude	Skill
1	Knowledge	Receiving	Imitation
2	Comprehension	Responding	Manipulation
3	Application	Valuing	Precision
4	Analysis	Organizing	Articulation
5	Synthesis	Characterizing	Naturalization
6	Evaluation		

Definition 1. Learning goal can be defined as a set of tuples in which each tuple is consisting of four items, learning goal, cognitive level, attitude level, and skill level.

$$\{< goal_p, C_i, A_j, S_k >\}, 1 \le p \le n, 1 \le i \le 6, 0 \le j \le 5, 0 \le k \le 5 \quad (1)$$

In expression (1), $goal_p$, C_i, A_j, and S_k denotes p-th learning goal, i-th cognitive complexity level, j-th attitude complexity level, and k-th skill complexity level respectively. For example, a teacher define a learning goal like as <"Understanding class inheritance in JAVA", C_3, A_3, S_2>.

Definition 2. Learning activity can be defined as a set of tuples in which each tuple is consisting of four items, learning activity, cognitive level, attitude level, and skill level. The types of learning activity performed by students defined as a set like as following expression (2).

$$LA=\{\text{READING}, \text{ESSAY}, \text{PRESENTATION}, \text{DISCUSSION}, \text{PRACTICE}, \text{EXERCISE}, \text{HOMEWORK}, \text{TEAM PROJECT}\} \quad (2)$$

$$\{< LA_p, C_i, A_j, S_k >\}, 1 \le p \le 9, 1 \le i \le 6, 0 \le j \le 5, 0 \le k \le 5 \quad (3)$$

In expression (3), LA_p denotes one of elements in a learning activity set. One or more learning activities should be mentioned in every week of lecture schedule in a syllabus.

Definition 3. Learning assessment can be defined with making connection to one or more learning goals.

$$\{\langle QE_p, goal_i \rangle\}, 1 \le p \le n, 1 \le i \le m \quad (4)$$

In expression (4), QE_p denotes one of activities for learning assessment, such as exercise, assignment, quiz, and exam. The connection between assessment and learning goals enables teachers estimate outcomes of students more precisely.

4 The structure of subject ontology

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 be studied in a class. Learner-based ontology contains concepts and knowledge structure created by students. When a teacher presents learning subjects, students investigate the subjects and extract meaningful concepts and knowledge structure to create a new learner-based ontology or extend existing learner-based ontology during their learning process.

Table 2. Classes, properties and relations defined in teacher-based ontology

Type	Name	Description
CLASS	LearningConcept	Root class
	FundamentalConcept	Conceptualization of fundamental topics of learning subjects
	AdvancedConcept	Conceptualization of advanced topics of learning subjects
	RelatedConcept	Conceptualization of additional topics of learning subjects
PROPERTY	Name	Concept name
	AuxiliaryName	Auxiliary name of concept name
	Definition	Definition of concept
	Description	Description of concept
RELATION	Fundamental-Concept-Of	A is fundamental class of B Reversed relation is Has-Fundamental-Concept
	Advanced-Concept-Of	A is advanced class of B
	Related-Concept-Of	A is related concept with B Reversed relation is Has-Related-Concept
	Example-Of	A is example class of B Reversed relation is Has-Example
	Exercise-Of	A is exercise class of B Reversed relation is Has-Exercise
	Same-Concept	Both concepts have same semantic

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. Table 2 represents classes, properties, and relations defined in subject ontology.

5 Experiments

We applied our method to classes, Understanding Data Structure and Java Programming, to evaluate the effectiveness of learning ontology-based education. 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. 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. The graph depicted in figure 3 shows the values of learning outcomes, which are understanding concepts(LO01), organizing relations(LO02), and so on, before and after applying learning ontologies to class. We compute the values of learning outcomes of students through evaluating of quiz, exams, homework, and so on.

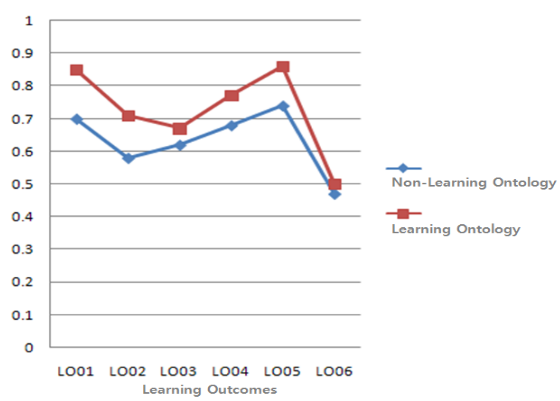

Figure 3. Learning outcomes before and after applying subject ontology to class.

Another experiment evaluates the retrieval performance of elements from syllabuses before and after transformation to our proposed syllabus template in section 3. Syllabus transformation and retrieval have been performed on 45 syllabuses of computer engineering field collected from the Web. As the result of our retrieval experiments, we know that precision, recall and f-measure averaged for 10 test sets is

0.78, 0.87 and 0.82 respectively. In addition, we know that our syllabus model is well structured and conceptualized than current syllabus formats from the result depicted in figure 4.

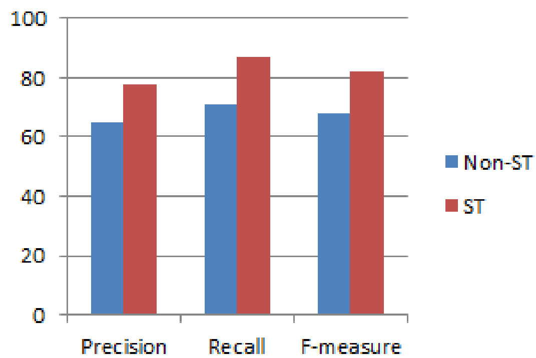

Figure 4. Comparison of retrieval performance between ST and Non-ST.

6 Conclusions

In this paper, we proposed the integrated and layered structure of learning ontologies for offline and online learning domains. Our ontology model's main entity is a syllabus because it is identification, definition, and contents of a course truly. We have designed curriculum ontology and subject ontology to be connected into syllabus ontology for supporting adaptive learning and knowledge sharing of students. In addition, our ontology model can be used as a knowledge base in intelligent e-learning management systems. Our future work will be adaptive learning path generation and recommendation based on the proposed learning ontology.

7 Acknowledgements

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