Domain Ontology for Personalized E-Learning Environment

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Abstract: The purpose of this paper is to describe domain ontology that provides an adaptive learning environment to facilitate sharing and reusing of learning materials. Proposed domain ontology has been realized to describe three adaptation processes that are presented in the learning environment: (1) Course based adaptation, to present a selected course content due to link adaptation techniques. (2) Concept based adaptation, to present a specific knowledge for a selected concept of the course. (3) Goal based adaptation, to present a part of a course such as a lesson due to a selected learning goal. In addition to this, we have considered to realize separately reusability of the learning content and also reusability of digital learning materials in the learning environment. In proposed domain ontology, the domain model structure has been adopted from AHAM Reference Model. Also, learning content structure has been considered due CISCO RLO approach. ADL SCORM v1.3 Application Profile has been selected to describe metadata of the digital learning materials. The ontology has been developed under OWL that is ontology language for Semantic Web applications. Protégé 2000 is an ontology development environment has been used to construct the domain ontology. Protégé 2000 OWL tool is main development tool for this ontology.

Keywords: Personalized E-Learning, Learning Objects, Instructional Ontology, OWL.

Introduction

Personalized E-Learning is an application area of AI-Education researches. It is a new direction for Intelligent Tutoring Systems (ITS) and Adaptive Hypermedia Systems (AHS) researches (Mizoguchi & Bourdeau, 2000). Basic goal of a personalized e-learning is to improve instructional planning practices for presentation of learning objects (LOs) by using course sequencing technique of ITS and adaptation techniques of AHS (Hatzilygeroudis et al at all 2005). LOs are web-deliverable digital sources that are used in e-learning environment. The LO is one of the main research topics in the e-learning. Especially, researchers pay attention the reusability and granularity issues of LOs and instructional quality of LOs. In order to address these issues, some researchers advocate the idea that ontology can be used to describe learning objects and also to describe learning domains. In recent years, researchers work to integrate between instructional design theories, LOs and e-learning environments by using ontological design approaches (Mohan at all 2003).
Development of educational ontology is a step towards creation of shared and reusable adaptive educational systems. Educational ontology is a conceptual courseware structure for constitute effective teaching and a visual navigation interface for the LOs (Sosnovsky & Gavrilova, 2006).

In this paper, we will discuss how to build a domain ontology that is based on LOs that have different granularity and instructional characteristics, to constitute a personalized learning environment.

**Related Works**

The proposed domain ontology is a framework for learning and instructional design from the viewpoint of ontological engineering and Semantic Web. The domain ontology has been developed under OWL language. OWL is the standard language that is proposed by the W3C, to represent ontology in the Web. In addition, an ontology development environment that is Protégé 2000 (v3.3.1 Build 430) has been used. Protégé 2000 OWL tool is main development tool for this work. In addition, Pellet 1.5 (Sirin et al) has been used for consistency checking and classifying of the proposed ontology.

AHAM Reference Model (Wu et al, 2001) was used for conceptual infrastructure of the domain model for the proposed ontology. However, domain model structure in AHAM has strong limitations for describing concepts and relationships between them. To overcome these limitations of AHAM, ontology based conceptualization of the concepts can be a solution (Madhour & Forte, 2006). Therefore, in this work, each concept and relationships between concepts in the domain model was defined through a series of arguments that were grouped to constitute presentation chain of a learning content. The learning content that is a LO, can be constituted providing specific knowledge about a concept or a course structure of a knowledge domain. In proposed ontology, a learning content has been constituted according to instruction oriented knowledge representation that is Cisco Reusable Learning Object (RLO) Approach (Cisco, 2003) which is implemented in an e-learning system. So, a course has been divided into modules and lessons and each lesson has its self content such as topic that have been described due to Cisco RLO guideline in the ontology. Advanced Distributed Learning Shareable Content Object Reference Model (ADL SCORM) v1.3 Application Profile (ADL, 2002) has been chosen to describe metadata of the digital learning materials that are used to form learning contents. In addition, SCORM metadata profile has been used for some properties of the leaning content.

**Definition of the Proposed Domain Ontology**

Ontology uses a representation vocabulary that is a collection of facts about domain to represent the knowledge of the domain (Oguejiofor, et al, 2004). Ontology typically consists of a hierarchical arrangement of the classes and subclasses. In addition, description of the features and attributes of these classes are specified as well as the relevant restrictions. Also, a knowledge base that is the addition of individuals, can be developed in the ontology.
The domain ontology has been considered to use for any knowledge domain. We have been tried to develop general educational ontology that can be used different knowledge domain and for different adaptation expectation for personalized e-learning. The proposed domain ontology has been realized to perform of the adaptation processes. Adaptation processes are course based, concept based and goal based. These processes organized for three goals. Firstly; the learner can select a course and the system presents learning content for the selected course by modules, lessons and topics due to link adaptation techniques. Secondly, the learner can select a concept from concept list of the course. And then, the system presents a set of lesson or a specific set of some topics to the learner. Finally, the learner selects a learning goal of the course. Then, the system presents a part of the course to the learner according to selected learning goals.

**Description of Classes in Domain Ontology**

Different classes defined in the ontology by using Protégé 2000 OWL tool. The domain ontology has four main classes. These are “CourseID”, “DomainKnowledgeBase”, “Resource” and “ObjectMetadata” classes. Each main class has its own subclasses and relationships. Each class is defined independent. So, individuals of a class can not be directly member of another class (Protege User Guide, 2004). Also, some additional relationships has been constitute between main classes to produce a learning path in the learning environment.

“CourseID” class represents any course in the learning environment. In proposed domain ontology, a course is a knowledge domain in the learning environment. Each knowledge domain has its own knowledge space. The knowledge space has two subspaces that are media space and domain model (Karampiperis,P and Sampson,D., 2005). Domain model is divided into two different semantic networks to represent domain knowledge and learning content in proposed ontology. Domain knowledge network consists of most important concepts and learning goals of the knowledge domain which are in different granularity level and relationships between them. Learning content network consists of structure of the learning content and relationships between the different types of learning contents. Also, the media space is a semantic network that is named resource network. Resource network is used to represent digital learning materials of the knowledge domain. Each concept of the domain knowledge is explained by a learning content. It can be a course, module, lesson or topic. In addition, each type of the learning content is composed of different digital learning materials. In that way, not only reusability of learning materials, also reusability of learning content for the learning environment has been achieved in proposed domain ontology.

Domain model has been represented by “DomainKnowledgeBase” class in the domain ontology. The class taxonomy of this class can been seen in Figure 1. “DomainKnowledgeBase” class has two subclasses that are represent parts of the domain model. These are respectively “AbstractKnowledge” class that represents domain knowledge network and “LearningObject” class that represents content network. “AbstractKnowledge” class has subclasses that are “DomainConcepts” and “LearningGoals” classes.
These classes have their own subclasses, too. "LearningObject" class has also its own subclasses. These are respectively, "Course", "Module", "Lesson" and "Topic" classes.

![Class Hierarchy Diagram](image)

**Figure 1:** The class hierarchy of "DomainKnowledgeBase" class.

Resource network has been represented by "Resource" class in the domain ontology. "Resource" class represents metadata of the all digital learning materials (web pages, URLs, pdf, doc, swf, etc.). "Resource" class has been designed metadata description of SCORM Application Model. In addition, "Resource" class has two sub classes. These are "LearningMaterial" class and "ResourceType" class. "LearningMaterial" class serves to classify digital learning materials according to different granularity levels such as (sharable content object, SCO; sharable content asset, SCA and Asset) and instructional function that is defined such in (Ullrich, C., 2004). Different granularity levels of "LearningMaterial" class have been defined by "Asset", "SCA" and "SCO" classes that are respectively, at least granularity level to most granularity level. A digital learning material that is least granularity level can be a text, a html page, a pdf and the others. It can be an individual of "Asset" class. A set of individual of "Asset" class have been used to constitute an individual of "SCA" or "SCO" class. In addition, some sub classes of "LearningMaterial" class have their own sub classes serve to define instructional function of the digital learning material. These are "Image", "Text", "ApplicationExercise", etc. that is shown in Figure 2.

Also, "Resource" class has another subclass that is named as "ResourceType" that is shown in Figure 4. This class is a property class. It has subclasses and individuals. These individuals serve to define educational property of a digital learning material. A set of digital learning materials that has different educational properties could be built a learning object such as a topic or a lesson.
Description of Relationships in Domain Ontology

In proposed ontology not only class taxonomy but also properties of classes and relationships of a main class in its own subclasses have been built. In addition, relationships between main classes that are used to connect semantic networks of domain model have been built. For this reason, object properties and data type properties have been defined for each class of the ontology and its subclasses. Object property is a link that connects two individuals of some classes. Object property is a same thing with a link that is a binding between two nodes of a semantic network. Some part of organization of the domain ontology that is proposed in this paper can be shown in Figure 3.

In Figure 3, subclasses of “DomainKnowledgeBase” class, object and data type properties of them can be seen. According to this part of the domain ontology, some classes have data type properties, such as “conceptDefinition” that is a brief description of a concept and “conceptTitle” that is name of the concept. The data type property has a data type.
Furthermore, some object properties have been defined. “AbstractKnowledge” class, its subclasses and their object properties have been used to present domain knowledge network of the domain model. “hasPart” or “isPartOf” that is inverse of “hasPart” serves to define a concept hierarchy and so, to establish a relation among the concepts that are learning goals or domain concepts and its sub concepts. In addition, while learning goals that are in domain knowledge network of the domain model have only hierarchical structure like a tree, domain concepts in domain knowledge network have been represented by a directed a cyclic graph (DAG) structure. According to this, “isRequiredBy” and “requires” object properties serve to define prerequisite relation between domain concepts in DAG. Each learning goal is related to one or more domain concepts in the ontology. Definition of this situation “relates” and “relatedTo” object properties have been used. Each individual of subclasses of “AbstractLearning” class is
related to a learning content. This relation is represented by “explainedBy” and “explains” object properties.

![Diagram of the "Resource" Class]

**Figure 4:** The “Resource” Class.

A set of digital learning materials, each of them has a resource type builds a learning object. Each digital learning material should defined by a resource type value in the ontology. So that, “hasResourceType” object property serves to define educational type of the “LearningMaterial” class. This can be shown in Figure 4. So, a set of digital learning materials that has different educational properties has been consists of a learning object such as a topic, a lesson.

**Conclusion**

In this paper, we have proposed the domain ontology to describe learning materials that compose a personalized e-learning environment that can be used for different adaptation requirements. It is shown that, this ontology is a framework for a Semantic Web application that purpose to perform a personalized learning path for a student in an e-learning environment. For this purpose, we used OWL language and Protégé 2000 ontology development environment to design the proposed ontology.

In proposed ontology, not only class structure but also relationship of classes and properties of classes has been built. For conceptual structure of the knowledge domain has been represented by classes.
These classes represent the domain concepts, learning content and learning materials structure of the proposed learning environment. A domain concept is explained by a learning content that is formed of digital learning materials. In addition, a personalized learning path has been produced in learning environment according to selected adaptation methods. For that, we designed a learning tool for providing the courses from the domain ontology. As a future work, we aim to improve adaptation capability of the learning tool.

References


W3C Technical Reports and Publications http://www.w3.org/TR
