Abstract—Sharing, re-purposing of learning resources are directions of e-learning system, and the developing semantic technology has potential to provide more advanced solutions for these requirements. There have been many research efforts in this direction. However, existing solutions have many weaknesses on resources usability and system availability. The paper proposes a feasible architecture for constructing learning resource sharing system with semantic technology, and ontology-based hierarchy semantic model and method to construct course ontology are described. The approach has been validated with prototype system.

Keywords—Course Ontology; Semantic Technology; e-Learning

I. INTRODUCTION

Learning resource sharing is the most important research aspect of e-learning [1], especially in today’s open education movement [2]. From the viewpoint of standard, a series of metadata standards have been proposed, such as Dublin Core, LTSC LOM, IMS CP, SCORM and so on, which aims to realize encapsulating, sharing and reusing of learning resources. These standards have been used in practice, for example, CanCore [3] is an optimizing profile based on LTSC LOM. With these standards, many learning resources sharing systems have been developed. However, there are still functional limitations within these systems, because they ignore or provide little capability for describing semantic in learning resource. During these years, the developing semantic technology has been adopted to construct more advanced learning resources sharing environments, for example, literature [4] proposes that ontology is required to enrich resources with semantics; literature[5] describes an approach that can facilitate composition of course materials using semantic web technology, and there are many other research efforts in this direction.

According to the aforementioned requirements, the paper proposes to construct learning resources sharing system based on ontology-based hierarchy semantic model. Section 2 introduces the concepts of ontology and course ontology, and gives a process of building course ontology based on our research. Section 3 describes the ontology-based hierarchy semantic model. In section 4, a use case of organizing learning resources for a special course based on the model is described. Section 5 introduces the progress of our research and compares it with other relative works. Section 6 gives the further research work.

II. ONTOLOGY AND COURSE ONTOLOGY

A. Ontology

At first, ontology is a philosophical concept, which is used to describe essence of existence in real world. Then, it was introduced into AI area of computer science, in which ontology is a discipline’s part of the knowledge representation field [6], and it is used to define the kinds of things that exist in an application domain. In the computing context, ontology is a framework for representing concepts (things, or ideas about things) and the relationships that exist between those concepts [7]. In practice, ontology ranges from simple taxonomies (such as the Yahoo hierarchy), to metadata schemes (such as Dublin Core), even to logical theories. There have been a lot of researches about ontology, and the principles and methods for building ontology have being proposed [8].

B. Course Ontology

Ontology technology is considered to be a highly suitable means of supporting educational-technology systems [9] and the increasing importance of semantic web has strengthen this argument. There have many researches on learning resources sharing with semantic technology based on ontology [10][11], and ontology for educational content adds flexibility through the explicit separation of knowledge and content. However, among existing studies, there have not sound research results on how to building course ontology, how to make suitable size of course concept in a ontology and how to provide learning resources sharing environment to users with high usability through semantic technologies. We attempt to address these problems, and provide a suitable solution for build semantic learning resource sharing environment with high availability.

Among these problems, how to build suitable course ontology is the first problem to be resolved, and we propose a process of developing course ontology, which is divided into seven steps (refer to figure 1). The first step is to make sure the scope of ontology. Step 2 is to find out key course terms, then refine the key concept of the course ontology. Step 3 is choosing and adjusting key terms to make sure that the concept in the ontology could be related to appropriate mount of
resources. The length of the chain of key terms is supported to limit in 3 to ensure the effectiveness of ontology usage. Step 4 is to select ontology concepts according to the key terms selected before, and all the selected concepts should reflect the key terms content. Step 5 is to mark the attributes of selected concepts, and all the attributes should materialize the content of related concepts. In step 6, semantic relationships should be annotated among the selected concepts, and these relationships are defined according to concept’s meaning in a course. In the step 7, learning resource is associated to the created ontology. The normal defined course ontology will be used to provide standard terms and reference relationships for learning resource sharing, and also, the relationships among ontology’s concepts can be used to create learning path for learners.

III. INTRODUCTION OF ONTOLOGY-BASED HIERARCHY SEMANTIC MODEL

A. Hierarchy semantic

While there have great progress in semantic computing model and tools, the complexity of the technology to system design, system development, and system usage block the practice in various fields. On the other hand, technology for automatic semantic creation is not mature, which includes ontology creating, relations annotating, metadata extracting, and hence, the price for semantic creation is very high. According to this situation, the hierarchy semantic facilities should be provided for various users in e-Learning environment, and the diversity requirements should be satisfied with various function modules for different users, which should reflect into the system design.

Based on the situation, a hierarchy semantic model is proposed, which include three levels, and they are Course Ontology Layer, Semantic-based Course Structure Layer and LO Layer (refer to figure 2). In the model, the function of Course Ontology Layer is to create ontology and provide API on ontologies. All the course ontologies are created by domain specialists, and the relations in them are compendiary and normative for learning resource production and management. In Semantic-based Course Structure Layer, Semantic-based Course Structure is created by providers of learning resource. Semantic relationships in this layer may be complicated according to different scenarios, and it holds most abundant relations among these three levels. The semantic relationships in LO Layer is the most compact one, and it is used to provide the capability for learning object searching and sharing for ordinary users. With all these three layers, the diversity requirements on semantic relationships can be satisfied, and tools should be provided according to this model for semantic technologies using in education.

B. Ontology-based hierarchy semantic model

As shown in figure 2, semantic relations in the system are distributed in three layers: Course Ontology Layer, Semantic-based Course Structure Layer and LO Layer.

- Course ontology is composed of key concepts and relations among them according to a course. It standardizes the basic relations of LOs and has mandatory power to guide the semantic relations in other two layers.

- Semantic-based Course Structure Layer is the bridge of semantic relations in course ontology and relations in LOs. It is a carrier of a course structure. Based on this design, semantic-based course structure is a three-dimensional and directed graph with central node (also known as root node). In figure 2, the nodes in the directed graph represent topic or knowledge-point in a course, and the relationships among these nodes come from three channels, the basic semantic relations among topics within course structure (usually is “OrderedCompose”), constraints guided by course ontology, and additional semantic relations among topics defined by resources providers according to their viewpoints. In terms of levels, the semantic course structure can also be considered as a tree based on topic and knowledge-point in a course, which has a root node. The leaf-nodes of the tree correspond to specific knowledge points, which can be expressed and managed in LOs. Corresponding to the demand of LO sizes, the depth of the tree can be increased or decreased, which is decided by the characters of learning resources binding with leaf-nodes. The interface among leaf-nodes and their father nodes is called Mapping Interface.

- LO Layer is used as a carrier to express knowledge classified in Semantic Course Structure Layer, and learning resource is attached in LOs. Based on the semantic relations conveying from course ontology and new relations generated from semantic course structure, the LO layer identifies the relations among LOs of a course. There exists a relation reducing process, within which complex relationships in Course Ontology Layer and Semantic-based Course Structure Layer are reduced into four kinds of relationships. They are “directed” (require/required-by), “constitute” (par-of/is-part-of), “equal” (has-equivalent) and “reference” (base-reference). The design approach is adopted to enhance the usability of system.
IV. USE CASE FOR LEARNING RESOURCE PRODUCTION WITH ONTOLOGY-BASED HIERARCHY SEMANTIC MODEL

To demo the idea, the course of “programming with java” is selected, which is a key course for the sophomore of Beijing Normal University. Four typical teaching materials of the course are selected, which are [12][13][14][15], and they are selected for building course ontology of the course.

A. Creating course ontology for the selected course

The ontology is created according the process refer to figure 1, and for demonstration, the course ontology created here just covered the basic syntax of java language, while other parts are curtailed.

1) Select important terms and key concepts for the course.

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First, the important terms of “overview of java language”, “the base of java language”, “object-oriented programming”, etc., are selected, and these are upper-level terms. Then, all these terms should be adjusted according to the granularity of the terms, for example, under the term of “overview of java language”, more lower-level terms can be identified, such as “origin and development of java”, “feature of Java”, “JVM”, etc. While the term of “class”, which is a lower concept of “object-oriented programming”, is not further classified into more lower-level terms, and it is marked with features of “specifiers of class”, “attribute”, “method”. Because if the term of “class” is further classified into terms of “public”, “class”, “extends”, and “throw” etc., then the complexity of the building ontology will be increased hugely, which will reduce its effectiveness and availability. During this process, “Complex data type” is also selected as important term, which can be used to relate the syntax of “class”, “interface”, “array”, and “string”. With this process, all the important terms and key concepts are selected, which is described in figure 3.

a) 2) Define semantic relations between concepts in the selected terms. After define the important terms and concepts, semantic relations among these concepts should be annotated.

In this example, four kinds of relations are considered, including kind of “IsBuildBy”, “Previous”, “Referenceto” and “Attributeof”. During the relation annotating process, we need to follow the following relationship annotating order, “Previous”, “IsBuildBy”, “Attributeof” and then “Referenceto”. According to this process, reference course ontology (partly) of “Programming with java” is described in figure 3.

B. Build Semantic-based Course Structure

Because every teacher has his own strategy of resources organization, the developing system should provided flexibility with semantic technology, which is provided in the Semantic-based Course Structure Layer. Based on the created course ontology, one can build his own semantic-based course structure.

Here, taken [15] of the four selected books as an example to show the building process of semantic-based course structure:

1) Define course structure according to book structure and ontology criterion. We chose the former 6 chapters of the book, including chapter 1 “Overview of Java”, chapter 2 “Java Programming environment”, chapter 3 “Basics of Java Language”, chapter 4 “Create a New Data Type”, chapter 5 “Inherit”, chapter 6 “Advanced Features of Object Oriented Programming”.

We can make course structure followed the selected teaching material as figure 4. During the building process, we need to consider about converting the topics of chapter name to normal forms in the created course ontology, i.e. chapter 4 “Create a New Data Type: Object and Class” should be convert to “Class and Object”, chapter 5 “How to Use the
Existed Production: "Inherit" should be converted to "Inherit". In chapter 3 "Data Type and Variables" should be converted to "Basic Data Type and variables".

To topic that don’t exist related concept in the created ontology, it depends on the definition in the teaching material or renamed by resource provider.

The layer depth in a course structure does’t limit to a certain number, and it depends on the content of the teaching material. The resources are associated with the topics at the end-point node of the structure.

With the afore-mentioned process, an initial course structure can be defined, which is composed with basic and normalized topics.

Individual semantic annotating. The resource provider can define new semantic relations according to their own knowledge and experience. Taken the figure 4 as an example, it has not only the four relations of “IsBuildBy”, “Previous”, “Attribute-of”, and “Referenceto” derive from the created course ontology, but also the new relations of “OrderedCompose” which refers to partial order relation and “FlowBy” which refers to subsequence relation. Such new semantic relations can be defined and added to the course structure with resource provider’s intention.

C. Generate the Learning Resource According the Created Course Structure

After the generation of semantic-based course structure according to special teaching material and user customization, learning resource should be generated with the guide by the course structure, and associations should also be created between learning resources and the course structure. The generated resources are in the form of learning object, and four semantic relationships have been defined to annotate relations between these learning objects, which have been introduced in section 3.

V. RELATED RESEARCH AND THE STATUS OF OUR RESEARCH

There are many research efforts on building learning resource sharing system with semantic technology. For example, in literature [16], Sinéad Boyce proposes the way to determine the most suitable ontological modeling notation for course, however, it didn't consider the level and granularity of adopted concepts during the process of ontology definition. In literature [17], researchers investigate basic issues that need to be addressed for developing an architecture that enables repurposing of learning objects in a flexible way. But this architecture did not pay attention to people’s requirements for resource sharing capability with different size. Literature [18] presents an original model to cluster information related to course topics with three levels of representation: SCORM meta-data, concept maps, and domain ontology. Although the research has comparability with our work, it didn't consider about different requirement of semantic application in education. Comparing to existing research efforts, our work focuses on providing solution for deeper learning resources sharing.

Currently, the proposed semantic model has been realized, which can provide tool to build course ontology for subject experts. Course ontology is managed in graph and parsed by Jena. For resources provider, they can build semantic-based course structure based on the created course ontology and their own course design strategy, and then, they can associate learning resources or teaching material according to this structure. The learning resource is in the form of learning object which is developed by our research team based on Fedora[19]. At present, the feasibility of this design principle has been validated.

VI. FUTURE WORK

Currently, we mainly focus on the building of learning resource generating environment. Now, we are going to realize the facilities for learning resource sharing in this environment, including facilities for semantic-oriented resources querying, functions for automatic or semi-automatic courseware generating, etc. All these facilities will also be distributed in all three layers. With these functions, a more advanced learning resource sharing environment will be created.

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