Dynamic Composition of Curriculum for Personalized E-Learning

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Abstract: This paper proposes an approach to dynamically compose an adaptive curriculum for e-learning based on a topic-centered resource space. By exploiting the semantic relationships that characterize learning objects (LOs) and learner profile, the approach dynamically selects, sequences, and links learning resources into a coherent, individualized curriculum to address learners’ focused learning needs. Semantic Web (e.g., XML, RDF/s) is used to represent LOs and their relationships, as well as, to support flexible navigation at semantic level. The system has been deployed and evaluated within an academic setting, enabling learners to organize, access, and share the learning resources in a more effective and personalized manner.

Keywords: Learning Object, dynamic composition, Knowledge Map, adaptive curriculum

1. Introduction

Nowadays, people are often motivated to educate themselves on new topics, but do not necessarily have time to take a full course of instruction. Actually, they often resort to the Web to search and gather enough information about a topic to be able to complete a task or carry on a discussion. However, the rapid growth of information available on the Web has led to people constantly fighting information overload in their pursuit of knowledge. Furthermore, as the information on the web is not effectively organized, the acquired knowledge is often disordered, disconnected, and not effectively integrated to address people’s learning needs. Especially, for people new to a subject, they feel very difficult to find and organize relevant information for effective learning.

E-Learning is just-in-time education integrated with high velocity value chains. It is the delivery of individualized, comprehensive, dynamic learning content in real time, aiding the development of communities of knowledge, linking learners and practitioners with experts [5]. But the production of learning content for e-learning is demanding and expensive. It is therefore a necessity to reuse e-learning materials for producing Web-based courses with less time and efforts. Unfortunately, existing electronic courses are seldom reused, as there is usually always a need to change some part for a new course to be held.

The notion of learning objects (LOs) has been introduced in the e-learning field to enhance the portability, reusability, and interoperability of learning resources. Learning objects aim to provide self-contained learning materials that once developed can subsequently be exchanged, composed, and reused. Actually, a single learning object of small granularity, in most cases, will not work to achieve a certain learning goal, so several related learning objects are needed to be assembled as a learning curriculum for this purpose.

1 Research work of this paper was supported by National Science Foundation (60402016)
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Ideally, Web-based course developers could quickly and easily assemble learning objects into coherent and effective organization for instruction to address a learner’s focused learning needs [9]. However, current Web-based courses are still developed largely manually. Additionally, they are often designed for general users and thus not adapt to individual learners. Therefore, a more automatic and flexible approach is needed that is sensitive to each learner’s unique needs and context, providing focused and structured learning resources.

The literature in education holds that a cognitive structure is defined as a hypothetical construct referring to the organization of relationships among the concepts of long-term memory [8]. A schema is identified as a cognitive construct that allows people to treat multiple elements of information (concepts) as a single element, classified according to the manner it will be used [1]. So, a schema is able to lessen the pressure on working memory and facilitates learning and understanding.

By separating the concept-centered knowledge schema from the distributed learning resources, this paper presents an approach generating the adaptive e-learning curriculums to address learners’ individualized learning needs. It is centered on the dynamic selecting, sequencing, and linking of learning resources into a coherent, focused organization for instruction. This approach enables diverse learners to organize, access, and share learning resources in a more effective and personalized manner.

2. Semantic Modeling of Learning Resources

The basic idea is to organize the learning resources in a concept space rather than in a page space. By explicitly defining the semantics of the resources and separating the knowledge structure from the learning materials, the distributed learning resources can be organized and reused in a more flexible and interoperable manner. The conceptual model of learning resources organization is shown in Figure 1.

Assets refer to any of the media files, such as Web pages, PDF documents, animations, and audios. They can be uniquely identified with URI, and their semantic description is embedded in the corresponding learning objects. The distributed huge amounts of learning assets are stored separately.

Learning objects tagged with metadata represent any chunk of learning material regardless of its form, granularity and functionality. The metadata for a generic learning object falls into three broad categories including content, structural, and context. The content description indicates what the learning object is about. The structural description indicates the learning object’s relationship with other learning objects. The context description indicates when to present the learning object, which expresses the pedagogical
information of a learning object. Learning Objects are self-contained learning components that once developed can subsequently be exchanged, retrieved and reused.

Knowledge Map (KM) describes the domain-specific knowledge schema (i.e. concepts, semantic relationships), which provides a semantic view of the linking learning objects. For example, it can describe the organization of instruction either for an entire course or for a part of it (e.g. lesson, lecture). Knowledge map can either be designed by the instructor as the universal for each learner’s references or devised by the learners to express their personal knowledge and preferences. We use semantic link network to represent knowledge map [10], which includes nodes and typed semantic links between nodes, encoded as RDF entities and properties.

Related assets are grouped together as a learning object, and one or more learning objects about the same subject are linking to the same concept as its instances. Users with different roles (e.g. instruction designer, content provider, and learner) can access the resources via the friendly interface, and the location and format of the learning assets are transparent to users. In this way, users can search and navigate in the resource space in a more flexible and efficient way.

3. Architecture

The system architecture is illustrated in Figure 2. The user interface allows the learners to access the system with different privileges by providing role authentication. Each learner is equipped with a profile to describe his personal information and learning history, which can be manually edited and updated by learners through the system's interface at anytime, or the system keeps track of learners’ activities and update it periodically. As for a specific domain, learner profile is actually an overlay of the knowledge map in terms of the knowledge structure where each node is attached with several attribute values (e.g. review times, master level, etc.). After received a learner query, the adaptive composition engine takes charge of selecting and organizing the learning objects according to learner profile, and finally delivering the generated curriculum to the learner. On the other hand, with the support of authoring tool, instructors can design and revise the knowledge map within a specific domain. The execution engine is responsible for executing the authoring operations. The index engine fulfills the task of searching the domain concept that matches the metadata of LOs. At the same time, instructors and learners can freely insert, delete, or modify LOs. The resource space composed of knowledge space (stores the knowledge map, LOs metadata, and pedagogical rules) and information space (stores the learning assets) offers the resource support for adaptive composition engine.

![Figure 2. The system architecture.](image-url)
4. Dynamic Composition of E-Learning Curriculum

The e-learning curriculum is generated on the fly to cater for the different learning needs of the learners. The majority of users are accustomed to expressing their learning needs in terms of keywords, and thus we provide the user interface enabling the learners to express their learning needs in terms of keywords during the learning process, but at the same time uses the semantic information regarding the application domain to obtain results that are not possible in traditional information retrieval. In addition to the keywords, the learners may specify other constraints, such as difficulty level, learning time, media type, etc. In this way, learners are able to actively drive the selecting and organizing of learning materials to meet their own learning needs. For the given query proposed by the learner, the curriculum composition is fulfilled by following the five-step process, which is shown in Figure 3.

**Figure 3.** Process flow of the curriculum composition.

Step 1: Query annotation. For a given query, the first step is to automatically process the query and annotate the query with possible semantic information to expedite the search for LOs in a large repository. For the case of linguistics ambiguity (e.g. synonym), users’ profiles (e.g. personal information, background knowledge, interests) are taken as the reference to select the proper annotation. Additionally, the search context and the popularity of the term as measured by its frequency of occurrence in a text corpus can also give hints for selecting the proper annotation for the search terms. In addition, other candidate terms are also presented to the learners so that they can select one of them if that is what they intended.

Step 2: LOs searching. After the query is processed, the next is to search the LO repository for relevant learning objects based on the keyword matching of the learning objects content and metadata to the query term. The search results are a set of learning objects.

Step 3: Topic mapping. Identify the target topics by mapping the LOs in the search results to the topics in the knowledge map. The simple way is to follow the links preset by the instructors if there exist links from learning objects to topics, otherwise, use the topic clustering to find the mapping topic based on the metadata of returning learning objects.

Step 4: Learning syllabus planning. Learning syllabus is represented as a sequence of semantically interrelated topics that a learner can follow to address his focused learning needs. Taken the mapping topics as anchor nodes, the learning syllabus is generated based on the graph traversal approach according to topic relationships. That is, the approach for selecting the target topics, based on the structure of the graph, is to collect the first N triples originated from the anchor topic, where N is the pre-defined traversal constraints. Actually, different learners have different backgrounds and preferences, so the property types of
nodes should not be treated as equally relevant. Therefore, learner profiles are taken into account to select and sequence the necessary topics while ignoring the unfocused semantic relationships. For example, if a learner is interested in a topic, then provide him with the prerequisites that are not studied or not well comprehended.

Step 5: LOs sequencing. Given the personal syllabus for an individual learner, it is time to substantiate each topic of the syllabus with one or more LOs. Pedagogical rules are used to select and sequence the learning objects about the same topic based on their metadata description. Some example pedagogical rules are as follows: 1) The learning object as the concept part must precede the learning object as the elaboration part; and 2) Regarding the same interesting topic, provide the novice with simple introduction and example, while presenting more detailed and in-depth information to the advanced learner. Additionally, the description about the quality of LOs helps selecting the LOs with high quality. The metadata can be specified by providers during the authoring process, such as best, better, normal recommendation mark, or computed based on the learners’ feedbacks.

To the end, serving as components of a learning curriculum, the target learning objects are sequenced and provided for the learners to address their focused and personalized learning needs. Taken a simple example to illustrate this working process, we assume that a novice proposes a query “Lattice homomorphism” but with no other constraints. After annotating the query as a mathematics term, search the matching learning objects in the LOs repository, and then select the topic corresponding to the matching LOs as anchor node. As the learner has little knowledge on this topic, the generated curriculum should contain the basic content and necessary background knowledge. That is, by using the reasoning rules (e.g. transitivity) on the semantic relationship (e.g. SubtypeOf, Sequential) between topics, its prerequisite topics with linking LOs are all selected and sequenced to compose a learning curriculum. The generated curriculum is depicted in Figure 4. It becomes obvious that different curriculum could be generated to cater for different learners with different backgrounds, capabilities and expectations.

![Figure 4. A schematic generated curriculum.](image)

5. Implementation

We have developed an e-learning platform WebCL (available at [http://www.webcl.net.cn](http://www.webcl.net.cn)) that has been used in more than twenty universities or high schools, and the total number of registered users exceeds 10000. WebCL provides a set of tools (e.g. course tools, evaluation tools, communication tools) to support cooperative and adaptive learning, while offering a plug-in interface for extension modules.
5.1 Authoring Tool for Instructors

An authoring tool has been developed for defining the domain knowledge and structure. Figure 5 shows the graphic user interface for constructing the course-KM. Experts and instructors can click the icons in the top toolbar to add the concepts and relationships, while deleting or editing them in the background graphical interface. Through the dialogs for defining the concept attributes and relationship types, experts and instructors can input the text or select one item from the drop-down list to specify the concept properties and relationship types. Figure 6 gives a graphical view of a part of course-KM. As the figure illustrates, the left frame shows a tree hierarchy of the course concepts on a specific subject, the upper part of the right frame shows the constructed course-KM, and the lower part of the right frame shows the list of properties corresponding to the concepts shown in the upper part.

![Figure 5. User interface for constructing course-KM.](image)

![Figure 6. Graphical view of a part of course-KM.](image)

5.2 Adaptive Curriculum for Learners
The adaptive curriculum application is built on top of the WebCL Workbench that offers a plug-in interface for extension modules. This module is implemented in Java and runs on web application servers compatible with the Servlet 2.0 specification. Web pages are created using JSPs and Learning Object content in XML is transformed to XHTML using the XSLT style sheet processor. Figure 7 shows the resulting curriculum for the query “Lattice homomorphism” proposed by a novice. As the learner has little knowledge on this topic, the generated curriculum contains the basic and comprehensive content. The componential learning objects are displayed in a sequence with hypertext navigation structure. Each learning object is described with semantic information to guide user’s navigation, such as the pedagogical role (e.g. “concept”, “example”), title, introduction, instructional objective, etc. To the right of each LO title is the learning time of the learning object. More related topics are given at the bottom of the page for learners’ reference, and thus learners can click any topic to get more focused information. Additionally, learners can click the “Advanced Search” to specify more constraints and preferences in addition to the keywords.

![Figure 7](image)

**Figure 7.** The interface for displaying e-learning curriculum.

### 6. Discussion and Comparison

Learning Content Management System (LCMS) focuses on the construction and maintenance of LO repositories for various e-learning applications, examples are MERLOT([http://www.merlot.org/](http://www.merlot.org/)), CAREO([http://www.careo.org](http://www.careo.org)), and SMETE([http://www.smete.org/smete/](http://www.smete.org/smete/)). As [7] pointed out, although they adopt standard e-learning metadata specifications to describe LOs, most of them use full text queries as the only way to access LOs in a disconnected way from the actual learners’ navigation. This functionality is quite different from that of our approach employing the relationship between LOs to select and organize semantic relevant LOs.

Considerable work has been conducted on adaptive hypermedia system [2][4], which are considered to be relevant with our approach. But much of the work is to assume that web resources are already richly linked and the job of the adaptive system is to show or hide various links [3]. By contrast, our approach achieves higher level of flexibility and scalability by modeling LOs with associated metadata, and encoding the relationship and sequencing between metadata instead of between learning resources.

Some other research groups driven by similar goals have proposed other architectures that match our vision. The CSD-Uoc portal [7] provides an online curriculum on the
Semantic Web by exploiting the semantic relationships established among LOs to generate a learning path. However, it is very difficult to specify the relationship between LOs in a large information space composed of a great deal of LOs. In our approach, we instead construct a domain-specific knowledge map as a basis for users to flexibly specify the relationship between LOs with less time and efforts. [6] presents an approach to assemble learning objects into coherent and focused learning paths from a repository of XML Web resources. It simply relies on the learner’s query to select matching LOs but not consider learner’s learning history and background.

7. Conclusion

By incorporating the learning objects and the Semantic Web technologies, this paper proposes an adaptive curriculum composition approach for e-learning. Driven by the specific queries from learners, adaptive e-learning curriculum is dynamically generated by selecting and structuring the semantic relevant learning objects according to knowledge schema, LOs metadata, and learner profile. In this way, the generated curriculum with tailored content and flexible structure caters for different learners with different backgrounds, capabilities and expectations, at different time and venue.

We currently provide authoring tools enabling the users to semi-automatically define and annotate knowledge schema and its instance resources with visual operations. Future work will extend this to automatically annotating the relationships between discovered topics or instances. Additionally, we are going to experiment on a large mount of users for widespread use during a long period to test the effectiveness of our proposed approach.

References