

AUTOMATIC ADAPTIVE RETRIEVAL OF LEARNING OBJECTS

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Abstract

This paper aims to propose a new approach to automatic retrieval of Learning Objects (LOs) in an adaptive e-Learning using multidimensional learner characteristics to enhance learning effectiveness. The approach focuses on adaptive techniques in three components of e-Learning: Learning Paths, LO Retrieval, and LO Sequencing Levels. This approach has been designed to enable the adaptation of rules which are represented by Prolog to become generic. Hence, the application to various domains is possible. The approach dynamically selects, and sequences LOs into an individual learning package based on the use of domain ontology, learner profiles, and LO metadata. The ontologies are represented by Web Ontology Language (OWL). The Sharable Content Object Reference Model (SCORM) is employed to represent LO metadata and learning packages in order to support LO sharing. The IMS Learner Information Package Specification (IMS LIP) is used to represent learner profiles. Both standards are represented by means of Extensible Markup Language (XML). Thus, the information can be exchangeable and interoperable with other systems. Based on the proposed approach, a prototype system has been developed and evaluated. It has been discovered that the system has yielded positive effects in terms of the learners' satisfaction.

Keyword: Adaptive Educational Hypermedia Systems, Personalized E-Learning, Web-Based E-Learning, SCORM

INTRODUCTION

The recent research trend of adaptive e-Learning has led to the development of Adaptive Educational Hypermedia Systems (AEHS's) (Karampiperis, 2005). In AEHS's, adaptive navigation and presentation techniques are employed to provide personalization of courses. AEHS's create models of goals, preferences, learning styles and knowledge of each learner and utilizes the models throughout the interaction with individual learners in order to adapt learning contents to meet learners' individual needs. The AEHS's adaptability can provide a greater learning effectiveness for learners. Although AEHS's provide various benefits, there are still some existing problems as follows:

- Many AEHS's focus only on a limited number of learners' characteristics in which learning styles are restrictedly supported. Therefore, a newly developed AEHS should allow or encourage the consideration and utilization of multidimensional learners' characteristics for greater effectiveness in adaptations.
- Many AEHS's employ inflexible representation schemes to model domain knowledge. This leads to the difficulty in modifying, exchanging, or reusing knowledge for other different domains.
- Most AEHS's are unable to automatically compose Learning Objects (LO's) for personalized course packages in a real-time manner. Therefore, learners cannot have their own portable course packages.

In this paper, an approach of automatic retrieval of LO's for AEHS's for individual learners and different knowledge domains is proposed. The approach adopts standards for the representations of information which are required for the retrieval and composition. The modeling of learners, domains, and adaptation rules is via Extensible Markup Language (XML) platform. Based on this approach, a prototype system has been developed with the following capabilities to solve the three problems of AEHS's:

- Support of multidimensional learners' characteristics.
- Support of flexible representation of general domain model.
- Adaptive selection of appropriate learning courses automatically based on the prior and background knowledge of learners.
- Adaptive selection and sequencing of LO's in a chosen course automatically based on learning styles.
- Automatic composition of LO's into a personalized Sharable Content Object Reference Model (SCORM) (ADL, 2004) package in real time.

In the next section, I describe the system architecture of this approach. The system evaluation will be detailed in section 3.

SYSTEM ARCHITECTURE

This research has explored an alternative way to accommodate learners' differences without proposing any changes to the existing SCORM learning environment. As SCORM standard does not support some aspects of adaptive e-Learning, it is necessary to adopt some popular XML-based standards for supporting the adaptation aspects throughout my system, such as IMS Learner Information Package Specification (IMS LIP) (IMS, 2008) for learners' profiles, Web Ontology Language (OWL) (W3C, 2004) for domain ontology based on ACM recommendation of Computer Science curriculum (ACM, 2008). Furthermore, we can exchange all information (courses and learners' profiles) or knowledge (domain knowledge and general rules) with others which are developed under the same standards and XML platform.

Framework

In my approach, I modified the AEHS Architecture Model by adding career goal function for extracting careers that can guide to courses, and the LO selection rule for selecting LO's which are suitable with learners' preferences and learning styles. The main components of my architecture and their structural interconnections are illustrated in Figure 1.

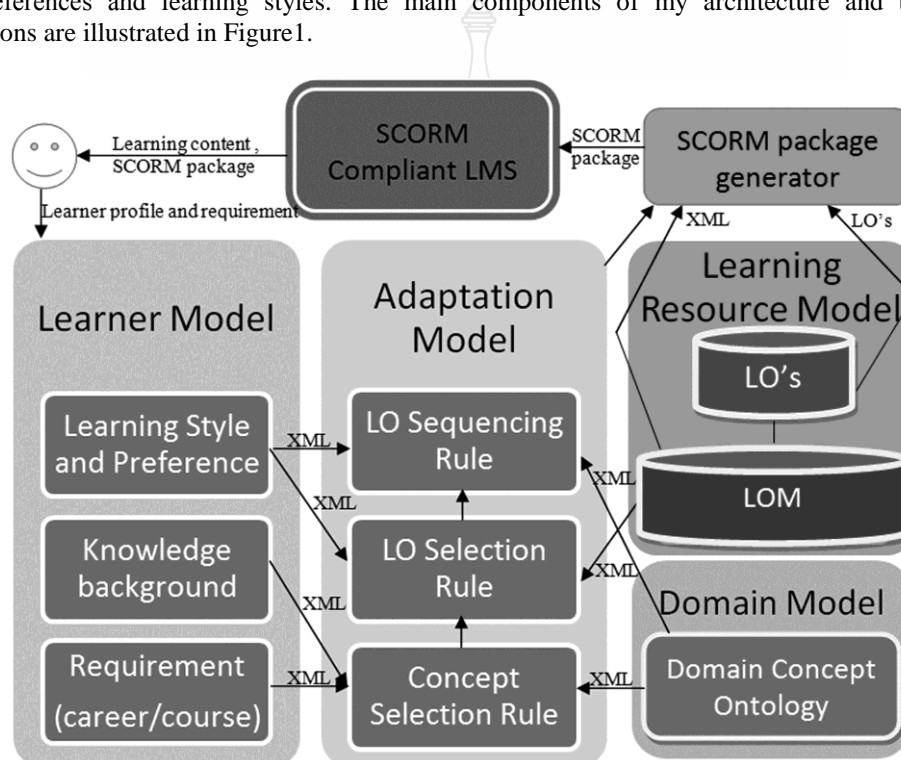


Figure 1. Framework of the system

It consists of four complementary models in the framework are: i) the learner model containing the requirements, knowledge, learning styles and preferences of learners, ii) the domain model being the domain concept ontology, iii) the learning resource model keeping LO's (physical learning resource files) and their metadata, iv) the adaptation model consisting of concept selection, LO selection, and LO sequencing rules which are an adaptation engine to perform the actual adaptation. The indirection line represents a logical connection between LO's and their metadata while the direction line shows the direction of information.

Learner Model

The learner model is designed to store the learners' profiles which consist of the identifications, learning histories, goals, preferences, and the learning styles of the learners. All elements in this model are based on the IMS LIP standards which can be represented by XML. The learner model is constructed according to the learners' knowledge and characteristics which are acquired directly or indirectly at the time of learning. The direct information extraction is used to acquire identification, learning history, goals, and preferences information of learners. In addition, the indirect information extraction is used to recommend a learning style. A psychological questionnaire namely the "Index of Learning Styles Questionnaire" is used for the learning style extraction tool. The questionnaire can classify learners according to 16 learning styles based on Felder's theory (Felder, 1993).

Domain Model

The domain model contains ontologies describing the structure of the domain knowledge and the associated learning goals. The ontologies are designed to provide the sharable common knowledge or terms for interoperability. They are particularly useful in defining complex structures based on the concepts of the courses and their relationships in learning environments. The ontologies represent the concepts of the domain as the connection (graph) between each concept linked together by OWL based on a W3C recommendation. OWL is an XML vocabulary that is used to define classes, their properties, as well as class and property relationships (W3C, 2004). I have applied my prototype to the case of learning of Computer Science (CS) courses in an undergraduate level. The ontology is based on ACM Computing Curricular 2008 for CS a comprehensive work that defines sound CS curricula for undergraduate studies (ACM, 2008). Being endorsed by both ACM and IEEE, it has a very broad acceptance in the CS. Knowledge of 14 areas, 16 units, 132 topics, learning objectives, and prerequisite courses were recommended. I used the ontology for acquiring information about courses sequence, number of units in a course, the topics of units, and the learning objectives etc. This information will provide the sequence of courses, guidelines, and conditions for the planning of the learning paths for each learner. The ontology consists of nodes and edges. Nodes are used to represent classes/subclasses such as fields, courses, units, and topics. The edges are the relation between classes. The properties will be included in each instance of classes such as prerequisite, unit of, topic of, course name, and unit name etc.

Learning Resource Model

The learning resource model is designed to store the LO's complying with the SCORM standard and their metadata which is needed for associating with the domain model. These LO's are represented in the forms of SCO's and Assets. The SCO's and Assets and their metadata are encapsulated in content packaging (SCORM) to allow interoperability and reusing of the LO's. IEEE Learning Object Metadata (IEEE LOM) (IEEE LTSC, 2008) is the LO metadata standard which is used in the imsmanifest.xml file of the SCORM content package. The IEEE LOMv1.0 base schema for imsmanifest.xml file consists of nine categories: General, Rights, Life Cycle, Relation, Meta-metadata, Annotation, Technical, Classification, and Education. From the nine categories of IEEE LOM, I select some elements of the categories as inputs in my adaptation model such as Keyword, Language, Format, Duration, Learning Resource Type, Typical Age Range, and Difficulty. I used these LOM elements for matching LO's with learners' preferences and requirements. If they are suitable to the learners' profile, their related LO's will be selected.

Adaptation Model

The adaptation model is designed to store the adaptation mechanisms and rules for the LO retrieval and sequencing. The LO's will adapt their attributes and behaviors based on the rules and the adaptation techniques. The adaptation model consists of three important rules which are: concept selection, LO selection, and LO sequencing rules. These rules use information from the domain, learning resource, and learner models as inputs for their processing.

I have designed the adaptation rules to become generalize. These rules are not specific to any courses and learners' profiles. Hence, the application to all domains is possible. Moreover, the rules are independent from each other. A rule can be modified and deleted with no effect on other rules. They can work although others are deleted or fail as shown in following examples. The both rules are used for checking pass courses. If one of them is fail the system is still work.

1. `passCourse(student(A),course(C)):- bagof(unit(U),unitOf(unit(U),course(C)),Result),pasAllUnit(student(A),Result).`
2. `passCourse(student(A),course(C)):-prerequisiteOf(course(C),course(X)),passCourse(student(A),course(X)).`

The concept selection rule uses the learners' background knowledge, learners' goals, and the domain concept ontology to be its inputs. The output of the rule is learning paths of the learners' course goals. The different background knowledge will provide different learning paths. The learning paths show the order of courses following the domain concept ontology. If any learners passed some courses which are prerequisite courses of the course goals, the passed courses will disappear in their learning paths. The concept selection rule consists of sub rules which are the prerequisite rule, the course pass rule, and the course recommendation rule.

The LO selection rule uses the learners' preferences (such as language, age, status, available time), learning styles (16 styles), and LO metadata (such as keyword, language, learning resource type, format, typical age range, difficulty, and duration) to be its inputs. The output of the rule is the set of LO's which have metadata matching with preferences and learning styles of learners. The selected LO's will be sequenced based on the LO sequencing rule (Educational Psychology fact) by matching LO metadata; learning resource types (Lecture, Simulation, Experiment, Problem statement, Exercise, Exam) and formats (Text, Figure, Audio, Video, Slide,

Animation) with learning styles of learners; active(A)/reflective(R), sensing(S)/intuitive(I), visual(Vi)/verbal(Ve), and sequential(Se)/global(G). So the learners who have different learning styles will get different LO sequences as following examples:

LO sequence of “Active-Sensing-Verbal-Global” learning style is:

Learning resource type order: Problem statement-> Exercise-> Experiment-> Simulation-> Lecture-> Exam and for *Format order in each learning resource type:* Audio-> Animation-> Video-> Slide-> Text-> Figure.

LO sequence of “Reflective-Inductive-Visual-Sequential” learning style is:

Learning resource type order: Lecture-> Problem statement-> Exam-> Simulation-> Experiment-> Exercise, and for *Format order in each learning resource type:* Video-> Animation-> Figure-> Slide-> Audio->Text.

EVALUATION

In order to evaluate the effectiveness of the proposed approach, an experiment with sixty undergraduate learners from Rajamangala University of Technology, Thanyaburi, Thailand, was conducted. They are the represents of all kind of learners. The approach is evaluated according to four different dimensions (treatments): “system usefulness”, “ease of system use”, “system adaptability”, and “intention to use the system”. I employed "The Randomized Complete Block Design" for statistic approach because I would like to survey satisfaction of learner in each dimension. The subjects were requested to study computer science topics via my prototype system. After a month, they were asked to evaluate the system by answering well-designed, four-dimension questionnaires with a ten-point range of scale or Likert scale (Tobing et al., 2008).

The evaluation results (Table 1) show the mean scores and standard deviation values for each dimension of the system use. The results show “all mean scores are high (almost 10) while all standard deviation values are low (about 1)”. The high mean scores mean most of the learners agree/strongly agree with the dimensions. The low standard deviation values mean each learner’s average score is near the dimension’s mean score. The means and standard deviations obtained from the answers of the subjects indicate that the subjects were consistently satisfied with the system with respect to all the four dimensions.

Table 1. Evaluation results

Treatment	Mean	N	Standard Deviation
1.00	8.0392	60	0.92884
2.00	7.9443	60	1.00125
3.00	8.2067	60	0.93716
4.00	7.9190	60	1.11477
Total	8.0273	240	0.99841

Moreover I re-evaluate the system with four opposing dimensions in a negative way: “system uselessness”, “difficult to system use”, “system inadaptability”, and “no intention to use the system” for confirmation of the evaluation results of the first four dimensions. The results from the second evaluation show the low mean scores (about 1) for all dimensions. The results from both evaluations mean the system can affect the learners' satisfaction in the dimension of “system usefulness”, “ease of system use”, “system adaptability”, and “intention to use the system”.

CONCLUSION

By incorporating SCORM, IMS LIP standards, and the Semantic Web technology, an adaptive system of retrieval and composition of LO’s has been developed. The system utilizes course enquiries from learners and their profiles as inputs. LO metadata, domain knowledge ontology and adaptation rules as knowledge base to select and compose relevant LO’s, and then to generate personalized learning paths and SCORM packages automatically. Regarding future studies, the adaptive features for m-Learning or u-Learning should be considered. Hence, learners can have more opportunity and flexibility in their learning.

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