Adaptive E-learning System: A Review

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***Abstract*— E-learning can be truly effective when it provides a learner centric adaptive learning experience. To meet the requirement of adaptive learning experience many adaptive learning systems are developed. There has been research on various modules of the adaptive e-learning system such as ontology, student model and different information retrieval techniques for adaptive delivery of learning resources. This paper presents the architecture of an adaptive e-learning system and the review of the work done in the area of ontology, student modelling and the available adaptive systems.**

***Keywords*— ontology, student model, adaptive e-learning system**

I. INTRODUCTION

The success of any e-learning system depends on the retrieval of relevant learning materials according to the requirement of the learner. This leads to the development of the adaptive e-learning system to provide learning materials considering the requirements and understanding capability of the learner. The block diagram of a typical adaptive e-learning system is shown in figure 1. The main modules of an adaptive system are the domain ontology, student model, adaptive retrieval module and the learning object repository.

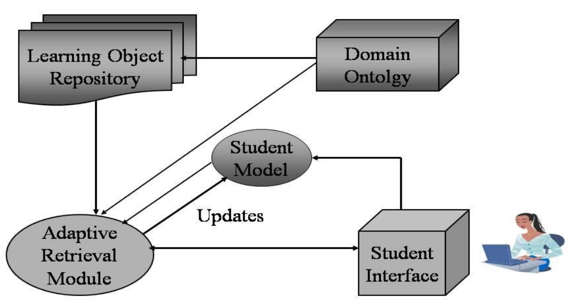

Figure 1 The block Diagram of an Adaptive System

For the development of an adaptive system, the domain ontology plays a crucial role [1],[2]. The ontological structures can be used for organizing, processing and visualizing subject domain knowledge, marking the topic and coverage of learning objects, and for building learner models in e-learning systems. The domain ontology can be used for concept-based domain specific information retrieval, visualization, and navigation that help learners to get oriented within a subject domain and build up their own understanding and conceptual association [3],[4].

The model of the student is an integral part of any system aiming for adaptive information delivery. Student modeling can be described as a process of building the personal preferences of users in terms of the student's knowledge about the subject, his behavioral aspects, goals, likes and dislikes. The model of a student is generally represented in the form of a *student profile*, which captures the personal preferences in a machine processable format. So, the student model can be seen as an abstract entity and the student profile represents an instantiation of the student model for a particular user. The different research works differs in the way they represent the student profile, how they update the student model and the strategies they adapt for providing the personalized information.

The adaptive retrieval module of the system is responsible for retrieving specific learning resources customized to the need of the student. The information retrieval techniques vary from system to system.

In this paper, we have discussed the work done on various aspects of an adaptive e-learning system such as the domain ontology, the student model and also some of the available adaptive E-learning systems. In Section 2, the research work done on ontology development and their use in various applications is discussed. Section 3 deals with the related work done in the area of student modeling. Personalization and adaptive presentation is especially important in e-learning. Some of the available adaptive learning systems are discussed in Section 4.

II. ONTOLOGY

An Ontology [5] refers to the shared understanding of a domain of interest and is represented by a set of domain relevant concepts, the relationships among the concepts, functions and instances. Ontology can be viewed as a vocabulary containing the formal description of terms and a set of relationships among the domain relevant concepts. The basic requirements for building a ontology are

- Identifying relevant domain entities to be included in the ontology.
- Establishing formal description of the domain entities and relationships among the entities.

Several ontologies have been developed in various domains for various purposes. They differ in the way the ontology is structured, the ontology representation language that has been used to represent the ontology and the application domain.

Dicheva et al. [6] proposed a framework for building a concept-based digital course library where subject domain ontology is used for classification of course library content. To create adaptive and modularized courses Hoermann [7] used learning object metadata together with a well-defined knowledge base.

In the work of ontology based automatic annotation of learning content [8], ontology is used to annotate learning objects with metadata. Similarly Gasevic et al [9] have also used domain ontology for semantically marking up the content of a learning object

The work by Baumann and others [10] has used ontology for document retrieval. They have kept two types of relationships in the ontology. The relations are "*is a*" and "*part-of*" relation. The relation "*is a*" is used to indicate specializations of concepts while the "*part-of*" relation denotes the required sub-concepts for understanding a given concept. The document retrieval technique is based on the vector space model. The documents and the queries are represented as vectors. They have used the cosine similarity measure to compute the angle between the document vectors to find similarity between the documents.

Aitken S. and Reid S. [11] evaluated the use of domain ontology in an information retrieval tool and showed that the retrieval using ontology gives higher precision and recall as compared to the simple keyword based retrieval without using ontology. They store the ontology in a hierarchical structure.

The work of Chaffee [12] explores a way to use the user's personal arrangement of concepts to navigate the web. They have used the existing ontology based informing web agent navigation (OBIWAN) system and mapped them to the user's personal ontology. OBIWAN allows the users to explore multiple sites via their own personal browsing hierarchy. The mapping of the reference ontology to the personal ontology is shown to have a promising level of correctness and precision.

The traditional development of ontologies by human experts is time-consuming and often results in incomplete and inappropriate ontologies. In addition, since ontology evolution is not controlled by end users, it may take too long for a conceptual change in the domain to be reflected in the ontology. Therefore in the work of Ramezani, M. Et al [13], they present a recommendation algorithm in a Web 2.0 platform that supports end users to collaboratively evolve ontologies by suggesting semantic relations between new and existing concepts. They use the Wikipedia category hierarchy to evaluate the algorithm and the experimental results show that the proposed algorithm produces high quality recommendations.

III. STUDENT MODEL

The knowledge about personal traits, skill levels, and learning material access patterns of students is the most important aspect of learner centric adaptive systems. A key requisite for intelligence and adaptation in a learning environment is student modeling. Looking to their own models and reflecting upon the content can benefit students themselves. Considering students as an active and integral part of a learning process, the student models become powerful tools that offer important opportunities to engage students in meaningful learning experiences.

IMS has defined a standard model for learners called IMS learner information packaging (LIP) model. IMS LIP is based on a data model that describes the characteristics of a learner needed for learner modeling. The characteristics are

- Recording and managing learning-related history, goals, and accomplishments
- Engaging a leaner in a learning experience
- Discovering learning opportunities for the learner

In this section, we discuss how the characteristics of a learner can be modeled in different adaptive learning systems.

Han B. et al [14] have developed student model for web based intelligent educational system. The student knowledge is represented by an overlay model, in which the current state of the student's knowledge level is described as a subset of the domain model. The domain independent part of individual student model includes the student's personal information, background and preferences of learning style. The domain specific part contains the student's competence level for each concept node, each unit in the content tree and his overall subject competence level.

In AHAM [15], the student model is also based on overlay model. The concepts known to the user and the user's knowledge about each concept are stored in the student model. The user's knowledge is a vector in a high dimensional space. It maintains a log of visited (concepts covered by those pages) pages. The user's model is updated by the system each time the user visits a page.

In many learning systems, learners are allowed to interact and update their own learning model. In NetCoach [16] student's state is updated either on the basis of test performance or a student can himself update by marking concepts known to him. Similarly Dimitrova et al. explored a collaborative construction of student models promoting student's reflection and knowledge awareness.

In the work by Shi H. et al. [17], learner modeling is done on two different time scales: long term and short term modeling. The long term modeling attempts to model those aspects of a learner that are not expected to change too dynamically. In their work, the short-term modeling is also being performed in two ways: indirectly and directly. Indirect short term modeling includes counting the number of times a learner reviews a learning object, measuring the total time taken to complete the topic. Direct short-term modeling is carried out by assessment on questionnaires that evaluates the learner performance as a skill level. The skill levels are Beginner, Novice, Intermediate, Advanced and Expert.

Most of the modeling approaches mentioned above are relatively simple. The models are slots and values, feature vectors or simple overlays. More complicated representational formalisms, such as Bayesian belief networks can be effectively used to construct student models. Several researchers in different areas have explored the use of Bayesian belief networks to represent student models [18],[19].

Landowska, A. [20] proposed a three-level student model framework that can be applied in educational agents. The model is intended to manage complexity of a student model for adaptive, intelligent and affective agents. The student model representation may be applied in virtual mentors as well as other e-learning software, especially in Intelligent Tutoring Systems.

IV. LEARNING OBJECT REPOSITORY

A learning object repository is storage of learning objects. allows users to search and retrieve learning materials from the repository. Many open learning object repositories like ARIADNE, Multimedia Educational Resources for Learning and Online Teaching etc. are developed for students and faculties. Apart from the manually developed learning object repositories, the World Wide Web contains large number of learning materials. An adaptive learning system can use World Wide Web as a repository for retrieving learning materials.

V. ADAPTIVE RETRIEVAL SYSTEM

Recent years witnessed a growing interest in development of adaptive learning systems where learning materials are selected and presented in adaptive manner, so as to fit each single user as much as possible.

In 1996, Brusilovsky et al. have developed ELE-PE [21], 1996), which provides an educational example based programming environment for learning LISP. The knowledge based programming environment ELE-PE was designed to support novices who learn the programming language LISP. But the limitation of ELE-PE is that it is platform dependent and requires powerful computers for its implementation. This limitation obstructed a wider distribution and usage of the system. To overcome the above limitations, work has been done on the development of web based learning systems and a number of web based adaptive learning systems have been developed. Some of the web-based learning systems are discussed below.

In 1998, Hockemeyer et al. [22] developed adaptive tutoring software (RATH), which combines a mathematical model for the structure of hypertext document with the theory of knowledge space. In the knowledge base, it maintains prerequisite relation between learning objects. Using this prerequisite relation between learning objects and the student model, it presents only those links in a hypertext document to the student for which he knows the entire prerequisites.

KBS hyperbook [23] is implemented for an introductory course on computer science. The adaptation techniques used for this course are based on a goal driven approach. This allows students to choose their own learning goal and get suggestions for suitable *information units* required to reach the learning goal.

ELM adaptive remote tutor [24] is the WWW based version of ELE-PE. It removes the limitations of ELE-PE and provides learning materials online in the form of an adaptive interactive textbook. It provides *adaptive navigation support, course sequencing* and *problem solving support*. The adaptation component of ELM_ART uses the information about *prerequisite* and *outcome* knowledge, which is available with the hypermedia documents.

In ELM_ART, each document is annotated with metadata information, which gives the information about the *prerequisite* and *outcome* of that document. NetCoach [25], the successor of ELM_ART maintains a knowledge base. The knowledge base consists of concepts and these concepts are the internal representations of the pages. The concepts are interdependent. NetCoach can be used via the web and offers templates to describe pages, to add exercises and test items, to adjust the interface and to set parameters that influence different features of the courses. With NetCoach, authors can create fully adaptive and interactive web based courses. The system guides the user to learn the prerequisite pages before suggesting the current concept. The knowledge base delivers information for adaptation by giving predecessors and successors for each document in the document space.

The work by Shang Yi et. al [26] present an intelligent agent for active learning. A student's learning related profile such as his learning style, background knowledge and the competence level are used in selecting and presenting the learning materials.

Metalinks [27] is an authoring tool and also a web server for adaptive hypermedia. The pages visited by the user are kept track of by the system. On the main page, a mark appears indicating whether the user has previously seen that page. It uses tree structure (parent, child and sibling) to organize the content. A parent page is the summary, or the overview, or the introduction of all of its children pages. Child nodes of any page cover the material in greater depth while the sibling pages contain the material at the same level.

The web is a large open corpus containing a variety of learning materials and can be used to enhance and personalize the learning experience in e-learning scenarios. Dolog et al. [28] show in their work that personalized e-learning can be realized in the semantic web. They integrate the closed corpus adaptation and global context provision in a personal reader environment. The primary goal of their work is to support the learners in their learning in two ways. The two ways are *local context provision* and *global context provision*. The *local context provision* provides the learner with references to summaries, general information, detailed information, examples, and quizzes from the closed corpus. *Global context provision* provides the learner with references to additional resources from the semantic web, which is not available in the closed corpus but might further help to improve his background on the topics that they want to learn.

Fouad et al [29] have developed an adaptive e-learning system based on fuzzy clustering approach. The student model is constructed by analysing the web-log to extract the interested terms in the visited pages by the learners. Then, the fuzzy clustering approach and statistical k-means clustering method is used to predict student's interest for delivering learning contents from semantic web.

VI. CONCLUSION

The main objective of an adaptive e-learning system is to deliver contents in a customized and adaptive manner. It has observed that domain ontology plays a crucial role in the development of the system. The domain ontology is the representation of the domain knowledge. Good design principles adapted in designing the domain ontology would help the system in selecting the proper learning materials for teaching. Adaptive retrieval means that the system moulds itself to cater to different needs of different students and to achieve it the system needs to judge the student's knowledge state and their preferences. Thus, a robust, flexible and comprehensive student model is required to build a real adaptive e-learning system. In this paper, the work done in the area of domain ontology, student model and different strategies for adaptive retrieval has been reviewed. A brief survey of adaptive learning systems is also presented.

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