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Adaptation and Personalization in Web-based Learning Support Systems

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Abstract

In order to achieve optimal efficiency in a learning process, individual learner needs his/her own personalized assistance. For a web-based open and dynamic learning environment, personalized support for learners becomes more important. This paper demonstrates how to realize personalized learning support in dynamic and heterogeneous learning environments by utilizing Adaptive Web technologies. We focus on course personalization in terms of contents and teaching materials that is according to each student's needs and capabilities. To accomplish this, a conceptual model based on the Knowledge Structure is presented. Using the hierarchy and association rules of the concepts, we can organize courses and lessons as a multi-layer knowledge network, which has a reasonable classification and interdependent relations among the knowledge. With retrieval based on concept and association among the concepts, we propose a framework of knowledge structure based visualization tool for representing a dynamic learning process to support students' deep learning, efficient tutoring and collaboration in web-based learning environment.

1. Introduction

Web based learning offers many benefits over traditional learning environments and has becoming very popular. The web is a powerful environment for distributing information and delivering knowledge to an increasingly wide and diverse audience. Typical web-based learning environments, such as Web-CT [1], Blackboard [2], include course content delivery tools, quiz module, grade reporting systems, assignment submission components, etc. They are powerful integrated learning management systems (LMS) which support a number of activities performed by teachers and students during the learning process [3]. Students who study a course on the Internet tend to be more heterogeneously distributed than those found in a traditional classroom situation. Therefore, the learning material should be presented in a more personalized way.

In a web-based learning environment, instructors provide online learning material such as text, multimedia and simulations. Learners are expected to use the resources and learning support tools provided. However, it is difficult and time consuming for instructors to keep track and assess all the activities performed by the students on these tools [4]. Moreover, due to the lack of direct interaction between the instructor and the students, it is hard to check the students' knowledge and evaluate the effectiveness of the learning process. When instructors put together the learning material (such as class notes, examples, exercises, quizzes, etc) on-line, they normally follow the curriculum and pre-design a learning path for the students, and assume that all the learners would follow this path. Often this path is not the optimal learning sequence for individual learners, and does not satisfy the learner's individual learning needs. This is typically the teacher-centered "one size fits all" approach.

Not all students have the same ability and skills to learn a subject. Students may have different background knowledge for a subject, which may affect their learning. Some students need more explanations than others. Other differences among students related to personal features such as age, interests, preferences, emotions, etc. may also affect their learning [5]. Moreover, the results of each student's work during the learning session must be taken into account in order to select the next study topics to the student [6].

By utilizing adaptive web technologies, particularly, Adaptive Educational Hypermedia (AEH) systems it is possible to deliver, to each individual learner, a course offering that is tailored to their learning requirements and learning styles [7]. These systems combine ideas from hypermedia and intelligent tutoring systems to produce applications that adapt to meet individual educational needs. An AEH system dynamically collects and processes data about student goals, preferences and knowledge to adapt the material being delivered to the educational needs of the students [8]. Since the learning process is influenced by many factors, including prior knowledge, experience, learning styles and preferences, it is important that the student model of an AEH system accommodates such factors in order to adapt accurately to student needs.

In this paper, we first provide an overview of concepts and techniques used in adaptive web-based learning support systems. Then we discuss and examine the use of student individual differences as a basis of adaptation in web-based learning support systems. This paper proposes a framework of knowledge structure based visualization tool for representing a dynamic and personalized learning process to support students' deep learning.

2. An Overview and the Basic Architecture of Web - based Adaptive Educational Hypermedia Systems

Adaptive hypermedia systems is one step forward of hypermedia-based systems. It combined the technologies of adaptive systems and hypermedia. The main purpose is to improve the usability of traditional hypermedia through the integration of intelligent techniques. It enables a system to arrange and present customized information and dynamic navigation support for Web-based learning material [8]. It has been shown in the literature that the efficient method of teaching is individualized teaching [9]. The ability to adapt and tailor the learning content to an individual learner's needs can significantly improve the teaching/learning process. Therefore, most of the developed adaptive hypermedia systems are applied in the field of education.

According to Brusilovsky [8], adaptive hypermedia systems can be defined as all hypertext and hypermedia systems that accommodate some user characteristics into the user model and apply this model to adapt various aspects of the system to the user. The major components of the system are the domain model, the user model and the ability to adapt the hypermedia using the user model (adaptation model). According to De Bra [10], an AHS builds a user model by observing the user's browsing behavior or by testing to determine what the user's background, experience, knowledge and interests are. These user characteristics are then used by the system to personalize the knowledge presentation. The presentation is adapted to the user model, and the user model is constantly updated as the user reads and interacts with the presentation. Figure 1 shows the classic loop of user modeling and adaptation in the system.

Adaptive hypermedia systems are the result of combining studies in the fields of hypermedia and user modeling. They represent an important research direction in adaptive systems based on user modeling [8]. Their main goal is to improve hypermedia functionalities through personalization. These systems not only allow users to browse and explore the learning material freely, but also are able to dynamically adapt the instructional sequence to the particular user knowledge level and learning goals. They provide intelligent guidance and support the user in acquiring knowledge [5]. Such system is able to adapt information and its presentation to each individual user's needs, and dynamically support the navigation through hypermedia material.

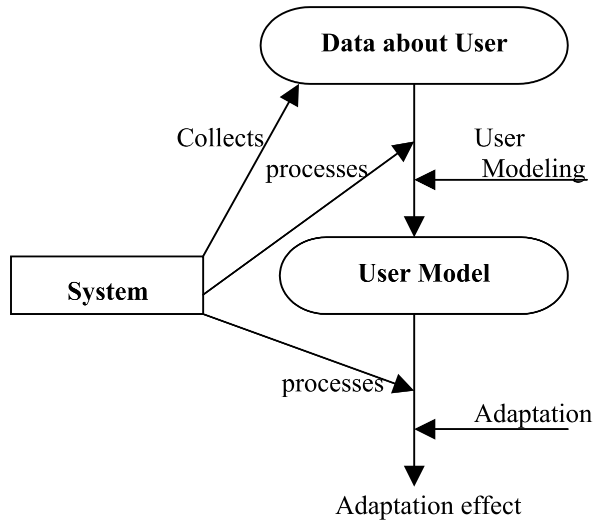

Figure 1. Classic "User modeling - adaptation" in adaptive systems [8]

Brusilovsky [5] presented the fundamental techniques and methods of how to achieve various adaptations. They are summarized as adaptive presentation and adaptive navigation support. Adaptive presentation is the techniques used to adapt the content of a web page based on user model. They include adaptive text presentation and adaptive multimedia presentation. Adaptive navigation support is the techniques used to modify the links accessible to the user at a particular time. They include: direct guidance, adaptive link sorting, adaptive link hiding, adaptive link annotation and map adaptation.

Web-based adaptive educational hypermedia (WBAEH) is one of the earliest and most popular applications of AHS. It is based on two earlier versions of adaptive educational systems: intelligent tutoring systems (ITS) and adaptive hypermedia systems (AHS). WBAEH actually combines two opposed teaching approaches: tutor-centered traditional AI based systems and the dynamic learner-centered browsing approach of hypermedia systems [11]. The basic components of the systems are domain model, the student model and the adaptation model. To be able to adapt itself to an individual student, the system has to be aware of the teaching domain, the individual students and their knowledge and has to monitor their learning progress. Therefore, beside adaptation model, the domain model and the student model are the most important parts of any adaptive system [12]. The relationship between all three models is shown in Figure 2.

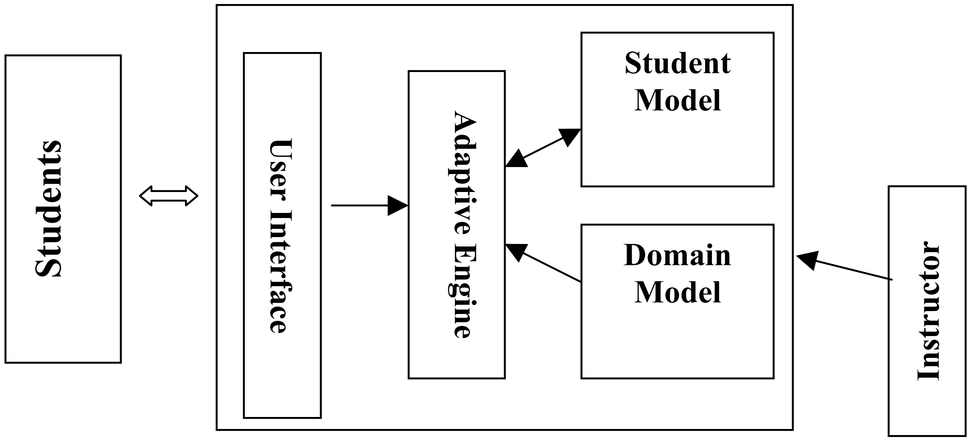

Figure 2. Architecture of Web-based Adaptive Educational System

2.1 Student model

The student model is the essential component in personalized learning. It is the student model that builds and maintains the system's understanding of the student. The learning process in a real adaptive educational environment is complex. A comprehensive student model should contain all features of the learner's behavior and knowledge that affect their learning and performance [13]. The adaptability of the system is influenced by the characteristics of the student contained in the student model. It is a complicated and challenging task to construct such a model containing all of student' features. In practice, most systems only consider those important and easy to implement features for use in design of the student model. Students' cognitive attributes such as emotions, social features have been ignored.

Table 1 shows some of the main student characteristics used for student modeling. The student model will build a student profile that stores information for each student. When constructing the student model, there are several things need to be considered: what characteristics of the student should be gathered into the model and how to collect them; how to represent the collected information in the system; and how to form and update the model. Information about the student in the student model can be categorized as domain independent and domain dependent, or divided into knowledge component and interfaces component; or as static and dynamic properties. Static properties of the student model [14] covers student's personal characteristics such as age, gender, background knowledge, student's preferences etc. These properties are normally gathered at the beginning of the learning process by using questionnaires and tests. The dynamic properties of the student model are the information about the student interaction with the system [15]. It includes student's knowledge, learning style, motivation, current goals, plans and believes, learning activities that have been carried out, objectives that have been achieved. The dynamic properties of the student model are collected from test results, problems solving behavior, browsing behavior, visited concepts, or time spent on page, total session time, navigation path, or searching for more information. This information is dynamically being gathered during the learning process and used for updating the student model. There are many different techniques can be used for constructing the student model [13]. Such as: Bayesian methods; Machine learning methods (rule learning, learning of probabilities, instance-based learning); Logic-based methods; Overlay methods; Stereotype methods.

Background	Experienced ; Non-experienced
Learning Style	Activist; Reflector; Theorist; Pragmatist (based on Honey-Mumford theory [15])
Knowledge	Novice; Intermediate; Expert;
Preference	Color; Size; Font
Goals	Global ; Local

Table 1. Student Model with individual differences

2.2 Domain model

The domain model contains a collection of learning materials that the adaptive hypermedia is intended to use as a resource. It supports composite concepts and concept relationships. The concepts are in a form of a hierarchical structure. For example, a course module in the system can be divided into a number of concepts with a particular value for each concept according to the level of difficulty. Each concept consists of several pages depending upon its complexity. The relationship between one concept and another can be expressed in terms of requirements such as pre-requisites. Students studying on a particular concept can undertake certain tests or quizzes at any time to evaluate their understanding for that concept. In order to move on to another higher-level course content, students must pass a threshold score that is defined in the relationship rules.

2.3 Adaptation model

The adaptation model describes the adaptation strategies. Most of the systems use rules to describe adaptation strategies. The adaptation rules specify how a page is presented to the student according to his/her own student model. Every time the student is assigned a score for a test/quiz, the student model will update his/her level of knowledge.

3. Adaptation and personalization support in WBLSS

Individuality means that a web-based learning support system [17] must adapt itself to the ability and skill level of individual student. Adaptive methods and techniques in learning have been introduced and evaluated since the 1950's in the area of adaptive instruction and the psychology of learning [18]. Adaptive instructional methods adapted the content of the instruction, the sequencing of learning units, the difficulty of units, and other instructional parameters to the students' knowledge. These methods have been empirically evaluated and shown to increase learning speed and to help students gain a better understanding through individualized instruction.

According to Brusilovsky [8], there are several goals that can be achieved with adaptive navigation support techniques, although they are not clearly distinct. Most of the existing adaptive systems use link hiding or link annotation to provide adaptive navigation support. Link hiding is currently the most frequently used technique for adaptive navigation support. The idea is to restrict the navigation space by hiding links that do not lead to the relevant pages. That means the pages are not related to the users current goal or they are not ready to be seen. Users with different goals and knowledge may be interested in different pieces of information and they may use different links for navigation. Irrelevant information and links just overload their working memories and screen [6].

De Bra [7] presented a course that uses a system they developed to track student progress and based on that, generate document and link structure adapted to each particular student. Links to nodes that are no longer relevant/necessary or links to information that the student is not yet ready to access are either physically removed or displayed as normal text.

Da Silva et al [19] use typed and weighted links to link concepts to documents and to other concepts. The student's knowledge of each concept is used to guide him/her towards the appropriate documents.

Adaptation may be supported according to different student characteristics, including his/her preferences of browsing hyperlinks. Five main features are identified for maintaining adaptation [8]. They include student goals, student knowledge and familiarity with the domain, student qualification, experience in the hyperspace, and personal preferences. Most of the adaptive systems use knowledge representation and domain models and consider the student knowledge for providing adaptation. Student knowledge is often represented by an overlay model, which is based on the domain knowledge base. The domain knowledge base provides the structural description of the subject area. That represented as concepts and relations between them.

Most of WBAEH systems use complex and multi-layered semantic networks for representing domain knowledge. The semantic relations describe relations among the concepts. There are two common models widely used, namely overlay model and stereotype model. The overlay model keeps track of the student knowledge about every element of the domain knowledge base and covers the whole domain. The idea is to mark each knowledge item with a value calculated as student knowledge. The value could be binary, qualitative or quantitative. Overlay models are powerful and flexible. They contain information about students' familiarity with different topics. It can be simplified to distinguish several classes of group users. The drawback of overlay model is that it does not consider student's misconceptions. There may be stereotypes for every dimension considered in the domain (novice, intermediate, expert). The stereotype user model is simpler and easier to initialize and maintain comparing to overlay model. Sometimes the two models are combined. At beginning, the system classifies the user to some stereotypes in an interview or test, then after collecting enough information about student performance, the system switches to an overlay model.

4. The Proposed Framework Based on KSM

A primary concern for web-based learning support system is the design of an appropriate structure so that a student can easily and naturally find the most relevant information depending on his/her needs [17]. we presented a model of personalization that attempts to assist learners in their learning based on their assessment results on the learning materials. It provides feedback on their performance and suggests the most suitable learning content to be learned next. Figure 3 shows the sample screen shot of adaptive course material.

Figure 3: Screen shot of the demonstration of the adaptive course material

In this paper, we propose a framework for integrating personalization and collaboration in web-based learning management environment. To support student-centric learning and to encourage students to actively engage in the learning process to construct their own learning and define their learning goal, knowledge structure map[20] is used as an effective learning aid for "Data Structure and Algorithm Analysis" course.

Knowledge structure map (KSM) is a method designed to produce a visual map of individual knowledge components comprising a study [21]. These components or map nodes are linked by lines that show learning dependencies. The map show clearly the pre-requisite knowledge needed for students in order to progress in the study. The nodes on the map provide access to learning material that allows the learner to acquire the particular piece of knowledge selected. A learning task can be made clear by using a KSM. The map will clearly show the learning goal, where to start and the paths to be taken.

Figure 4 shows a sample knowledge structure map for the “Data Structure and Algorithm Analysis” course.

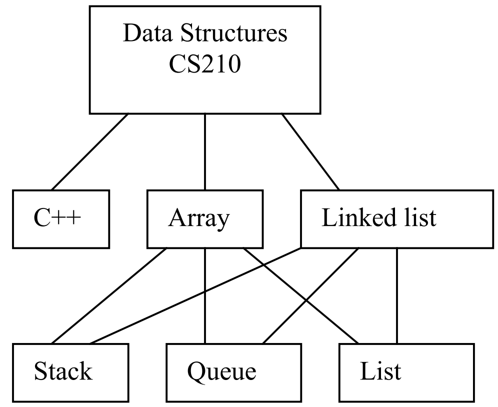

Figure 4. Sample partial knowledge structure map

According to Ausubel [22], knowledge structure maps foster meaningful learning by teaching the connections among course concepts, and promote meaningful learning by encouraging students to generate their own connections between concepts.

Figure 5 and Figure 6 demonstrate the difference between an expert and a novice' knowledge structure.

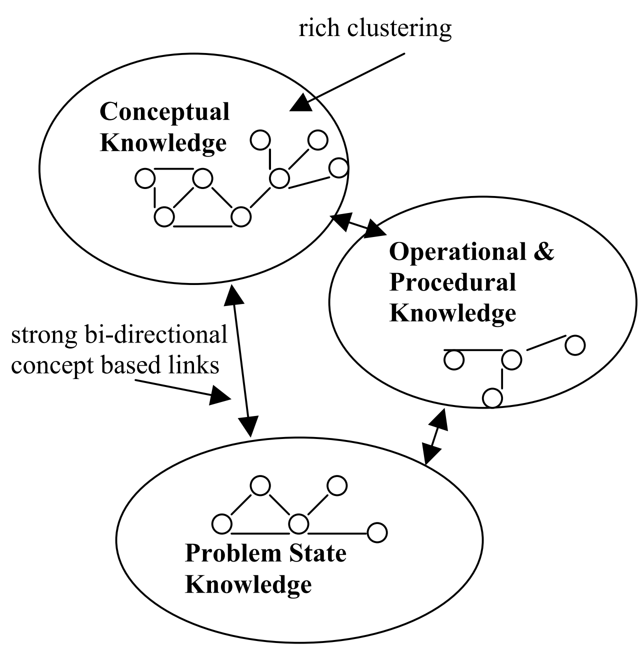

Figure 5. Expert's knowledge store [23]

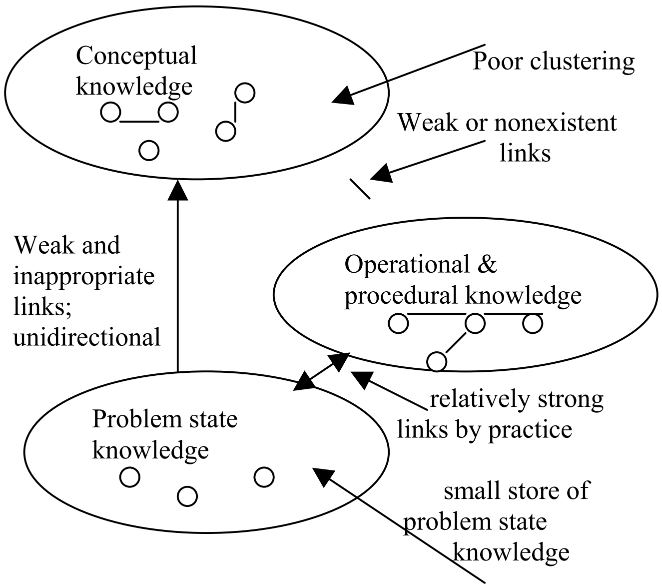

Figure 6. Novice's knowledge store [22]

From Figure 5 and Figure 6, we can see that the differences of an expert and a novice knowledge structure. The expert knowledge structure represents a strong linkage between conceptual knowledge and problem state knowledge, whereas the novice knowledge shows a weak linkage.

In the knowledge structure map, each node represents a piece of knowledge and the label in the box is the name of this knowledge. Links or arcs between nodes are unidirectional. A link shows that it is necessary for a student to know a particular piece of knowledge before it is possible for that student to have a full and detailed understanding of another piece of knowledge.

In order to provide an in depth understanding of the fundamental data structures and to motivate the students, a web-based adaptive course with analysis tool based on student learning styles has been proposed. The idea here is to create a tool for students and teacher to visualize and trace the learning process. Since viewing concepts in a different way can help to gain additional insight into knowledge, we see lots of opportunities in this new approach. Our main goal is to involve the students to take active role in planning his/her studies. The system should encourage student to go deeper into learning, to evaluate his/her studies, and to find out the most appropriate learning paths.

When the KSM is connected to student database, the system reflects the study process. All the concepts a student has learned can be marked with a certain color. Some comments can be added to the map. This will help students and the teacher to analyze the study process. For teachers who want to see how their students are doing, this allows quite efficient way to do it. The teacher can easily see her students' progress, strength and weakness and can help the student in future studies. Whenever a student adds a new concept to his/her personal knowledge store, the system suggests and recommends other concepts related to the concept to be added to the structure. With this feature, a student can build a logical map quickly and observe all the time the structure of his/her studies. The students' knowledge maps of the course can also be implemented and presented as animations. With an animation, the student can see all the time how the learning process is proceeding and which concepts are recognized to be similar. Personalized presentation based on each student knowledge level can be presented visually. The maps can be compared. This approach helps the students to get insight into the maps being compared. This makes it a reasonable platform for supporting students' collaboration. Students can compare his/her knowledge map with the instructor (expert), peers, or mentors. Through the process, student can view his learning process, and the dynamic changes of the student knowledge map will indicate how the student knowledge grows.

We can also construct dynamic and clickable knowledge structure maps by utilizing the web technologies. For example, student click on the node indicating “Stack”, it would give options for simulation of the algorithm; examples and demos of how to use it; or simple text file of the formal definition of stack. When suitable knowledge structure is designed, the system can be used for effective learning, tutoring, problem solving, or diagnosing misconceptions.

5. Conclusion

Our primary goal is to provide an adaptive learning support environment that will effectively accommodate a wide variety of students with different skills, background, and learning styles. The web offers dynamic and open learning environment. Based on the student-centered philosophy, personalization and adaptation are the important features for the Web-based learning support systems.

In this paper, we examined and discussed the adaptation and personalization in the web-based learning support system based on the student model. It is a challenging task to develop a fine-tuned WBLSS due to the uncertainty and complexity of the student model, particularly the students’ cognitive attributes.

In order to support the students' deep learning and understanding the difficult concepts about algorithms and data structures, we proposed a feasible framework by dynamically constructing knowledge structure map during the learning process. It can be visualized and clickable. Student can use his/her knowledge structure map to compare with the instructors or peers knowledge structure maps. When suitable knowledge structure is designed and constructed, the system can be used for effective learning, tutoring, problem solving, or diagnosing misconceptions.

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