Published in the Proceedings of ED-MEDIA 2001, Tampere, Finland, June 25-30 2001, 1516-21

Architectural Aspects of a Web-Based ITS for Teaching New Information Technologies

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Abstract: In this paper, we present the architecture of a Web-based Intelligent Tutoring System (ITS) for teaching new information technologies (e.g. Internet). The system is addressed to high school teachers. It contains a variety of courses starting from introductory topics addressed to beginners and scaling up to more advanced topics. Its distinctive functionality is its ability to tailor the presentation of the educational topics to the users' diverse needs. This is accomplished by using AI techniques to record each user's learning model as well as the various pedagogical decisions. The teaching process is under the control of a hybrid expert system.

1 Introduction

Numerous computer-based systems have been used in education during the last decades. The first such systems were called Computer Aided Instruction (CAI) systems. Those systems were quite effective in helping learners. A major disadvantage, however, was the fact that they did not take into account the user's knowledge level and skills. They were thus unable to adapt instruction to the individual's needs. These drawbacks gave rise to a new generation of education systems known as Intelligent Tutoring Systems (ITSs). An attractive feature of these systems is their ability to adapt the presentation of the teaching material to the needs and abilities of the individual users (Aiello et al. 1993; Woolf 1992; Vassileva 1997; Stern & Woolf 1998; Brusilovsky, Kobsa & Vassileva 1998). This is achieved by using Artificial Intelligence techniques to represent the pedagogical decisions as well as information regarding each student. For these reasons, ITSs have become extremely popular during the last years and have been shown to be quite effective at increasing their users' performance and motivation (Beck et al. 1996).

ITSs were usually developed as stand-alone systems. However, the emergence of the World Wide Web offers the potential for revolutionary changes in education at all levels. The Web gives an educational system such as an ITS, the chance to reach many real users. In this way, its functionality can be tested with numerous and diverse cases (Stern, Woolf & Kurose 1997).

In this paper, we describe the architecture of a Web-based ITS for teaching new information technologies (e.g. Internet). The system is addressed to high school teachers. It contains a number of courses starting from introductory concepts appropriate for beginners and scaling up to concepts for more advanced users. The system models the students' knowledge state and abilities. Based on this information, the appropriate pedagogical strategy for teaching each individual user is selected. Moreover, the corresponding teaching material is chosen.

This paper is organized as follows. Section 2 presents an overview of the system's architecture and afterwards describes in detail its component parts. Section 3 deals with implementation issues. Finally, Section 4 concludes.

2 System Description

During the last decade, computer technology has been introduced in many Greek high schools. A variety of computer-based systems have been used to support teaching activities, thus increasing the students' performance and motivation. Teachers are also provided with various generic tools facilitating the creation of educational applications. It is clear though that they needed some sort of training in new technologies. Teaching, however, people with quite different knowledge backgrounds may turn out to be a rather difficult task. Our Web-based system intends to cover this gap by offering a user-adapted framework for teaching new information technologies.

Conventional Web-based educational systems exhibit some special characteristics such as the following:

(i) They are addressed to people having different goals, interests and knowledge level.
(ii) The studying motives of the traditional teaching process due to the competition among the trainees and the direct contact with the tutor are missing.
(iii) The courses are static meaning that they do not adapt to the trainees' needs.
(iv) The Web imposes restrictions on the users' interaction with the system.
(v) The Web as an educational medium does not offer mechanisms of focusing the teaching process on specific pedagogical goals.

Our system is aiming to develop methods and tools dealing with the teletraining of persons with different traits and skills. The following figure (Fig. 1) depicts the basic architecture of the ITS. It consists of the following components:

(a) the domain knowledge containing the teaching material
(b) the user model which records information concerning the user
(c) the pedagogical model which encompasses knowledge regarding the various pedagogical decisions
(d) the user interface.

As shown in the figure, the domain knowledge and the pedagogical model are parts of an expert system aiming to control the teaching process. The remaining part of this section will elaborate on the system's key aspects.

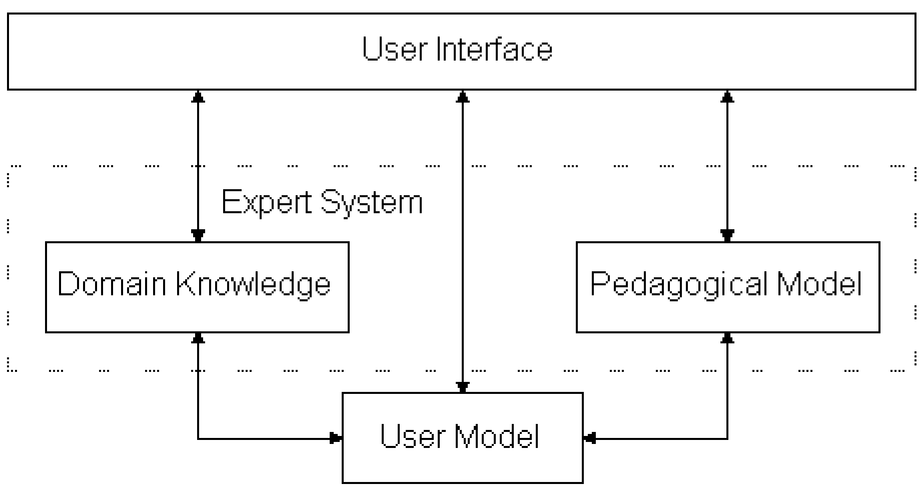

Figure 1: Architecture of the ITS

2.1 Domain Knowledge

The domain knowledge contains the teaching material presented to the system's users. The teaching material involves a variety of courses starting from introductory topics and scaling up to more advanced ones. The educational content of each course is distributed in sections, subsections and topics.

Each course unit is associated with a number of knowledge concepts. These can be either goal or prerequisite concepts. Prerequisite concepts are required to be known by the user in order to grasp the knowledge related to the goal concepts. The concepts are related to each other by describing each one's prerequisites and outcomes.

Each topic comprises a series of educational screens containing theory as well as examples. The examples assist the user in grasping the theory's key points. The number of presented examples depends on the user model. A user with high acquisition skills will be presented a small number of examples in contrast to a user with low such skills. The teaching material also contains various problems based on the examples. Each problem is associated with an explanation assisting the user in case of a wrong answer.

The course units are presented in a variety of ways, such as interactive simulations, hypertext, appropriate images and animations. This depends on the multimedia type the user prefers to interact with. These user preferences are part of the user model (section 2.2). To facilitate the selection of the material, each course unit is associated with attributes denoting which type of user preferences it corresponds to.

2.2 User Model

The user model records information concerning the user and regarding his/her knowledge state and traits (Beck et al. 1996; Anderson 1993). This information is vital for the system's operation according to the user's needs. However, such data may be difficult to gather because it is not easy to represent the user's knowledge abilities. Moreover, the nature of the Web imposes certain constraints on the system's perception of the user. For the time being, it is difficult and time-consuming to record every user action. Furthermore, it is clear that the user model should not contain unnecessary information so that the system will not be encumbered with useless interactions.

A user model used quite often in the past by other educational systems and which is used in our system is the overlay model (Carr & Goldstein 1977). In this model, the user's knowledge is considered to be a subset of the knowledge perceived by an expert in the learning field. Using this representation, the system presents the educational material to the user so that in the end his/her knowledge matches the expert's knowledge. A primary disadvantage of the overlay model is its inability to represent possible misconceptions from the user’s part. For this reason, other learning models are often used such as the bug catalogue or its successor, the bug-parts-library.

The user model is based on the concepts associated with the course learning units. Further information modeled in the system concerns the user's acquisition and retention skills. Acquisition pertains to how fast a user learns new concepts. The system's response during its interaction with a user determines how high or low these skills are estimated to be. In addition, the user preferences regarding the multimedia type (e.g. text, images, and animations) of the course units is recorded. These preferences are recorded when the user obtains an account but he/she also has the option to change them during the teaching process.

Only registered users have access to the system. In this way, the system is able to record their knowledge state as well as their learning skills. A registered user identifies himself/herself to the system whenever logging on by giving a valid login name and password. An unregistered user must first submit to the system information about himself/herself (e.g. name, email address, multimedia type preferences) in order to obtain an account and access to the system's functionality.

2.3 Pedagogical Model

The pedagogical model represents the teaching process. It provides the knowledge infrastructure in order to tailor the presentation of the teaching material according to the information contained in the user model. The pedagogical model encompasses decisions involving the various teaching strategies. These strategies determine how a teaching course should be planned. Moreover, the pedagogical model possesses knowledge regarding the selection of the various course units according to the user’s preferences.

2.4 Expert System

The pedagogical model and the domain knowledge are parts of an expert system controlling the teaching process. The expert system has an inference engine in order to make decisions based on the known facts. In addition, explanations concerning the solution of complex problems are provided.

Symbolic rules constitute a popular knowledge representation scheme used in the development of expert systems. The corresponding rules reflect an expert's knowledge in the field of educational software and they are elicited mainly through interviews. Rules exhibit a number of attractive features such as naturalness, modularity and ease of explanation. They are a typical approach to symbolic knowledge representation. One of their major drawbacks is that the interaction with the expert may turn out to be a bottleneck causing delays in the system's overall development.

During the last years, artificial neural networks are used quite often in the development of expert systems. Neural networks represent a totally different approach to the problem of knowledge representation known as connectionism (Gallant 1993). Some advantages of neural networks are their ability to obtain their knowledge from training examples (reducing the interaction with the experts), their high level of efficiency and their ability to represent complex and imprecise knowledge.

In our system, we adopt a hybrid approach integrating symbolic rules with neurocomputing (Hatzilygeroudis & Prentzas 2000). Our goal is to augment the corresponding advantages of these two knowledge representation formalisms and to simultaneously minimize their disadvantages. Other known hybrid approaches have proven to be quite effective (Medsker, 1994).

2.5 User Interface

The user interface is responsible for the system's interaction with the user. Due to the fact that it is a layer of the system that communicates directly with the user it should be carefully designed (Kommers, Grabinger, Dunlap 1996).

Primary aspects of the system's user interface are the following:

(a) Interactions, flow, or navigation between screens or other various parts of the system
(b) Interrelationships between messages within the system
(c) Screen designs and
(d) Messages to the user that keep him informed and grasp his/her interest. This feedback takes the following forms:
  (1) Status messages will be used to show progress of a task being performed.
  (2) Warning messages let the users know the consequences of the action to be performed.
  (3) Correctness feedback indicates whether an action or response is correct or not.
  (4) Navigational feedback shows the users where they are in the program. This is particularly important because the structure of the system will not be necessarily hierarchical.

We can distinguish two basic views as far as the users are concerned:

(i) *General view:* In the general view, the user can access all available teaching material by navigating through the sections, subsections and the topics of the application.
(ii) *Administrator view:* In the administrator view, the user can establish login names and passwords for the users of the system. Furthermore, the user can update the pedagogical model and the domain knowledge either by inserting new items or changing and removing existing ones.

Only the system's administrator has access to the administrator view. The general view is used by the trainees as well as by the administrator.

2.6 Offline Communication Among Users

The system provides an 'offline' way of communication among the system's users via an electronic bulletin board. The bulletin board is a shared location for posting and viewing electronic announcements in a simple text format. Each announcement contains its subject, its submission date, the author name and its body. The user is able to send replies to announcements and replies to replies creating thus a chain of messages. Furthermore, he/she can sort all types of announcements according to their subject and submission date, "filter" the announcements he/she wants to view depending on their submission date. Additionally, the user sees which announcements were altered or posted later than the last time he/she logged on the system. The purpose of the bulletin board will be to increase the collaboration among the system users.

3 Implementation Aspects

The system is still under development and a prototype of it is on the way. The development of the system is based on the Microsoft Internet Information Server for Windows NT. The MS SQL Server is used to implement the databases containing the educational material and users' profiles. Active Server Pages and C CGI scripts manipulate the information stored in the databases and dynamically produce the contents of the applications presented to the users.

4 Conclusions

In this paper, we describe the design of a Web-based Intelligent Tutoring System (ITS) for teaching new information technologies. The system is addressed to high school teachers. It will offer a variety of courses starting from introductory topics addressed to beginners and scaling up to more advanced topics. The system tailors the presentation of the teaching material to the diverse needs of its users. It consists of the following four components: the domain knowledge, the user model, the pedagogical model and the user interface. The domain knowledge contains the teaching material. The user model records information concerning the user's knowledge state and preferences. The pedagogical model encompasses the various pedagogical decisions regarding the planning of the course and the selection of the course units based on the user's preferences. Finally, the user interface is responsible for the interaction with the users trained in the specific teaching subject and with the system's administrator. A hybrid expert system incorporating the domain knowledge and the pedagogical model controls the teaching process.

The system will acquaint high school teachers with modern computer technologies by enriching their knowledge in education software. Its adaptability will make some kind of teaching possible without the assistance of a tutor. The Web's universality will enable many users to gain access to the system's operations and consequently, its functionality will be tested with numerous and diverse cases. Significant conclusions regarding the system's efficiency will thus be drawn. A future goal will be to use methods of Distributed Artificial Intelligence (Solomos & Avouris 1999) to achieve communication between our system and other intelligent systems with similar subject domains such as the adaptive hypermedia system described in (Papanikolaou, Magoulas, Grigoriadou 2000).

Acknowledgements

This work is supported by the Greek General Secretariat of Research and Technology within the framework of the research project PENED99ED234.

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