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Combining Expert Systems and Adaptive Hypermedia Technologies in a Web Based Educational System

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Abstract

In this paper, we present a web-based intelligent education system to help students in the context of an AI course. We concentrate on the adaptivity and student evaluation aspects of the system. Adaptivity refers to the capability of the system to adapt teaching to student needs, specified by the student model characteristics. Student evaluation refers to the evaluation of the knowledge level of a student, which is one of the most important characteristics, with regards to taught concepts. Adaptive hypermedia techniques, like graphical link annotation, and an intelligent technique, i.e. a rule-based expert system, are used to achieve the above goals. An evaluation of the system showed encouraging results as far as its usability and learning are concerned.

1. Introduction

Intelligent Tutoring Systems (ITSs) constitute a popular type of intelligent education systems. ITSs take into account the user's knowledge level and skills and adapt presentation of the teaching material to the needs and abilities of individual users. This is achieved by using Artificial Intelligence (AI) techniques to represent pedagogical decisions as well as domain knowledge and information regarding each student. ITSs were usually developed as stand-alone systems. However, the emergence of the WWW gave rise to a number of Web-based ITSs [1], a type of *Web-Based Intelligent Educational Systems* (WBIESs) [4].

Another type of educational systems is Adaptive Educational Hypermedia Systems (AEHSs) [1]. This type of systems is specifically developed for hypertext environments such as the WWW. The main services offered to their users are adaptive presentation of the teaching content and adaptive navigation by adapting the page hyperlinks. Compared to 'classical' ITSs, they offer a greater sense of freedom to the user, since they allow a guided navigation to the user-adapted educational pages. Furthermore, they dynamically construct or adapt the educational pages in contrast to 'classical' ITSs in which the contents of the educational pages are typically static. Enhancing AEHSs with aspects and techniques from ITSs creates another type of WBIESs.

Although WBIESs can be considered as products of combinations of ITSs and AEHSs, most of existing systems use techniques mainly coming from one of those types of systems (e.g. [2, 6, 7, 8]) So, WBIESs that use techniques from both its origins are an interesting case. In this paper, we present a WBIES that uses adaptive hypermedia techniques (e.g. adaptive annotation) for lesson planning and a rule-based expert system for student evaluation.

The structure of the paper is as follows. Section 2 presents the system architecture. In Section 3, the domain knowledge structure is described. Section 4 deals with the user model, whereas Section 5 with the adaptation capabilities of the system. Section 6 concentrates on how knowledge level of a student is estimated and Section 7 explains how the expert system is involved in that. In Section 8 an evaluation of the system is presented and finally Section 9 concludes.

2. System Architecture

The architecture of the system is depicted in Figure 1. The system consists of four main components: question database (QDB), user interface (UI), LISP application (LA) and adaptive hypermedia application (AHA).

AHA consists of three other components: domain model (DM), student modeling (SM) module and expert system (ES). The user of the system is an individual student. SM component contains all the necessary information about students, like their preferences, interests, knowledge level, etc. When a student logs on for the first time an initial profile is set for him/her (by querying), so the system has initial data for adaptation.

The student communicates with the system through UI, which controls the whole learning process. An embedded control unit is used to achieve this. The tutoring part of the system is in fact the AHA sub-system. The teaching material, the concepts and their structure are saved in DM. DM specifies a general sequence in which concepts should be presented and the prerequisite relations between concepts.

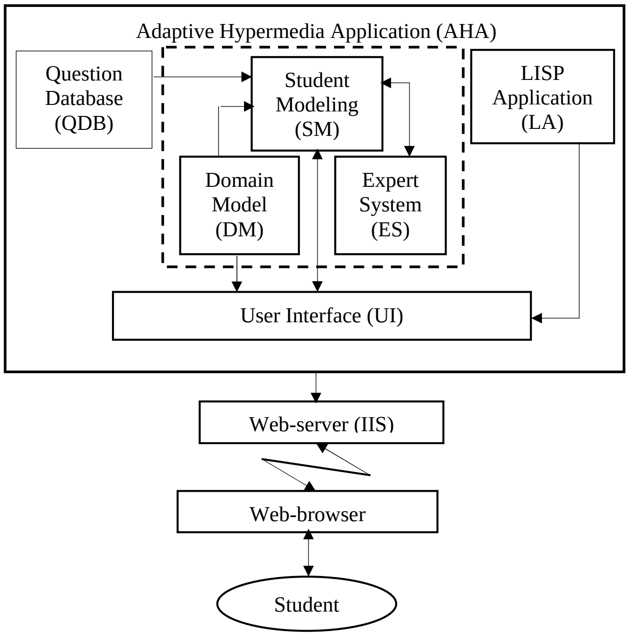


Figure 1. System Architecture

Adaptation of the system to the user has to do with the SM component, which contains information about his/her individual characteristics and progress. SM, after having received the proper information from DM and QDB, creates an appropriate test. After the student has posted his/her answers to the test, the system evaluates him/her with the help of ES. SM gives ES all the necessary information and ES returns its result to SM. Then, UI presents the result.

AHA implements another kind of adaptation: adaptive presentation and adaptive navigation. It gathers all necessary knowledge from SM, DM or both, processes that information and sends it to the presentation unit.

3. Domain Knowledge

The domain knowledge of the system, at the moment, concerns predicate logic as a knowledge representation language. Domain knowledge is structured in a tree-like way, called the *domain tree*. The root of the tree is the above *field*. The field is divided in *subjects* and the subjects into *topics* which are the leaves of the tree. Each topic deals with a number of *concepts*. Topics may have common concepts.

The domain tree is displayed in the navigation area of the user interface (at the left side of the screen). From that tree the student can choose a topic, which constitutes a *learning goal*. Each topic corresponds to a *topic page*, which is an ASP page. Only topics, in the domain tree, correspond to displayable material. The selected topic page is presented in the content area (which resides at the centre and the right part of the screen). Each topic page contains an *ordered list* of concepts. Each concept is linked to the corresponding *concept page*. Concept pages constitute the real teaching material.

The teaching material, apart from concept pages, however, includes all the available *questions*, which are stored in the QDB (see Figure 1) and are used for the creation of the *tests*, mentioned in Section 2. Each topic page contains a link to a test. Each test consists of a number of questions that examine the topic's concepts.

4. User Model

The user model holds the student's individual characteristics. Those characteristics include some *demographic information*, the *learning style* and the *knowledge level*. Demographic information constitutes the identity of a student and includes his/her login name, password, e-mail, his/her name and sex.

A student can select one of three learning styles: theorist, pragmatist and constructivist. A *theorist* follows the “traditional” way of learning: theory-examples-exercises. On the other hand, a *constructivist* prefers the other way round: exercise-examples-theory. Finally, a *pragmatist* likes the sequence: examples-theory-exercises.

Subject	Topic	Concept
Insufficient Basic Intermediate Advanced Professional	Novice Experienced Master	Low Medium High

Table 1. Knowledge level values

Knowledge level is an estimation of a student's knowledge about a concept, a topic, a subject or a field. The values of the knowledge level for a concept, a topic and a subject are presented in Table 1. The knowledge level for a field is a number indicating the percentage of the acquired knowledge. How the values of the knowledge level for each item are computed is presented in Section 6.

5. System Adaptation

System adaptation has mainly to do with the learning content presented to the student. The interface of the system consists of two main areas: *navigation area* and *content area*. The content area is the area where the teaching content is presented. The navigation area, at the left side of the screen, displays the domain tree that is, the available subjects and topics of a field. Adaptation takes place at both the navigation and content areas.

The navigational area builds its contents in a hierarchy (tree) based on the priorities stored in DM. So, a simple type of curriculum sequencing is achieved. Visual indicators (see Table 2) guide the student through the learning material. These indicators (icons) provide adaptive navigation to the students.

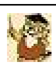
Icon	Location	Knowledge Level
	Subject	Insufficient
	Subject	Basic
	Subject	Intermediate
	Subject	Advanced
	Subject	Professional
	Topic	Novice
	Topic	Experienced
	Topic	Master
	Concept	Low
	Concept	Medium
	Concept	High

Table 2. Visual Indicators and Knowledge Level values

There are five different indicators for a subject (four based on traffic light states: no light, red light, yellow light, green light, and the fifth is an owl). They are put next to the name of a subject and indicate the knowledge level of the student on that subject. Two of them are also used for a topic to indicate whether a student is "ready" (green light), i.e. has the background, or "not ready" (green light), i.e. should study some prerequisite concepts or topics first. However, there are other three visual indicators (bronze medal, silver medal and gold medal) put next to a topic's name, for reflecting the student's knowledge level on that topic. Finally, the three medal type indicators are also used to indicate the knowledge level of a student on a concept. Existence of a medal indicator means that the student has already visited the corresponding topic/concept page. So, those indicators provide indirect guidance to the student by graphical link annotation.

In the content area, topic and concept pages are presented. A topic page contains a list of links to the concepts that it is composed of. The concepts (links) are sorted on a priority basis. Concepts higher up in the list should be studied prior to those lower down. However, the student is free to select any concept, ignoring the system's suggestion. After the end of the list, there is a link to a test generation page.

Next to each concept link, as mentioned, there is a visual indicator, which annotates the link according to the student's knowledge level on the corresponding concept. So, the user knows which concepts he has already mastered and which concepts he/she should study further. Following a concept's link, the user is led to a page, which presents the teaching material related to that concept. The declared learning style (see previous section) of the user affects what is presented and how.

There is also another type of adaptation that takes place at that point. The system gives an advice to the student, about the appropriateness of his/her concept choice. Knowing that the student can freely follow a link, retrieval of a concept page comes with a proper comment. If the student is ready to study that concept the system advises him to go on. If he/she is not, the system presents him/her links to prerequisite concepts that have not been learned in an adequate degree, sorted in the most appropriate sequence. However, the system leaves the initiative to the student to continue either with the selected concept or with the proposed prerequisite concept.

6. Student Evaluation

Student evaluation refers to the estimation of the knowledge level of a student after having dealt with a topic page. In other words, estimation of how well a student has learnt the concepts of a topic page. This is achieved by processing the results of the test offered at the end of a topic page. The system uses different ways for estimation of the knowledge level for a concept, a topic, a subject and a field. The knowledge level of a student for a topic depends on the knowledge levels of the student for corresponding concepts. A similar relation holds between a subject and its topics as well as a field and its subjects.

The knowledge level of a student, as far as a concept is concerned, is classified in one of the following three categories: (a) high, (b) medium and (e) low. A concept is examined by two or three questions. A question has one of three levels of difficulty: easy, medium and difficult. The knowledge level of a student for a concept (CL) is calculated by passing the test results to ES, which processes them. ES returns a value for CL (low → 1, medium → 2, high → 3). The new CL replaces the old one, if the new one is larger. If it is less, no change is made. The way ES calculates CL is explained in the next section.

After the level of a concept C_i has been changed then the following update algorithmic rule is applied:

$$\text{if } (CL_i = 3) \text{ then } \forall j, i \neq j: (C_j \rightarrow C_i) \Rightarrow CL_j = 3 \quad (1)$$

where C_i, C_j represent concepts, CL_i, CL_j represents the knowledge levels of the concepts and ($C_j \rightarrow C_i$) means that C_j is prerequisite of C_i. That is, acquisition of a 'high' knowledge level on a concept is interpreted as 'high' knowledge level on all its prerequisite concepts too. Then the knowledge levels of all topics, subjects and fields related to the concept are updated (see below).

The knowledge level of a topic (TL) can take one of three values (1→ novice, 2→ experienced and 3→ master). TL is calculated via the mean value TLM of the knowledge levels of its concepts:

$$TLM = \frac{\sum_{i=1}^{n} CL_i}{n} \quad (2)$$

where n represents the number of concepts and CL_i represents the knowledge level of concept C_i The outcome of (2) is a number in [1, 3]. Then, the next rule is applied:

if (TLM < 1.5) then TL = 1
else if (1.5 ≤ TLM < 2.5) TL = 2
else TL = 3

The knowledge level value of a subject (SL) can take one of five values (1→ insufficient, 2→ basic, 3→ intermediate, 4→ advanced, 5→ professional). In a similar way to the above, we first calculate the mean value SLM, via a formula similar to (2), having substituted TL_i for CL_i. TL_i represents the level value of topic T_i of the subject and n represents the number of topics in the subject. SLM takes values that belong to [1, 3]. Then, the following rule is applied:

if (SLM= 1) then SL = 1
else if (1 < SLM ≤ 1.5) then SL = 2
else if (1.5 < SLM ≤ 2) then SL = 3
else if (2 < SLM ≤ 2.5) then SL = 4
else SL = 5

Finally, the knowledge level value of a field (FL) is calculated by the formula:

$$FL = \frac{\sum_{i=1}^{n} (SL_i - 1)}{(4 \times n)} \times 100 \quad (3)$$

where SL_i represents the level of subject S_i of the field and n is the number of subjects that the field includes. FL is a real number between 0 and 100 and gives the percentage of the knowledge of a field that a student has acquired.

7. The Expert System

The structure of the expert system (ES) is illustrated in Figure 4. It consists of the fact base (FB), the rule base (RB) and the Jess inference engine (JESS IE). FB and RB constitute its knowledge base (KB). ES is a rule-based expert system implemented in Jess, which is an expert system shell [3]. FB contains facts, which are created from the problem data, whereas RB contains the rules used by the IE to solve problems.

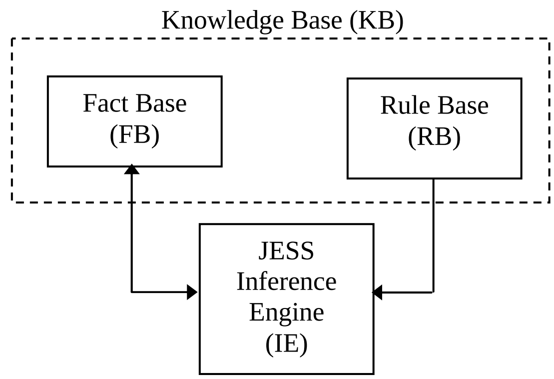


Figure 2. The structure of ES

Now, let's see the way ES helps in the computation of CL for a given concept C. Initially, the data collected from the student's answers to the test is converted to corresponding facts. The expert system processes those facts via the rules of RB, according to the JESS IE instructions, and deduces the knowledge level values of the student for the concepts involved in the delivered test. Rules represent the way a tutor evaluates the answers of a student. For example, Table 3 depicts that way for the case that the test includes two questions for a concept. There are similar tables for the cases that the test includes three or four questions related to a concept.

Quest. 1	Answer status 1	Quest. 2	Answer status 2	Level
Easy	Wrong	Medium	Wrong	Low
Easy	Correct	Medium	Wrong	Low
Easy	Wrong	Medium	Correct	Medium
Easy	Correct	Medium	Correct	High
Easy	Wrong	Difficult	Wrong	Low
Easy	Correct	Difficult	Wrong	Low
Easy	Wrong	Difficult	Correct	Medium
Easy	Correct	Difficult	Correct	High
Medium	Wrong	Difficult	Wrong	Low
Medium	Correct	Difficult	Wrong	Medium
Medium	Wrong	Difficult	Correct	High
Medium	Correct	Difficult	Correct	High

Table 3. Rules for two-questions-based evaluation

8. System Evaluation

The current version of the system released in December 2004 and used by the class of the Artificial Intelligence course at our department. The students had been taught about logic as a knowledge representation and reasoning language during the course lectures. They were instructed to use two versions of the system, the old one [5] and the new one. The old version had no student modeling and evaluation capabilities. However, the students instructed to use different, almost not-overlapping parts of the two systems. After the use of the two systems, they were asked to fill in a questionnaire, including questions for evaluating usability and learning.

The questionnaire included nine questions, three for the old version part (Q1-Q3), four for the new version part (Q4-Q7) and two (Q8-Q10) for the combined system, i.e. the whole new version. Q1 and Q3 were the same as Q4 and Q6 respectively. Q1/Q4 was of multiple-choice type and concerned the time needed for a student to adapt to the system. Q8 was also a multiple choice type question and concerned a comparison of using the system and attending a tutorial session. The rest of the questions were based on Likert scale (1: not at all, 5: very much).

Fifty five students filled in the questionnaire. Their answers to Q1/Q3 showed that over 80% of the students needed less than 10 min to cope with both versions. Also, most of the students (>70%) see the system as a companion to tutorial, whereas the rest consider that an hour with the system is better than an hour tutorial (Q8).

Q	QUESTIONS	ANSWERS (%)				
		1	2	3	4	5
Old Version Part						
2	How much did the system help you to learn AI concepts?	0	7	27	51	15
3	Did you enjoy learning with the system?	0	4	40	40	16
New Version Part						
5	How much did system guidance help you to learn AI concepts?	0	6	18	60	16
6	Did you enjoy learning with the system?	0	0	29	53	18
7	How satisfactory do you judge the adaptation icons?	4	9	64	16	7
Both Parts						
9	Are you going to suggest the system to next year students?	0	4	5	49	42

Table 4. Questionnaire Results

In general they enjoyed learning with both versions of the system very much (Q3 and Q6, Table 4), with an overhead (of about 15%) for the adaptive version. Also, most of them found both versions quite helpful in learning (Q2 and Q5, Table 4), with a preference (about 10% more) to the adaptive version. Furthermore, they consider the adaptation icons of Table 2 just satisfactory (Q7, Table 4). Finally, they very warmly suggest the system to the next year students (Q9, Table 4).

9. Conclusions

In this paper, we present a web-based intelligent education system to help students in the context of an AI course. We concentrate on the adaptivity and student evaluation aspects of the system. Adaptivity refers to the capability of the system to adapt teaching to student needs, specified by the student model characteristics. Student evaluation refers to the evaluation of the knowledge level of a student, which is one of the most important characteristics, with regards to taught concepts. Adaptive hypermedia techniques, like graphical link annotation, and an intelligent technique, i.e. a rule-based expert system, are used to achieve the above goals.

An evaluation of the system shows it is warmly acceptable by the students and, regarding a comparison with its previous non-adaptive version [5], a slight preference to its adaptive version in some aspects.

The system, as it is now, adapts to the student needs, but not to the tutor ones, as for example [7] does. It would be interesting to explore this direction.

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