A WEB-BASED INTELLIGENT TUTORING SYSTEM TEACHING NURSING STUDENTS FUNDAMENTAL ASPECTS OF BIOMEDICAL TECHNOLOGY

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Abstract-**In this paper, we present the architecture of a Web-based Intelligent Tutoring System (ITS) for distant education of nursing students in fundamental aspects of the most common medical equipment. It offers course units covering the needs of users with different knowledge levels and characteristics. It tailors the presentation of the educational material to the users' diverse needs by using AI techniques to specify each user's model as well as to make pedagogical decisions. This is achieved via an expert system that uses a hybrid knowledge representation formalism integrating symbolic rules with neurocomputing.**
***Keywords* - Intelligent Tutoring Systems, health care technology**

I. INTRODUCTION

The introduction of new technologies in health care, can be seen as improved diagnosis and treatment as well as increased efficiency of the services involved. At the same time, however, the implementation of these new improved technologies, introduces concerns about trained personnel and imposes new demands for tools and methods for their overall management. The support services, for biomedical technology, address a variety of technical and administrative issues, concerning the safe and efficient operation of medical equipment over the period of its intended use. Health care technology is our first line of defence against any disease. Health care professionals such as nurses have to be familiar with the most common medical equipment used in health care units. Educational programs already include courses with the fundamental aspects of the proper care and safety of medical instruments [12]. Throughout the last years biomedical education as well as medical practice education depends widely on Computer Aided Instruction (CAI) systems [9],[5],[11].

Intelligent Tutoring Systems (ITSs) constitute an advanced generation of CAIs. Their key feature is their ability to provide a user-adapted presentation of the teaching material [2],[14],[15]. This is accomplished by using Artificial Intelligence techniques to represent the pedagogical decisions and the information regarding each student. ITSs have become extremely popular during the last years and have been shown to be quite effective at increasing users' performance and motivation [1]. The emergence of the World Wide Web increased the usefulness of such systems [3],[4],[10],[13], in distant learning environments.

In this paper, we present the architecture of a Web-based ITS for teaching the use and safety aspects of health care technology. The system is addressed to nursing students or health professionals. It includes course units covering the needs of users with different knowledge levels and characteristics. The system models the users' knowledge state and skills. Based on this information, it constructs lesson plans and selects the appropriate course units for teaching each individual user. The functionality of the system is controlled by an expert system based on neurules, a type of hybrid rules integrating symbolic rules with neurocomputing [6],[7].

II. SYSTEM DESCRIPTION

Fig. 1 depicts the basic architecture of the ITS. It consists of the following components:

- the domain knowledge, containing the structure of the domain and the educational content. The educational content refers to the following main chapters: magnetic resonance, computed tomography, nuclear medicine, electro-medicine, ultrasound, anesthesia systems, radiographic systems, medical informatics, lasers and intensive care systems. Each chapter concerns specific equipment. For each piece of equipment primary learning items involve its structure, its manipulation and internationally recognized safety standards.
- the user modeling component, which records information concerning the user,
- the pedagogical model, which encompasses knowledge regarding various pedagogical decisions,
- the user interface

The ITS is based on an expert system aiming to control the teaching process. The expert system employs a hybrid knowledge representation formalism, called neurules [6]. In the following, we elaborate on the system's key aspects.

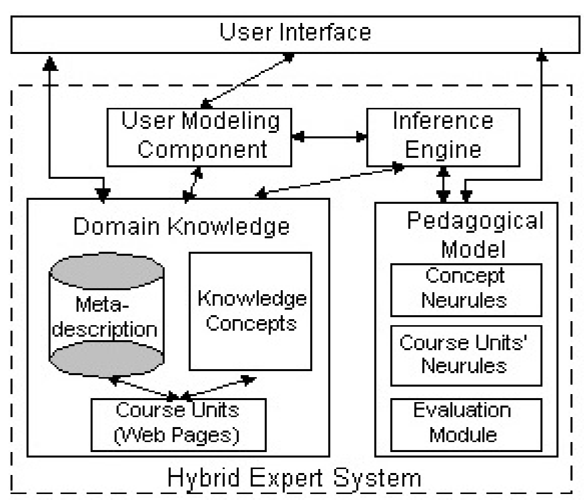

Fig. 1. Architecture of the ITS.

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A. Domain Knowledge

The domain knowledge contains knowledge regarding the subject being taught as well as the actual teaching material. It consists of two parts: (a) the *knowledge concepts* and (b) the *course units*.

The knowledge concepts refer to basic pieces of knowledge concerning the domain of health care technology. Every concept has a number of general attributes such as, its name, its level of difficulty etc. Furthermore, it can have links to other concepts. These links denote its prerequisite concepts. In this way, one or more *concept networks* are formed representing the pedagogical structure of the domain to be taught.

The concepts are organized into *concept groups.* A concept group contains closely related concepts based on the knowledge they refer to. Therefore, the domain space is dissected into subdomains. For instance, a concept group can involve magnetic resonance imaging whereas some of its concepts may concern the structure or the manipulation of the specific equipment.

The course units constitute the teaching material presented to the system users as Web pages. The teaching material can form a variety of courses starting from introductory topics and scaling up to more advanced ones. Each course unit is associated with a knowledge concept. The user is required to know the concept’s prerequisite concepts in order to be able to grasp the knowledge contained in the corresponding course unit. The distinct representation of the domain’s pedagogical structure (concepts) and the actual teaching content (course units) facilitates the updates in the domain knowledge.

A course unit may present theory, may be an example or an exercise. Examples assist a user in grasping the theory's key points. Exercises as questions with multiple choice answers are based on the examples and are used to evaluate a user’s knowledge level. When solving an exercise the user can ask the system for help and view related examples. Each exercise is associated with an explanation assisting the user in case of a wrong answer.

The pedagogical model based on the user model selects and orders the course units presented to the user. In this way, a user-adapted presentation of the teaching material is achieved. To this end, the explanation variant method is used, implemented by the page variant technique [4]. More specifically, the system keeps variants of the same page (course unit) with different presentations.

To facilitate the selection and ordering of the course units, the domain knowledge includes a *meta-description* of the course units based on their general attributes. Main such attributes for a course unit are its level of difficulty, its pedagogical type (theory, example, exercise), its multimedia type (text, image, animation, interactive simulation), the required Internet connection, etc.

B. User Modeling Component

The user modeling component is used to record information concerning the user which is vital for the system's user-adapted operation. It contains models of the system's users and mechanisms for creating these models (Fig. 2).

The user model consists of four types of items: (i) *personal data* (e.g. name, email), (ii) *interaction parameters*, (iii) *knowledge of the concepts* and (iv) *student characteristics*. The student characteristics and the knowledge of the concepts directly affect the teaching process, whereas the interaction parameters indirectly.

The interaction parameters form the basis of the user model and constitute information recorded from the interaction with the system. They represent things like, the type and number of the units accessed, the type and the amount of help asked, the answers to the exercises etc.

The student characteristics are mainly the following:

(a) Multimedia type preferences (e.g. text, images, or animations) regarding the presented course units.
(b) Knowledge level (novice, beginner, intermediate, advanced) of the subdomains and the whole domain.
(c) Learning ability level.
(d) Concentration level.
(e) Experience concerning the use of computers, hypermedia applications and the specific ITS.
(f) Available Internet connection.

The student characteristics are represented with the stereotype model, that is the user is assigned to predefined classes (stereotypes). The stereotypes denote typical users. Based on the way they acquire their values, student characteristics are discerned into two groups. They can be either *directly obtainable* or *inferable*. The directly obtainable characteristics such as (a) and (f) obtain their values directly from the user whereas the values of the inferable ones such as characteristics (b)-(e) are inferred by the system based on the interaction parameters and the knowledge of the concepts. The knowledge level of the whole domain is deduced from the knowledge levels of its subdomains. A neurule base containing *classification neurules* is used to derive the values of the inferable characteristics. The user models are updated during the teaching process.

The stereotype model cannot sufficiently represent the user’s knowledge of the domain because the adaptation techniques of the pedagogical model require a more fine-grained model in order to be effective. For this reason the user’s knowledge of the domain is represented as a combination of a stereotype and an overlay model. The stereotype denotes the (sub)domain knowledge level. The overlay model is based on the concepts associated with the course learning units. More specifically, each concept is associated with a value denoting the user knowledge level of this concept.

The combination of stereotype and overlay modeling for the representation of a user’s domain knowledge has given good results [4]. The overlay model has the problem of initialization since for a new user it is hard to set the knowledge values for all of the concepts. This difficulty can be overcome by associating a fixed set of concept-value pairs with each stereotype [4]. This association will be based on the concepts' level of difficulty.

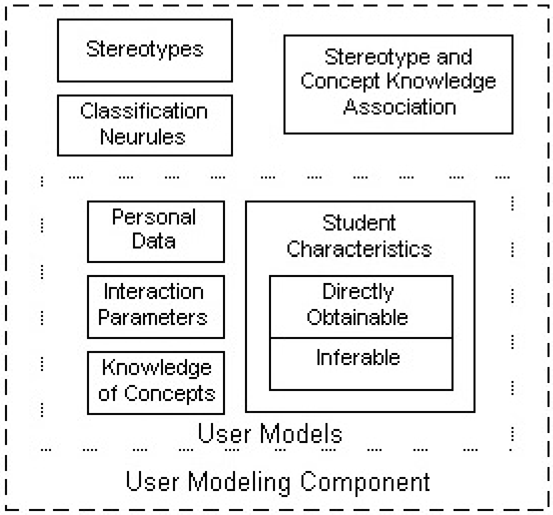

Fig. 2. The User Modeling Component.

In order to maintain user models, only registered users have access to the system. A registered user identifies himself/herself to the system whenever logs on by giving a valid login name and password. An unregistered user must first submit personal data (e.g. name, email) to the system in order to obtain an account and access to the system's functionality.

A new user must give values for the directly obtainable student characteristics. The user has the option to change them during the teaching process. Furthermore, a new user is required to take some tests in order to initialize the other student characteristics.

C. 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. As shown in Fig. 1, the pedagogical model consists of three main components: (i) *concept neurules*, (ii) *course units' neurules* and (iii) *evaluation module*.

The task of the concept neurules is to construct a user-adapted lesson plan by selecting and ordering the appropriate concepts. This is based on the user's knowledge of the concepts, the user's (sub)domain knowledge level, the concepts' level of difficulty and the links connecting the concepts.

According to the plan constructed by the concept neurules, the course units' neurules select and order the course units that are suitable for presentation. For this purpose the student characteristics of the user model as well as the meta-description of the course units are taken into account.

The evaluation module evaluates the user's performance and updates accordingly the user model. More specifically, it assigns knowledge values to the concepts based on the interaction parameters and updates the inferable student characteristics based on the classification neurules of the user modeling component. When the user gains an acceptable knowledge level of the concepts belonging to the initial lesson plan, a new plan is created.

The user can intervene in the teaching process. An experienced user has the ability to set learning goals based on the concept groups. For this purpose, the user can view a list of the concept groups and choose the concept group he/she is more interested in. The list of concept groups is sorted in decreasing order according to the user's knowledge state of their concepts. Therefore, the system supports active learning increasing the user's performance and motivation and giving him/her some control on its adaptation. These features increase the system's usability taking into consideration the fact that the users will be adults.

D. Expert System

Our ITS operates under the control of a hybrid expert system. The expert system has an inference engine, to make decisions based on the known facts and the rule bases contained in the user modeling component and the pedagogical model. The expert system's knowledge representation formalism is based on neurules, a type of hybrid rules integrating symbolic rules with neurocomputing. The attractive feature of neurules is that they improve the performance of symbolic rules [6] and simultaneously retain their naturalness and modularity [7] in contrast to other hybrid approaches.

The form of a neurule is depicted in Fig. 3a. Each condition C_i is assigned a number sf_i, called its *significance factor*. Moreover, each rule itself is assigned a number sf_0, called its *bias factor*. Internally, each neurule is considered as an adaline unit (Fig. 3b). The *inputs* C_i (i=1,...,n) of the unit are the *conditions* of the rule. The weights of the unit are the significance factors of the neurule and its bias is the bias factor of the neurule. Each input takes a value from the following set of discrete values: [1 (true), 0 (false), 0.5 (unknown)]. The *output* D, which represents the *conclusion* (decision) of the rule, is calculated via the formulas:

$$D = f(\mathrm{a}),\ \ \mathrm{a} = sf_0 + \sum_{i=1}^{n} sf_i C_i \qquad (1)$$

where a is the *activation value* and $f(x)$ the *activation function*, a threshold function ($f(\mathbf{a}) = 1$, if $a \geq 0$, and $f(\mathbf{a}) = -1$, otherwise). Hence, the output can take one of two values, '-1' and '1', representing failure and success of the rule respectively.

Neurules are constructed either from empirical data (training patterns) or symbolic rules. Each neurule is individually trained via the LMS (Least Mean Square) algorithm. In case of inseparability in the training set, special techniques are used [6],[7]. In this way, the neurules contained in the pedagogical model and the user modeling component are constructed. The inference mechanism is based on a backward chaining strategy.

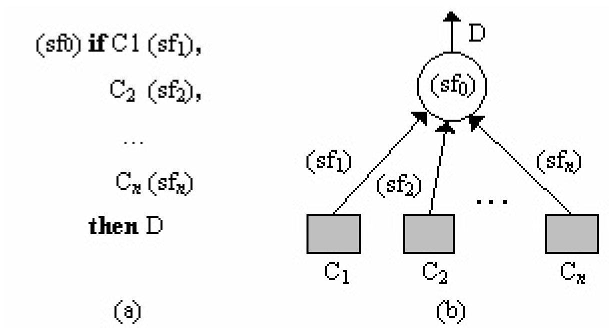

Fig. 3. (a) Form of a neurule (b) corresponding adaline unit

E. 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 [8]. The primary objective is to design a user interface that will be usable by users with diverse abilities, needs, requirements and preferences.

III. IMPLEMENTATION ASPECTS

For the development of the system, the Microsoft Internet Information Server and the MS SQL Server for Windows NT are used. Active Server Pages scripts manipulate the information stored in the databases and dynamically produce the contents of the applications presented to the users.

IV. CONCLUSIONS

The ever-increasing specialization of nursing care may require nursing professionals to provide nursing care outside of their specialty. Nurses will have to familiarize themselves with a new specialization area at short time [12], [9]. In this paper, we describe the design of a Web-based Intelligent Tutoring System (ITS) for teaching nursing student fundamental aspects of the most common medical equipment. It will also support training of hospital personnel, safe and efficient use of medical equipment and quality assurance of services offered by the clinical engineering department, according to internationally recognized quality standards. The focus has been placed on the effective management of medical equipment with significant expected benefits relating to safety and proper use.

The system tailors the presentation of the teaching material to the diverse needs of its users. To some degree, the users can intervene in the teaching process. The system's function is controlled by a hybrid expert system.

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.

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