E-LEARNING FOR HEALTH ISSUES BASED ON RULE-BASED REASONING AND MULTI-CRITERIA DECISION MAKING

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Abstract: The paper presents an e-learning system called INTATU, which provides education on Atheromatosis. Atheromatosis is a disease that is of interest not only to doctors, but also to common users without any medical background. For this purpose, the system maintains and processes information about the users' interests and background knowledge and provides individualized learning for the domain of Atheromatosis. More specifically, the reasoning mechanism in INTATU uses a novel combination of rule-based reasoning and a multi-criteria decision making theory called SAW for selecting the theory topics that appear to be most appropriate for a particular user with respect to his/her background knowledge and interest.

1 INTRODUCTION

E-learning and e-health can help users take more control of their well-being and improve their lives by accessing health information. However, this information is sometimes inaccessible for most people, as they do not have the background knowledge to understand the medical terminology used. A solution to this problem may be achieved by providing each user with personalized information that is tailored to his/her knowledge and interests.

In view of the above, we have developed an e-learning system for a medical domain that has the ability to adapt its interaction to each user dynamically. The system is about Atheromatosis, which is a topic that is of interest to many categories of people. Atheromatosis of the aortic arch has been recognized as an important source of embolism. System embolism is a frequent cause of stroke. The severity of Atheromatosis is granted by the fact that aortic atheromas are found in about one quarter of patients presenting embolic events (Sheikhzadeh & Ehlermann 2004). Information about Atheromatosis is considered crucial because the diagnosis of this particular disease is mostly established after an embolic event has already occurred.

The e-learning system developed is called INTATU (INTelligent Atheromatosis TUtor). As it operates over the web, users can access medical information from any-where and at any time. INTATU maintains information about its users centrally on a Server. This information may be processed so that the system can personalize its inter-action to each user. More specifically, INTATU is based on hybrid intelligence that uses a novel combination of user stereotypes with a decision making theory in order to provide personalised interaction of learners with the system. The user stereotypes constitute rule-based reasoning that is widely used in user modelling systems for drawing inferences about users based on a small set of observations (Rich 1989, Rich 1999). The information of the stereotypes is used in combination with a multi-criteria decision making theory called Simple Additive Weighting (SAW) (Fishburn 1967, Hwang & Yoon 1981) in order to evaluate each theory topic on Atheromatosis and present the information that would be of interest to the user interacting with the system and in a way that it would be appropriate for him/her.

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More specifically, INTATU makes use of stereotypes for providing default assumptions about the interests, background knowledge and needs of the users belonging to a certain group until the user model acquires sufficient information about each individual user. In INTATU, users are classified into four categories, namely, Experts, Users with good knowledge, Users with medium knowledge and Novices in Atheromatosis. Furthermore, users are classified into one of three categories with respect to his/her computer skills.

2 EMPIRICAL STUDY

Requirements specification and analysis play an important role during software development. For this purpose, an empirical study was conducted. During the empirical study, a questionnaire was distributed to 347 subjects of various interests and occupations. The main characteristic of the sample selected was that the background knowledge of the subjects with respect to the disease of Atheromatosis and the ICT varied significantly. The collected questionnaires were analysed by 10 human experts in software engineering in order to capture the software requirements.

The analysis of the protocols was used for dividing the subjects of the empirical study into main categories of users with similar interests, knowledge and needs. As a result two different categorisations of users took place and the subjects of the empirical study were categorized according to their level of knowledge in cardiovascular diseases and Atheromatosis and in ICT.

More specifically, users were divided into four main groups according to their background knowledge about cardiovascular diseases and Atheromatosis: experts in Atheromatosis, intermediates with good knowledge of Atheromatosis, intermediated with medium knowledge of Atheromatosis and novices in Atheromatosis. For each one of these groups the empirical study revealed the topics of most interest regarding cardiovascular diseases and Atheromatosis.

Users were also divided into three main categories with respect to their knowledge about ICT: Experts in ICT, Intermediates in ICT and Novices in ICT. The empirical study also revealed how each group of users used the computer and the Internet and as a result their computer skills.

Table 1: Categorisation of users with respect to their knowledge both in Atheromatosis and ICT

	Expert		Intermediate		Novice		Not categorised	
Experts in Atheromatosis	7	70%	2	20%	1	10%	0	0%
Good knowledge in Atheromatosis	42	55%	31	40%	4	5%	0	0%
Medium knowledge in Atheromatosis	39	28%	71	52%	26	19%	1	1%
Novices in Atheromatosis	22	18%	39	32%	62	50%	0	0%
Sum	**110**		**143**		**93**		**1**	

In view of the above, the analysis of the empirical data revealed that the system should adapt taking into account the users' interests and need for knowledge, their background knowledge on Atheromatosis and ICT as well as their knowledge of medical terminology. Finally, the allocation of the users in each group with respect to their knowledge in Atheromatosis to the different groups of ICT revealed that even experts in Atheromatosis may be novices in ICT (Table 1). As a result, the system should provide additional help in the usage of ICT in order to make the system more usable and easy to use.

3 OVERVIEW OF THE SYSTEM

INTATU (Intelligent Atheromatosis Tutor) is an Intelligent Tutoring System about Atheromatosis. The system addresses a variety of users, such as patients, patients' relatives, doctors, medical students, etc. The main goal of INTATU is to adapt dynamically its interaction to each user. For this purpose, the system faces the decision problem about which theory topic of cardiovascular diseases and Atheromatosis might be of interest to the user interacting with it. Therefore, INTATU incorporates a user modelling component. This component maintains information about the interests, needs and background knowledge of all categories of potential users.

In order to locate which theory topic is to be presented to a user, each theory topic is evaluated on a set of criteria that reflect the user's interests, previous knowledge and computer skills. The user model that the system maintains provides continuously the evaluation data of the theory topics against the criteria. For the evaluation of the different theory topics the system uses a reasoning

mechanism that uses rule-based reasoning and a multi-criteria decision making method.

4 RULE-BASED REASONING IN USER STEREOTYPES

INTATU uses user stereotypes in order to maintain information about the different groups of users of the system. The user stereotypes constitute rule-based reasoning that is widely used in user modelling systems for drawing inferences about users based on a small set of observations (Rich 1989, Rich 1999).

According to the results of the empirical study that was conducted during the early phases of the software's life – cycle, each user of INTATU is categorized into one of four stereotypes according to his/her knowledge about Atheromatosis and his/her relation to the disease and into one of three stereotypes with respect to his/her knowledge on ICT.

Therefore, the four stereotypes that are used for categorizing users with respect to their knowledge about Atheromatosis are: Experts in Atheromatosis, Users with good knowledge in Atheromatosis, Users with medium knowledge in Atheromatosis and Novices in Atheromatosis.

Additionally, the user modelling component uses three stereotypes in order to categorise users with respect to their knowledge in ICT: 'Experts in ICT', 'Intermediates in ICT' and 'Novices in ICT'. Each one of these classes represents an increasing mastery in computer skills.

The main reason for the application of stereotypes is that they provide a set of default assumptions, which can be very useful during hypotheses generation about the user. Generation of default assumptions can prove very effective for modelling a large proportion of users. These assumptions in most cases that stereotypes have been applied as a user modelling technique are presented in the form of rules. However, in our case the default assumptions are parameterized and they are given as values of some criteria that can characterize the user. These criteria were proposed by the 10 human experts that analysed the protocols of the empirical study.

In view of the above, the stereotypes that categorise users according to their knowledge on cardiovascular diseases and Atheromatosis maintain values for the following criteria:

- **Degree of Interest (i):** The values of this criterion show how interesting each topic of theory about Atheromatosis is for the users belonging to one particular stereotype. The values of this criterion are based on the data gathered during the empirical study and are presented in Table 2.
- **Need for information (n):** This criterion shows how important a topic of theory about Atheromatosis is for the users belonging to one particular stereotype. The values of this criterion have been given by doctors that are experts on Atheromatosis that have taken into account the analysis of the data that has been gathered during the empirical study and are presented in Table 1.
- **Compatibility to medical background (m):** This criterion shows how comprehensible each topic of theory about Atheromatosis is to the users belonging to each stereotype. This criterion is mainly concerned with the special medical terminology used in the presented topic of theory.
- **Comprehensibility of the theory topic(c):** This criterion also shows how comprehensible each topic of theory about Atheromatosis is to the users belonging to each stereotype. However, this criterion is mainly concerned with the capability of the users belonging to the stereotype of understanding the presented topic of theory with respect to their educational level.

Finally, the 10 human experts proposed another one criterion, which values are maintained in the stereotypes that categorise users according to their computer skills:

- **Level of computer skills (l):** This criterion shows how comprehensible the way of presentation of each topic of theory about Atheromatosis is to the users belonging to each stereotype. This criterion shows how comprehensible the technology used for the presentation of a topic of theory is and how much help a user may need.

5 DYNAMIC ADAPTATION

The main feature of INTATU is that it can adapt its interaction to each user. In order to achieve that, the system uses multi-criteria decision making. More

specifically, the system uses SAW to evaluate every alternative theory topic. Then the theory topics are ranked and the one with the highest value is selected to be presented to the user.

The SAW approach consists of translating a decision problem into the optimisation of some multi-criteria utility function U defined on A. The decision maker estimates the value of function $U(X_j)$ for every alternative X_j and selects the one with the highest value. The multi-criteria utility function U can be calculated in the SAW method as a linear combination of the values of the n criteria:

$$U(X_j) = \sum_{i=1}^{n} w_i x_{ij} \quad (1)$$

where X_j is one alternative and x_{ij} is the value of the i criterion for the X_j alternative.

In view of the above, INTATU calculates a multi-criteria utility function for each theory topic. The function U is calculated as a linear combination of the five criteria presented above:

$$U_{SAW}(T_j) = w_n n_j + w_i i_j + w_m m_j + w_c c_j + w_l l_j, \quad (2)$$

where T_j is the evaluated theory topic, w_n, w_i, w_m, w_c, w_l are the weights of the criteria and n_j, i_j, m_j, c_j, l_j are the values of the criteria for the jth theory topic. The values of the criteria are acquired by the stereotype. The weights of the criteria, on the other hand, have been calculated during the previous experimental study. More specifically, the 10 experts that selected these criteria were also asked to define the corresponding relative importance in their reasoning process. This process revealed that the weight for the criterion i: $w_i = 0.28$, the weight for the criterion n: $w_n = 0.26$, the weight for the criterion m: $w_s = 0.21$, the weight for the criterion c: $w_d = 0.14$ and the weight for the criterion l: $w_c = 0.11$.

In view of above, the formula for the calculation of the multi-criteria utility function U is: $U_{SAW}(T_j) = 0.26 n_j + 0.28 i_j + 0.21 m_j + 0.14 c_j + 0.11 l_j$.

6 CONCLUSIONS

The paper presents an e-learning system for Atheromatosis called INTATU (INTelligent Atheromatosis TUtor), which allows its users to access relevant medical information from anywhere and at any time. The main advantage of the system is that it maintains and processes information about its users' background knowledge and interests in order to personalize its educational content. The novelty of the approach presented lies in the fact that it uses a combination of rule-based reasoning and a decision making theory for selecting the theory topic that is most appropriate for the particular user. More specifically, the system uses stereotypes, which is a common technique of rule-based reasoning, and the most common multi-criteria decision making theory (SAW).

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