

Intelligent Student Profiling with Fuzzy Models

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Abstract

Traditional Web-based educational systems still have several shortcomings when comparing with a real-life classroom teaching, such as lack of contextual and adaptive support, lack of flexible support of the presentation and feedback, lack of the collaborative support between students and systems. Based on the educational theory, personalization increases learning motivation, which can increase the learning effectiveness. A Fuzzy epistemic logic has been built to present student's knowledge state, while the course content is modeled by the concept of context. By applying such Fuzzy epistemic logic, the content model, the student model, and the learning plan have been defined formally. A multi-agent based student profiling system has been presented. Our profiling system stores the learning activities and interaction history of each individual student into the student profile database. Such profiling data will be abstracted into a student model. Based on the student model and the content model, dynamic learning plans for individual students will be made. Students will get personalized learning materials, personalized quiz, and personalized advices. In order to understand the students' perception of our prototype system and to evaluate the students' learning effectiveness, a field survey has been conducted. The results from the survey indicate that our prototype system makes great improvement on personalization of learning and achieves learning effectiveness.

Key words: Software agents, Fuzzy model, Web-based education, Student profiling

1. Introduction

A Web-Based educational system is an environment created on the WWW in which students and educator can perform learning-

related tasks. In recent decade, Web-based educational systems have been forming one of the fastest growing areas in educational technology research and development. Benefits of Web-based education are independence of teaching and learning with respect to time and space flexibility. A successful teaching system needs to know the subject domain, it needs pedagogical aims, the ability to formulate a model of the student and respond to student activities (Rosbottom and Moulin, 1998). However, education is fundamentally cooperative and motivating process. Comparing to a real-life classroom, Web-based educational systems still have several shortcomings, such as lack of contextual and adaptive support, lack of flexible support of the presentation and feedback, lack of the collaborative support between students and systems, lack of guidance and incentive functionalities.

To achieve the requirements and answer the various drawbacks of web-based education systems, the intelligent multiple agents' technologies are applied and mediated within web-based educational systems.

In this research, we argue that educational materials can directly support cooperation through electronic documents that provide context critical to learning. A Fuzzy epistemic logic has been built to present student's knowledge state, while the course content is modeled by the concept of context from AI. Our profiling subsystem stores the learning activities and interaction history of each individual student, such as the overall learning progress, time spent on each chapter, each section, and each concept, time spent and answers of quiz, etc. Based on such profiling data and other relevant information, such as the learning content's structure and the learning model, the subsystem is able to reason and to make a dynamic learning plan for a particular student. Such plan involves personalized

learning goal, personalized material, personalized quiz, and personalized advices.

The paper is organized as following: Section 2 gives a brief literature review on web-based education systems development and the related Fuzzy logic support student model. Education theory on the effectiveness of learning and the relationships between personalization, motivation and effectiveness of learning are addressed in section 3. In section 4, we formulate the student model, content model and student profile with Fuzzy logic theory. The description of the Intelligent Agents supported system is presented in section 5. The operation and observation of the prototyped system are addressed in section 6. The final section is the conclusion.

2. Background

Our research is based on two different disciplines: Web-based educational systems and Fuzzy logic supported modeling, which are described below.

2.1 Web-based educational systems

With the constantly increasing popularity of the Internet, education has taken on a new meaning. The Internet promises to change how people will be educated, and how they will acquire new knowledge. However, most of the commercial web-based educational environments provide electronic book with one-fit-all function, which cannot meet each learner's individual needs, such as BlackBoard, WebCT etc. Adaptive support for web-based education systems are aimed at using the Internet to support students communicating with and collaborating with each other as a pedagogical technique, rather than just using Web pages for posting of materials, or email or chat rooms for student-teacher messages (Hiltz and Lewis 1999). Intelligent agents technologies facilitate the interaction between the students and the systems, and also generate the Artificial Intelligent model about learning, pattern recognition and simulation (Dufresne 2000), such as user's model, task's model and pedagogical model. Those models meet together in a productive way to support students' learning activities adaptively.

There are some related researches on this field. ABITS is an highly re-usable Intelligent tutoring Framework, which is able to extend a traditional course management system with a set of

intelligent" functions allowing both student modeling and automatic curriculum generation (Capuano 2000). SAFARI developed at Heron Laboratories in an intelligent tutoring system with a multi-agent architecture, defined for the pedagogical component. These systems use multiple learning strategies and cognitive agents that can model the human behavior in learning situations (Cleaver and Toole, 1999).

The SQL Tutor+ prototype demonstrates that the repository technology is an appropriate technical solution to support multi-user co-operation and collaboration in complex intelligent tutoring systems (Wang 1997). The information repository and student profiling components provide facilitate the knowledge communication within a multiple agents system, and address several co-operative intelligent tutoring systems for distance learning online learning.

2.2 Fuzzy logic supported modeling

Zadeh introduced Fuzzy set theory with a continuous range of membership values for the operator \in (Zadeh, 1965). Later he combined Fuzzy set theory with Lukasiewicz's many-valued logic for a version of Fuzzy logic, which is resemble, compete with, or confused with the continuous range of numbers derived by other methods such as statistics, neural networks, and Dempster-Shafer theory.

Recently, Zadeh demonstrated that the main contribution of Fuzzy logic is a methodology for computing with words, which cannot be done equally well with other methods (Zadeh 1996). Therefore, Fuzzy-set technologies, with their ability to naturally represent human conceptualizations, can make many useful applications in the modelling of human-like intelligent system. Anderson presented a Fuzzy model that combines the essence of Personal Construct Psychology with Fuzzy set theory (Anderson 1998). This model can be used to generate structural measure for construct system in terms of the complexity of that system.

Yager gave an interesting example of how to using Fuzzy modeling for building intelligent agents. There are two steps in his Fuzzy modeling process (Yager, 2000). The first step is to partition the variables in terms of natural language linguistic terms. This linguistic portioning, an inherent feature of what Lotfi Zadeh just calls computing with worlds, greatly simplifies model building. A next step in this process is to represent these linguistic concepts in terms of Fuzzy subsets. For example, the

concept “young” is represented as a Fuzzy subset YOUNG over a set of ages.

In Fuzzy logic supported modelling, a Fuzzy term may be context dependent. For example, The term “oldness” would have different standards for college students and professors. At age 28, a college student would be considered *old*, but a professor would be considered *young*. Thus, the Fuzzy modeling would benefits from context reasoning formalized in AI as done in this paper.

3. Education theory in online education system

To achieve a successful learning effectiveness, the online education system should be built by adapting learning theory (Lassey, Peter 1998). From education psychology point of view, however, the key to successful learning is motivation. It is the energy that drives forward a learning society and its significance should never be underestimated. Indeed, the structure of a learning society is designed to promote a motivated work force.

Motivation involves the internal processes that give behavior its energy and direction. Energy means that behavior is relatively strong, intense, and persistent; direction means that behavior aims itself toward achieving a particular purpose or goal. The phrase of internal processes is necessary because environmental events such as rewards and requests by other people can give our behavior energy and direction, too (Reeve, Johnmarshall 1996).

On the other hand, people are different in nature, who come from different places, with different

sharps and different backgrounds. Different people need the different ways to motivate them (Nordstrom and Ridderstrale 2000). In web-based education environment, students come to their tasks with different personalities, different substantive backgrounds and different amounts of learning experience. To enhance motivation of those students to learn, it is essential to excite the learner and to ensure that control and choice are open to the students in a personally meaningful way. So, it’s necessary to integrate the Personal Development Plans (PDPs) in the online education system, to use the flexible learning materials to meet each individual student’s needs. Paulsen and Feldman have a report ASHE-ERIC Higher Education issued using a model that views strategies for improving instruction as motivation for individual faculty members to improve their teaching performance (Paulsen and Feldman, 1995). Also, Ralph Grove has discussed that using the personal software process may motivate the good programming practices (Grove, 1998).

Based on such education, the following personalized interactions to enhance the personalization level of our online educational system are addressed:

- Personalized student learning materials
- Personalized quiz
- Personalized suggested readings
- Personalized advices
- Personalized warnings

The overall relationship among personalization, motivation and effectiveness of learning is shown in figure 1.

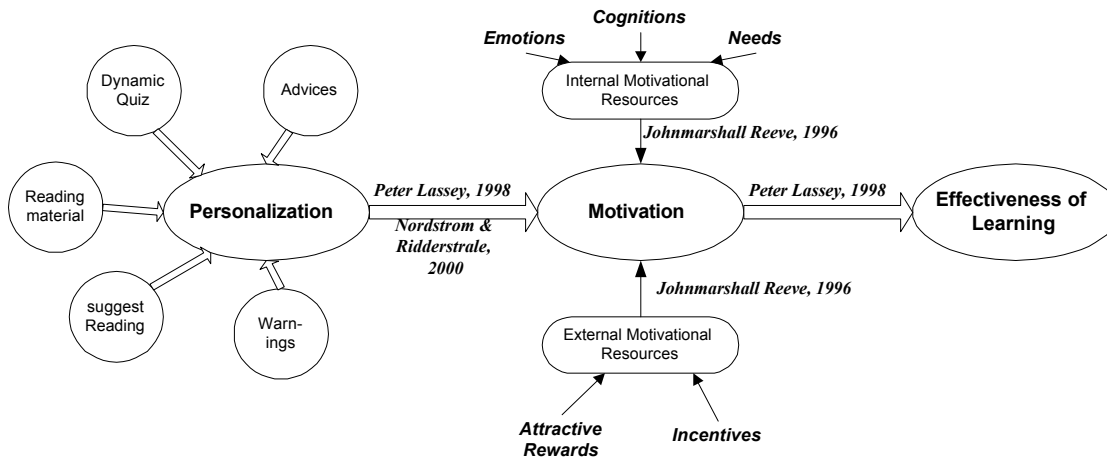


Figure 1. Effectiveness and Personalization

4. Fuzzy models

To match these requirements, we develop a Fuzzy epistemic logic to present student's knowledge state, while the course content or the domain theory is modeled by the concept of context from AI.

4.1 Content model

Definition: A Curriculum is defined as a structure:

$\langle C, SR, PR, IST, DG \rangle$

where

- C is the set of topics;
- $SR \subseteq C \times C$ is a relation;
- $PR \subseteq C \times C$ is a partial ordered relation, such that $SR \subseteq PR$;
- IST is a function that maps each element of C to a subset of CL , the Context Language;
- DG is a function that maps each element C to a real number of $[0,1]$.

The value of $DG(c)$ indicates how much time should be taken to learn the topic of C .

4.2 Fuzzy relations

Given a topic c , we use five categories for pieces of knowledge about the topic: very hard, hard, moderate, easy, and very easy (or v_1, v_2, v_3, v_4 and v_5 for short). On the other hand, we allow those propositions of the form $\mathbf{I}(i, c)$ to have five Fuzzy values (u_1, u_2, u_3, u_4 and u_5), which represent that student i knows the topic c very well, well, moderately, poorly and very poorly, respectively.

Notations: We use $ist^{v_j}(c, \phi)$ to denote that ϕ is a piece of knowledge about the topic c with the hardness v_j ($0 < j \leq 5$). By $\mathbf{I}^{u_j}(i, c)$, and K_i is the modal operator for the knowledge of the student i . We denote that student i knows about the topic c at level u_j , this is, $\mathbf{I}(i, c)$ has the value u_j ($0 < j \leq 5$).

We have these rules:

1. $ist^{v_j}(c, \phi) \Rightarrow ist(c, \phi)$

2.
$$\begin{aligned} \mathbf{I}^{u_k}(i, c) &\Leftrightarrow \forall j \geq k \forall \phi (ist^{v_j}(c, \phi) \\ &\Rightarrow K_i ist(c, \phi)) \end{aligned}$$

Given topic c_1 and c_2 , for $0 < j \leq 5$ and $0 < k \leq 5$, P_{ij} be the prerequisite relation between $\mathbf{I}^{u_j}(i, c_1)$ and $\mathbf{I}^{u_k}(i, c_2)$, i.e. student i should know the topic c_1 at level u_j first if he or she wants to know about the topic c_2 at level u_k . Thus, we have 25 kinds of prerequisite relations between two topics.

If $0 < j, k, l, m \leq 5$, we have that

1. if $P_{jk}(c_1, c_2), P_{lk}(c_1, c_2)$ then $j = l$;
2. if $P_{jk}(c_1, c_2)$ and $P_{lm}(c_1, c_2)$ then $k \leq m$ implies $j \leq m$.

4.3 Student model

Definition: The student model is a structure $\langle KS, *, PF \rangle$

where

- $KS \subseteq CLK$ is an initial student's knowledge set, while CLK is the CL appending the modalities,
- $*$ is a revision function,
- PF is a behavior interpretation function that maps the current record of student's behavior to new knowledge of the student.

Given a student i , the system will give an initial student's knowledge set Γ_0 . After receiving a record Δ of the student's behaviors, the system use the function PF and interpret the record Δ to new knowledge set $PF(\Delta)$ of the student. By using the revision function $*$, the system gets the new student's knowledge set, i.e. $\Gamma_0 * PF(\Delta)$.

4.4 Student Profile

Definition: A student profile is a set of following pairs: $\langle t, e \rangle$, where e is a behavior of the student, t express the time while the behavior occurs. The t could be a point of time or an interval of time. There are two main types of behaviors, reading a particular topic (in symbol $RD(c)$) and making a choice in a quiz (in symbol $ANS(q)$).

A function PF to abstract a student model from the student profile could be defined as

$$PF(\Delta) = \bigcup_{q \in \Delta} DG_q \cup \{I^{t_j}(i, c) | c \in C\}$$

where DG_q is a set of formulas, which is resulted from the diagnosis process of the student's answer of the quiz; t_j is determined the total time for reading the topic c according to the profile Δ .

4.5 Learning plan

A learning goal is a set of formulas with the form $I^{u_j}(i, c)$. A learning planning towards a learning goal G is an ordered set Δ of behaviors such that

$$G \subseteq \Gamma_0 * PF(\Delta)$$

where Γ_0 is the current student's knowledge set. Given a learning goal, we can get a learning function that makes a student learning plan from the student model and content model.

5. System Description

Based on the student model and the content model, a prototyped multi-agent based educational system has been implemented.

The main functionalities of the system are shown in Figure 2. There are five entities in the figure, described below:

- (1) Student profile: a database application. All the student information is stored in this database, including static information, such as previous course grades, and the dynamic information, such as the learning activities, etc.
- (2) Student model: As described in the previous sections, the student model contains Fuzzy values of the student's behaviors.
- (3) Content model: The content model contains the definitions of each topic, the Fuzzy relations between these topics, and a number of Fuzzy functions.
- (4) Learning plan: The learning plan is the learning plan at the current time. It

contains a sequence of topics associated with Fuzzy values.

- (5) Adaptive interface: The interface contains both learning materials and quiz.

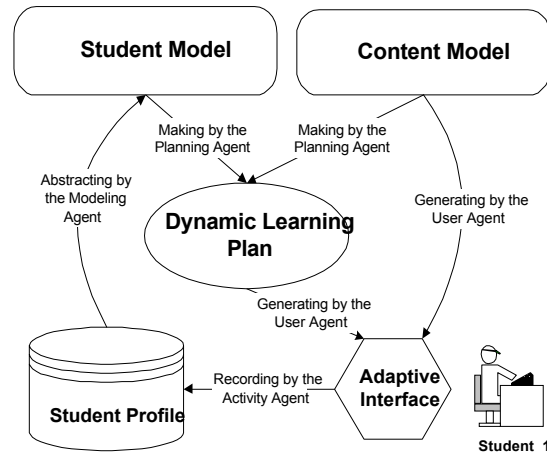


Figure 2. Student model and its relationship

There are a number of actions shown in the figure 2. Such actions are performed by a number of intelligent agents (shown in figure 3):

- Recording activities by the Activity Agent: The agent captures student activity such as mouse clicks (time and target) and document load/unload etc. and to store such activities into the student profile.
- Abstracting student model by the Student Modeling Agent: The agent abstracts the student model, based on the student profile. As an example, the model may contain that "John studied the topic *DFD Diagrams* very hard on May 3 2001".
- Making plan by the Planning Agent: The agent analyzes the current learning plan of the particular student, based on the student model and the content model. Based on such analysis, the agent may modify the learning plan. As an example, the topic sequence may be modified.

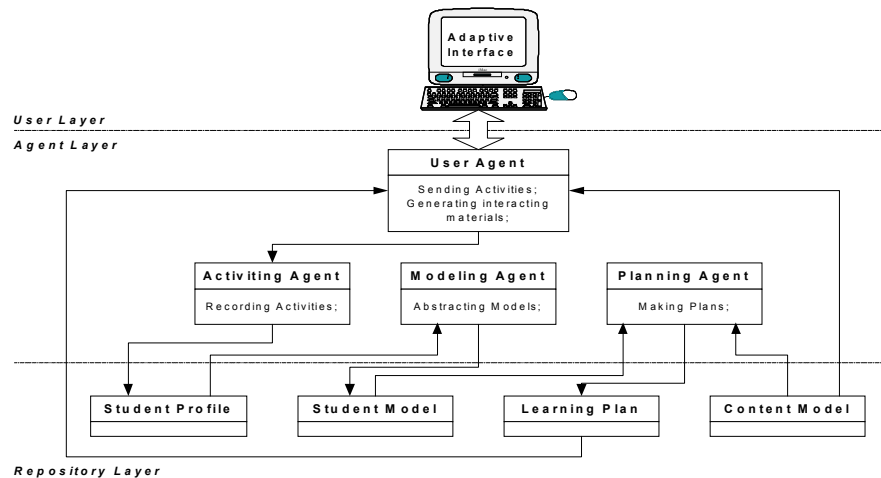


Figure 3. System Architecture

6. Operation and Observation

An interface of our prototyped system, Intelligent Learning System, is shown in figure 4. When the students enroll the course at the first time, they are required to provide some related information and to take a pre-test to record the levels of their background knowledge into the student profile.

After the students register the course, the learning process will follow:

- (1) Learning: Different types of learning materials are provided to students, based on the dynamic learning plan, as described in the previous sections.
- (2) Quiz: After learning, a quiz is required to take. The quiz is generated

dynamically based on students' performance and related learning plan.

- (3) Quiz analysis: The answers of the quiz will be analyzed by the system. Such analysis is based on the matching between the correctiveness of the quiz and the learning plan. The outputs are the achievement degree of the learning plan, as well as the modification of the student model. Such outputs are transparent to the student.
- (4) Learning Analysis: The system will analyze the learning activities and may make a new learning plan for the student. Based on the new learning plan, the system may give some learning advices and suggestions promptly.

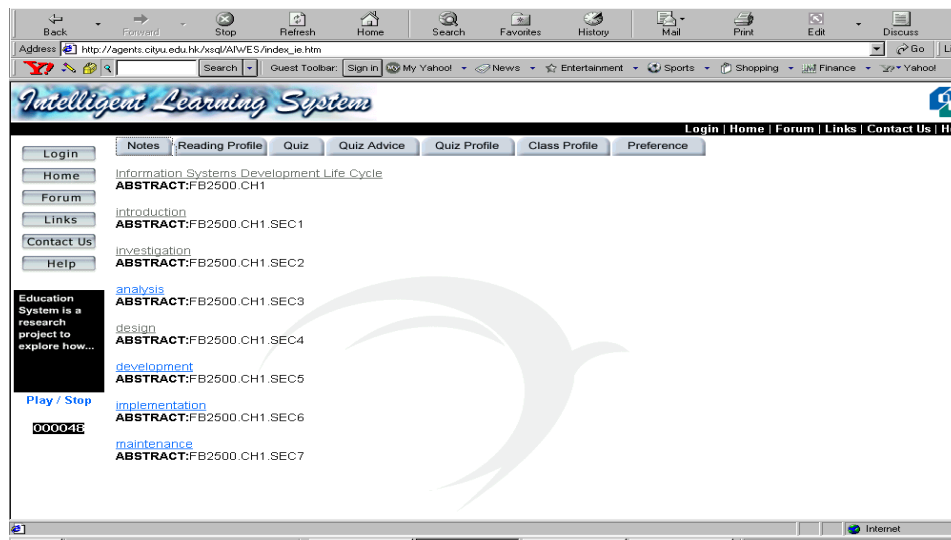


Figure 4. Prototyped On-line Education System

In order to understand the students' perception of our prototype system and to evaluate the students learning effectiveness, a feedback was collected from a group of students who participated this field survey. During the survey, about one hundred questionnaires were randomly distributed to students studying in the university in February 2001. 74 students completely answered questionnaires. All the questions used a five-point Lickert scale.

The results from the data analysis indicate that the personalization functionality of our prototype system is significantly better than traditional classroom teaching (shown in table 1). The mean of our system is 3.77 and the mean of classroom teaching is 2.36 with p-value 0. Therefore, comparing to classroom teaching, our prototype system makes great improvement on personalization of learning and achieves the effectiveness of learning.

Table 1. The result of personalization comparison from t-test

	Mean	Standard Deviation	t-value	df	Sig. (2-tailed)
in Classroom Teaching	2.36	.63			
in IOLS	3.77	.52			
Differences of Means	-1.41	.885	-13.693	73	.000

7. Conclusions

Web-based educational systems have been forming one of the fastest growing areas in educational technology research and development. Comparing to a real-life classroom, most Web-based educational systems still have several shortcomings, such as lack of contextual and adaptive support, lack of flexible support of the presentation and feedback, lack of the collaborative support between students and systems, lack of guidance and incentive functionalities. The main objectives of our research are to personalize online educational systems.

Based on the educational theory, personalization increases learning motivation, which can increase the learning effectiveness. A Fuzzy epistemic logic has been built to present student's knowledge state, while the course content is modeled by the concept of context. Based on such Fuzzy epistemic logic, the content model, the student model, and the learning plan have been defined formally. A multi-agent based student profiling system has been presented. Our profiling subsystem stores the learning activities and interaction history of each individual student into the student profile database. Such profiling data will be abstracted into a student model. Based on the student model and the content model, dynamic learning plans for individual students will be made. Students will get personalized learning materials, personalized

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