

Towards a Personalized E-Learning System

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INTRODUCTION

To cope with the increasing trend of learning demand and limited resources, most universities are taking advantage of Web-based technology for their distance education or e-learning (Montelpare & Williams, 2000). One of the reasons is due to the significant price drop of personal computers in recent decades; the Internet and multimedia have penetrated into most households. Moreover, most students prefer to learn from an interactive environment through a self-paced style. Under the Web-based learning model, students can learn anytime, anywhere because they are not required to go to school on schedule (Appelt, 1997). Meanwhile, universities also enjoy the economic benefit due to the large student base that can share the development cost of course materials and other operational expenses. Gradually, more and more universities follow this similar way to provide online education.

Currently, most online learning systems follow the structured classroom lessons where a tutor's major responsibilities are to make sure the course materials fit for the students and to monitor their learning processes. Generally, the functions include a course builder, assignments, personal schedules, chat rooms, quizzes, surveys, and so on. However, the online learning environment is quite different from the traditional classroom setting. In a virtual environment of online learning, the initiative is driven by the students, and the traditional teacher-based learning model is no longer suitable for online education. To focus on online education, understanding individual students' background knowledge and learning needs so as to provide proper course materials for their own study becomes critical (Wolz, McKeown, & Kaiser, 1992).

In response to the above-mentioned issues in IT-based learning, we have done some preliminary work in the context of a personalized e-learning system (PEELS; Fung, Leung, & Li, 2003; Leung & Li, 2003, 2004).

In this research, an agent-based architecture with an innovative mechanism that utilizes user profiles and dynamic conceptual networks is developed to provide personalized course materials to the students.

RESEARCH BACKGROUND

Over the past decade, some researchers have focused on the areas of agent-based, multimedia, and adaptive approaches for e-learning systems. Before we introduce our PEELS approach, some related research projects are discussed below.

For agent-based research work, Andes (Gertner & VanLehn, 2000), a collaborative project started in 1995 between the University of Pittsburgh and the U.S. Naval Academy, has taken a modular architecture and is implemented in Allegro Common Lisp and MS Visual C++. The main agents of Andes contain a problem author, a problem solver, an action interpreter, and a help desk. These agents function in the sequence of creating a problem definition, generating a problem-solution graph model, and referring to the student model to make decisions upon receiving appropriate feedback and assistance. LANCA (Frasson, Martin, Gouarderes, & Aimeur, 1998) adopts an intelligent agent's approach to distance learning in a distributed environment by using a constructive approach instead of user profiles to assist students in difficulty by building a common and useful data bank. Unlike Andes and LANCA, DT Tutor (Murray & VanLehn, 2000) uses decision-theoretic methods for coached problem solving to select tutorial actions that are optimal given the tutor's beliefs and objectives. It employs a model of learning to predict the possible outcomes of each action, weighs the utility of each outcome by the tutor's belief that will occur, and select the action with the highest expected utility.

Among the multimedia-based projects, Classroom 2000 (Pimentel, Abowd, & Ishiguro, 2000) is designed to automate the authoring of multimedia documents from live events. The researchers have outfitted a classroom at Georgia Institute of Technology with electronic whiteboards, cameras, and other data-collection devices that collect data during the lecture, and combined these facilities to create a multimedia document to describe the class activities. Cornell Lecture Browser from Cornell University (Mukhopadhyay & Smith, 1999) captures a structured environment (a university lecture). It automatically produces a document that contains synchronized and edited audio, video, images, and text so as to synchronize the video footage in the live classroom with prerecorded slides used in the class. Last but not the least, MANIC, from University of Massachusetts (Stern, Steinberg, Lee, Padhye, & Kurose, 1997), discusses the ways of effectively utilizing WWW- (World Wide Web) based stored materials and presentation paradigms. In particular, MANIC proposes that students be given the opportunity to browse the materials at their own pace, stopping and starting the audio at their will.

For the adaptive approaches for online course materials, WebCT (n.d.) has been widely used in education sectors to produce online courses or to act as a tool for publishing supplementary materials for existing courses. A WebCT course is mainly created by using a series of linked HTML (hypertext markup language) pages, which are defined as paths or road maps, and all these interactions take place through a Web browser. InterBook (Brusilovsky, Eklund, & Schwarz, 1998) is based on a specific concept-based approach to develop an adaptive Web-based LISP textbook, while NetCoach (Weber, Kuhl, & Weibelzahl, 2001), an authoring system, allows the users to create adaptive and individual course modules without programming knowledge. The concepts used in InterBook are basically elementary pieces of knowledge for the given domain with a more advanced form of the domain model being a network. Each page has a set of outcome concepts and a set of prerequisite concepts associated with it to support adaptive navigation and hyperlink annotation. Unlike WebCT and InterBook, NetCoach implements two adaptive navigation techniques: curriculum sequencing and adaptive annotation of links. In NetCoach, the knowledge base of a course consists of concepts that are internal representations of the pages to be presented to the learner at the front end.

However, individual or tailored instruction based on learners' needs and backgrounds has not been supported yet. As a matter of fact, the integration of multiple agents (Lesser, 1999), user profiling (Bradley, Rafter, & Smyth, 2000), and multimedia technologies into a collaborative learning environment supporting personalization remains a very challenging problem. In the following, we elaborate on these constituent technologies in the context of PEELS (which ends up integrating them into the same environment for its ultimate goal of personalization).

AGENT-BASED APPROACH

An agent is a generic concept that represents an encapsulated computer program (Wooldridge, 1997) situated in some environments and is capable of flexible, autonomous actions in that environment in order to meet its design objectives. In particular, an agent has the following characteristics (Jennings, 2000).

- (1) Clearly identifiable problem-solving entities with well-defined boundaries and interfaces
- (2) Situated (embedded) in a particular environment—they receive inputs related to the state of their environment through sensors and they act on the environment through effectors
- (3) Designed to fulfill a specific purpose, they have particular objectives (goals) to achieve
- (4) Have autonomy and control both over their internal state and over their own behavior
- (5) Capable of exhibiting flexible problem-solving behavior in pursuit of their design objectives; they need to be both reactive and proactive

Accordingly, if we denote the environment by S as a set of external states without imposing any constraints on the structure of the elements in the set, then the description for an agent A is a 3-tuple as follows:

$$A = (Db, E^S, Act) , \quad (1)$$

where Db is a database that contains the agent's acquired knowledge, $E^S = \{e_1, \dots, e_x\}$ ($x > 0$) is a set of partitions of the environment S that constitute the possible perceptions of the agent, and $Act = \{act_1, \dots, act_y\}$ ($y > 0$) is a set of possible actions of the agent. According to Equation (1), an agent can determine how the state of

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