Intelligent Multi-Agent Cooperative Learning System

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INTRODUCTION

A computer-aided education environment not only extends education opportunities beyond the traditional classroom, but it also provides opportunities for intelligent interface based on agent-based technologies to better support teaching and learning within traditional classrooms. Advances in information technology, such as the Internet and multimedia technology, have dramatically enhanced the way that information and knowledge are represented and delivered to students. The application of agent-based technologies to education can be grouped into two primary categories, both of which are highly interactive interfaces: (1) intelligent tutoring systems (ITS) and (2) interactive learning environments (ILE) (McArthur, Lewis, & Bishay, 1993). Current research in this area has looked at the integration of agent technology into education systems. However, most agent-based education systems under utilize intelligent features of agents such as reactivity, pro-activeness, social ability (Wooldridge & Jennings, 1995) and machine learning capabilities. Moreover, most current agent-based education systems are simply a group of non-collaborative (i.e., non-interacting) individual agents. Finally, most of these systems do not peruse the multi-agent intelligence to enhance the quality of service in terms of content provided by the interfaces.

A *multi-agent system* is a group of agents where agents interact and cooperate to accomplish a task, thereby satisfying goals of the system design (Weiss, 1999). A group of agents that do not interact and do not peruse the information obtained from such interactions to help them make better decisions is simply a group of independent agents, not a multi-agent system. To illustrate this point, consider an ITS that has been interacting with a particular group of students and has been collecting data about these students. Next, consider another ITS which is invoked to deal with a similar group of students. If the second ITS could interact with the first ITS to obtain its data, then the second ITS would be able to handle its students more effectively, and together the two agents would comprise a multi-agent system.

Most ITS or ILE systems in the literature do not utilize the power of a multi-agent system. The Intelligent Multi-agent Infrastructure for Distributed Systems in Education (I-MINDS) is an exception. It is comprised of a multi-agent system (MAS) infrastructure that supports different high-performance distributed applications on heterogeneous systems to create a computer-aided, collaborative learning and teaching environment. In our current I-MINDS system, there are two types of agents: teacher agents and student agents. A *teacher agent* generally helps the instructor manage the real-time classroom. In I-MINDS, the teacher agent is unique in that it provides an automated ranking of questions from the students. This innovation presents ranked questions to the classroom instructor and keeps track of a profile of each class participant reflecting how they respond to the class lectures. A *student agent* supports a class participant's real-time classroom experience. In I-MINDS, student agents innovatively support the *buddy group* formation. A class participant's buddy group is his or her support group. The buddy group is a group of actual students that every student has access to during real-time classroom activities and with which they may discuss problems. Each of these agents has its interface which, on one hand, interacts with the user and, on the other hand, receives information from other

agents and presents those to the user in a timely fashion.

In the following, we first present some background on the design choice of I-MINDS. Second, we describe the design and implementation of I-MINDS in greater detail, illustrating with concrete examples. We finalize with a discussion of future trends and some conclusions drawn from the current design.

BACKGROUND

In this section, we briefly describe some virtual classrooms, interactive learning environments (ILE), and intelligent tutoring systems (ITS)—listing some of the features available in these systems—and then compare these systems with I-MINDS. The objective of this section is to show that I-MINDS possesses most and, in some cases, more advanced functionalities and features than those found in other systems. What sets I-MINDS significantly apart from these systems is the multi-agent infrastructure where intelligent agents not only serve their users, but also interact among themselves to share data and information. Before moving further, we will provide some brief definitions of these systems. A *virtual classroom* is an environment where the students receive lectures from an instructor. An *ILE* is one where either the students interact among themselves, or with the instructor, or both to help them learn. An *ITS* is one where an individual student interacts with a computer system that acts as a tutor for that student. At its current design, I-MINDS is a full-fledged virtual classroom with an ILE, and has the infrastructure for further development into a system of intelligent tutors. I-MINDS currently has a complete suite of similar multimedia support features, important in virtual classrooms and interactive learning environments: live video and audio broadcasts, collaborative sessions, online forums, digital archival of lectures and discussions, text overlay on blackboard, and other media. The uniqueness of I-MINDS is that the features of its interactive learning environment and virtual classroom are supported by intelligent agents. These agents work individually to serve their users and collaboratively to support teaching and learning.

Most ITSs such as AutoTutor (Graesser, Wiemer-Hastings, Wiemer-Hastings, Kreuz, & the Tutoring Research Group, 1999) have not been considered in the context of a multi-agent system. For example, one ITS *A* may store useful information about the types of questions suitable for a certain type of student based on its own experience. Another ITS *B* encounters such a student but fails to provide questions that are suitable since it does not know yet how to handle this type of student. If the two ITSs can collaborate and share what they know, then *B* can learn from *A* to provide more suitable questions to the student. In systems such as AutoTutor, agents do not interact with other agents to exchange their experiences or knowledge bases. I-MINDS is different in this regard. First, an agent in I-MINDS is capable of machine learning. A teacher agent is able to learn how to rank questions better as it receives feedback from the environment. A student agent is able to learn to more effectively form a buddy group for its student. Further, these student agents interact with each other to exchange information and experience.

I-MINDS

The I-MINDS project has three primary areas of research: (a) distributed computing (i.e., the infrastructure and enabling technology), (b) intelligent agents, and (c) the specific domain application in education and instructional design. Our research on distributed computing examines consistency, scalability, and security in resource sharing among multiple processes. In our research on intelligent agents, we study interactions between teacher agent and student agents, and among student agents. For our application in education, we focus on automated question ranking by the teacher agent and buddy group formation by the student agents.

In this section, we will focus our discussions on the intelligent agents and the multi-agent system and briefly on the instructional design. Readers are referred to Liu, Zhang, Soh, Al-Jaroodi, and Jiang (2003) for a discussion on distributed computing in I-MINDS using a Java object-oriented approach, to Soh, Liu, Zhang, Al-Jaroodi, Jiang, and Vemuri (2003) for a discussion on a layered architecture and

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