Introduction to the Special Issue on Real World Applications of Intelligent Tutoring Systems

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INTELLIGENT tutoring systems (ITS) appeared during the 1970s, most driven by the success of knowledge-based systems and expert systems. ITS are able to instruct and train students and professionals without the intervention of human beings. ITS introduced a set of ideas, like the use of computational models of domains, allowing the possibility of reasoning and explaining domain problems automatically. Developments were made in trainees' models, instructional and pedagogical planning, and user interface. In the 1990s, with the Web boom, some ITS ideas were incorporated in new computer-aided instruction paradigms, like e-learning and distributed learning. However, there is a clear difference in the level of interactions and types of skills addressed by ITS and other e-learning systems.

ITS are a good example of the use and combination of artificial intelligence techniques. Besides expert systems, other areas like natural language, machine learning, planning, multi-agent systems, ontologies, semantic Web, and social and emotional computing have been used with success in ITS. Other technologies have been applied or combined with ITS, namely, multimedia, object-oriented systems, distributed systems, databases, modeling, simulation, statistics, and communications. However, the success of ITS requires the attention of other nontechnological areas, like education sciences, psychology, and sociology.

In the last several years, ITS have moved from research labs into the real world. Many systems were developed and deployed, even for critical and complex domains. The reported benefits demonstrated by the users of these systems are impressive. ITS-taught trainees generally learn faster and translate the learning into improved performance better than classroom-trained participants. Today, ITS can be produced by authoring tools, and specific evaluation and assessment methods can be used.

Since 1988, a conference has been organized every two years: the International Conference on Intelligent Tutoring Systems, held recently in Montreal, Canada. Several conferences organize tutorials, workshops, special tracks, and sessions dedicated to the ITS topic (e.g., the ITS special track at FLAIRS 2008 held in Miami, Florida).

The idea behind creating this special issue on real world applications of intelligent tutoring systems was to bring together in a single publication some of the most important examples of success in the use of ITS technology. This will serve as a reference to all researchers working in the area. It will also be an important resource for the industry, showing the maturity of ITS technology and creating an atmosphere for funding new ITS projects. Simultaneously, it will be valuable to academic groups, motivating students for new ideas of ITS and promoting new academic research work in the area.

From a set of submitted papers with high-quality work, eight have been selected to be included in this special issue.

The paper by Vincent Aleven, Bruce M. McLaren, and Jonathan Sewall from Carnegie-Mellon University describes the use of Cognitive Tutor Authoring Tools (CTAT) in the creation of Mathtutor, an open-access Web site supporting sophisticated tutoring behaviors, such as teaching multiple solution strategies, showing dependencies among problem steps, and supporting multiple interpretations of student behavior.

The paper by Mingyu Feng, Neil N. Heffernan, Cristina C. Heffernan, and Murali Mani from the Worcester Polytechnic Institute uses the ASSISTment System with a fine-grained skill model. Experiments with eighth grade students in mathematics in Massachusetts show that ITS can predict state scores accurately.

MATHEMA, an adaptive educational hypermedia system, is presented in the paper by Alexandros Papadimitriou, Maria Grigoriadou, and Georgios Gyftodimos from the University of Athens. This system supports senior students in Greek high schools or students of colleges who are novices in physics (electromagnetism) individually and/or collaboratively, overcoming their misconceptions and learning difficulties.

Computer science students are faced with some difficulties in programming with some data structures. The work of Davide Fossati, Barbara Di Eugenio, Stellan Ohlsson, David G. Cosejo, and Lin Chen from the University of Illinois at Chicago, and Christopher W. Brown, from the United States Naval Academy, presents iList, an ITS way of helping students in learning linked lists and giving explanations for syntax and execution errors.

The paper by Orla Lahart, Declan Kelly, and Brendan Tangney from the National College of Ireland presents PACT, Parent and Child Tutor, an ITS that addresses the

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challenge of building an adaptive system which simultaneously supports both parents and children in the home tutoring environment. The paper focuses on the effect of PACT on parental self-efficacy.

The paper by Luiz Faria, António Silva, and Zita Vale from the Institute of Engineering, Polytechnic of Porto, and Albino Marques from the Energies of Portugal utility describes the use of ITS for training control center operators in tasks like incident analysis and diagnosis (DiagTutor) and service restoration (CoopTutor) of power systems. The system combines several artificial intelligence techniques.

Emilio Remolina, Sowmya Ramachandran, Richard Stottler, and Alex Davis, from Stottler Henke Associates, present PORTS TAO-ITS, a deployed ITS for the instruction of Tactical Action Officers in training at the Surface Warfare Officers School in Newport, Rhode Island. PORTS TAO-ITS illustrates a simulation-based learn-by-doing tactical system where students interact with simulated teammates.

ASSISTment Builder is a tool designed to effectively create, edit, test, and deploy tutor contents. Leena Razzaq, Jozsef Patvarczki, Shane F. Almeida, Manasi Vartak, Mingyu Feng, and Neil T. Heffernan, from the Worcester Polytechnic Institute, and Kenneth R. Koedinger, from Carnegie-Mellon University, describe the use of this tool for reducing the cost of content creation.

The guest editors of this special issue wish to express their gratitude to all authors who submitted their papers and to the reviewers who contributed their reviews and suggestions for improvements to the papers, especially those accepted for this issue. We are also indebted to Editor-in-Chief Wolfgang Nejdl and Associate-Editor-in-Chief Peter Brusilovsky for the opportunity to make this special issue a reality and for their helpful opinions. Marion Wicht deserves our thanks for facilitating the process. We expect that this special issue will be very helpful for *IEEE Transactions on Learning Technologies* readers and for the intelligent tutoring systems community.

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Guest Editors

Carlos Ramos graduated from the University of Porto, Portugal, in 1986 and received the PhD degree from the same university in 1993. He is a coordinator professor in the Department of Informatics at the Institute of Engineering, Polytechnic of Porto (ISEP-IPP). His main interests are in artificial intelligence and decision support systems. He is the director of GECAD (Knowledge Engineering and Decision Support Research Centre), the largest R&D center of the Polytechnic system in Portugal, which is dedicated to AI topics. He coordinates the Ambient Intelligence and Decision Support group of GECAD. He has about 50 publications in scientific journals and magazines and more than 200 publications in scientific conferences.

Claude Frasson received the PhD degree (doctorat d'état) in informatics in 1981 from the University of Nice, France. Since 1988, he has been a full professor in computer science at the University of Montreal and director of GRITI, a multidisciplinary group involving seven universities in Québec. He is the founder of the Intelligent Tutoring Systems (ITS) International Conference, which is held every two years. In 1998, he was responsible for the SAFARI project, a very large project supported by the Ministry of Industry, Science, Trade and Technology of Quebec which produced about 70 graduate students. His domains of interest are on brain function applied to education and involving emotional intelligence, student modeling, and intelligent e-learning. He is the director of the HERON Laboratory, has more than 300 published papers and five books, and has served as a member of the editorial board of several scientific journals and magazines.

Sowmya Ramachandran received the PhD degree in artificial intelligence from the University of Texas at Austin. At present, she is a research scientist and project manager at Stottler Henke Associates, Inc. Her current research interest is focused on advanced educational technology, including intelligent tutoring systems (ITS), intelligent agent for simulations and serious games, and authoring tools for ITS and simulations. An avid learner herself, Dr. Ramachandran is interested in the entire spectrum of human learning, including metacognition and motivation. Experience with military and private industry gives her a unique perspective on the needs and requirements of the ultimate end-users and their constraints. She contributes expertise in AI, instructional systems, probabilistic reasoning, and knowledge management.