The field of computer-based training has experienced a series of revolutionary changes since the advent of computers 50 years ago. In 1960, none of the following learning environments existed: adaptive computer-based training, dynamic multimedia, hypertext, hypermedia, interactive simulation, intelligent tutoring systems, inquiry-based information retrieval, animated pedagogical agents, virtual environments, serious games, and collaborative learning. None of them have become mainstream technologies used in schools today, even though they’re potentially available to all Web users.

Today’s challenges

Education in the 21st century faces an increasing number of challenges that require intelligent systems. The learning environments of today and tomorrow must handle distributed and dynamically changing content, a geographical dispersion of students and teachers, and generations of learners who spend hours a day interacting with multimillion-dollar multimedia environments. The new learning environments are moving beyond kindergarten through college classrooms to distance learning, lifelong education, and on-the-job training; they’re entering the multifaceted universe of virtual worlds and ambient spaces. These requirements pose strong demands for intelligent educational systems that are tailored to both students’ and teachers’ individual needs and that are a seamless part of our complex, mobile lifestyles. In addition to facilitating learning, these systems must prevent learners from getting lost in a multitude of interactions, modalities, and content.

Intelligent educational systems benefit enormously from their ability to provide adaptivity and customization, thus maximizing system personalization. Both cognition and emotion play an essential role in designing systems that are tailored to individual learners. These systems need sophisticated computational algorithms and processing mechanisms to model each learner’s cognitive and emotional states and to dynamically adapt to each learner. These algorithms and mechanisms are formulated at a much finer grain size than the computer-based training systems of yesterday.
This special issue

The articles in this special issue report on novel, cutting-edge, intelligent learning environments. The systems not only have intelligent computational architectures but also are empirically tested on humans. Empirical research is of course essential to test system fidelity in delivering the intended pedagogy and to assess learning gains, usability, and learner satisfaction.

Vivien Robinet, Gilles Bisson, Mirta B. Gordon, and Benoît Lemaire present an approach to modeling student knowledge and skills. Their system applies machine-learning techniques that automatically uncover students’ high-level abilities from the problem-solving traces of students’ behaviors that are produced in a learning environment. They illustrate the system with examples from students’ actions in the domain of algebraic transformations.

Luca Chittaro and Roberto Ranon’s system delivers personalized learning content in 3D educational virtual environments. The techniques extend those in existing adaptive hypermedia systems to the new contexts of virtual worlds, which are structured and navigated in a completely different way. The article describes a case study on creating content in interactive 3D graphics.

Antonija Mitrovic, Brent Martin, and Pramuditha Suraweera report their progress in building and testing constraint-based tutors. These intelligent tutoring systems follow the evolution of constraint-based modeling, an approach that specifies instructional domains at an abstract level that’s aligned with the content’s functional characteristics. They’ve had several commercial successes, which have motivated them to build authoring tools to make the technology widely available to instructors.

Eduardo Guzmán, Ricardo Conejo, and José-Luis Pérez-de-la-Cruz present empirical studies of their SIETTE system, which constructs and administers adaptive tests through the Internet. They collected data from students in two university courses on programming languages over four years. Their article describes how SIETTE uses intelligent techniques to infer student knowledge, with adaptation depending on the question selection process and the test finalization decision.

Sidney D’Mello, Rosalind W. Picard, and Arthur Graesser investigate the reliability of detecting students’ emotional states while they’re learning from an intelligent tutoring system. AutoTutor uses an animated conversational agent that helps students who are learning about physics and computer literacy by conversing with them in natural language. The system infers emotions such as confusion, frustration, boredom, and engagement on the basis of the dialogue history and the learner’s facial expressions and posture. The next step is to design AutoTutor to adapt to learners’ emotions as well as their cognitive states.

Winslow Burleson and Rosalind W. Picard report on an experiment in which children interacted with an emotionally intelligent conversational agent. This agent tracks the learner’s affect states through facial expressions, a pressure-sensitive mouse, a skin conductance sensor, and a posture chair. They report empirical evidence on the importance of properly coordinating the relationships among affect, task-based interventions, and nonverbal mirroring with respect to girls’ and boys’ affective states.

Finally, Siriwan Suebnukarn and Peter Haddawy describe COMET, a collaborative intelligent tutoring system for medical problem-based learning. It uses Bayesian networks to model the knowledge and activities of both individuals and groups and to generate tutoring hints. COMET has a multimedia interface that integrates text and graphics to facilitate communication. Their results show greater gains in clinical reasoning when students learn from COMET compared with human-tutored sessions.

This selection of articles provides a snapshot of current research in the field of intelligent educational systems. These systems illustrate novel applications of intelligent techniques for learner modeling, personalization, and adaptation to the learner’s cognitive, emotional, and social states. The results from the case studies and the systematic empirical research show a promising marriage between intelligent system design and complex learning.

Related Links

• AutoTutor: www.autotutor.org
• SIETTE: http://marte.lcc.uma.es/siette
• SQL-Tutors: www.aw-bc.com/databasemakeplace

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