Intelligent Tutoring Systems (Guest Editorial)

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Intelligent Tutoring Systems (ITS) are meant to provide useful tutoring services for assisting the student. These services include coaching, assisting, guiding, helping, and tracking the student during problem-solving situations. To offer high-quality tutoring services, an ITS must be able to establish the correct student profile, then understand and diagnose the student cognitive as well as its affective state. This special issue of Educational Technology & Society presents recent works dealing with those matters.

Extracting Procedural Models Using Educational Data Mining

The main goal of an intelligent tutoring system is to actively provide guidance to the student in problem-solving situations. Relevant feedback should be founded on a thorough understanding and diagnosis of student responses. Building such understanding and diagnosis model is a difficult issue that is also a time-intensive process involving human experts. This issue becomes even more difficult in ill-defined domains where an explicit representation of the training task is hard, if not impossible, to set up. Educational data-mining (EDM) brings some promising solutions to this issue.

You will find in this special issue two EDM-based solutions proposed for coping with this problem. Each of these solutions consists of a model that can constantly learn from new learner or user data and thus, guarantees that the tutor provides an up-to-date feedback.

In one hand, Barnes and Stamper propose a novel application of Markov decision processes (MDPs) to automatically generate hints for an intelligent tutor that learns. This approach eases the process of building the understanding and diagnosis model of student actions. The authors extracted MDPs from four semesters of student solutions created in a logic proof tutor, and calculated the probability of being able to generate hints for students at any point in a given problem. The results indicate that extracted MDPs and their proposed hint-generating functions are able to provide hints over 80% of the time. The results also indicate that they can provide valuable tradeoffs between hint specificity and the amount of data used to create an MDP.

In the other hand, Fournier-Viger et al. present a novel framework for adapting the behavior of intelligent agents based on human experts’ data. The framework consists of an extended sequential pattern-mining algorithm that, in combination with association rule discovery techniques, is used to extract temporal patterns and relationships from the behavior of human learners of multiple profiles, executing a procedural task. The proposed framework has been integrated within CanadarmTutor, an intelligent tutoring system aimed at helping students solve procedural problems that involve moving a robotic arm in a complex virtual environment. CanadarmTutor acts in an ill-defined domain where the problem space associated with a given task consists of an infinite number of paths. The framework was used to improve the behavior of a cognitive agent that adapts its decision by learning from data gathered during past cognitive cycles. The results of the experimentation demonstrate the benefits of the framework for tutoring systems acting in ill-defined domains.

Filling the Gap Between Student Profiles Through Metacognitive Problem-Solving Strategy

One benefit of tutoring is of narrowing, even eliminating the gap between High and Low learners. Low learners are those who are more sensitive to variations in learning environments. Effective ITS should narrow the gap as much as possible without pulling the High learners down. In their paper, Chi and VanLehn present a study that investigates this issue. The study involved two groups of college students who studied probability first and then physics. The experimental group studied probability with Pyrenees, an ITS that explicitly taught and required them to employ a...
general problem-solving strategy; the control group studied probability with Andes, an ITS that does not teach or require any particular strategy. During subsequent physics instruction, both groups used Andes.

Results showed that an Intelligent Tutoring System teaching a domain-independent problem-solving strategy indeed closed the gap between High and Low learners, not only in the domain where it was taught (probability) but also in a second domain where the strategy had not been taught (physics). The strategy includes two main components: one is solving problems via Backward-Chaining (BC) from goals to givens, named the BC-strategy, and the other is drawing students' attention on the characteristics of each individual domain, named the principle-emphasis skill. Evidence suggests that the Low experimental group transferred the principle-emphasis skill to physics while the High experimental apparently already possessed it and thus mainly transferred the BC-strategy.

**Coping with Affective Issues in Tutoring Systems**

Considering learners' affective responses during learning episodes is a key issue for more effective tutoring dialogue. Hence, recent work has begun to investigate the emotions experienced during learning in a variety of environments. McQuiggan *et al.* contribute to this effort by investigating the likelihood of affective transitions that occur throughout narrative-centered learning experiences. The study was conducted with the Crystal Island, a learning environment in which narrative is used as a mechanism to contextualize learning.

The results suggest two directions for future work. First, they call for investigation of what type of feedback pedagogical agents should consider when empathy does not promote desirable affective states for learning. For instance, reactive empathy was likely to encourage transitions to either flow or frustration. Second, analysis of individual differences is necessary to determine the affective transitions common across a variety of demographics such as gender, but also across learning attributes such as efficacy, goal orientation, interest, and abilities to self-regulate both learning and affect.