Intelligent Tutoring Systems (ITSs): Advanced Learning Technology for Enhancing Warfighter Performance

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TUTORIAL ABSTRACT

The tutorial will provide the foundation to help simulation users, developers, and acquisition specialists determine how best to exploit the benefits of intelligent tutoring systems. Intelligent Tutoring System (ITS) technology provides the means to expand the educational capabilities of simulation to include individualized teaching without the man-power required of individual human tutors or observer/controllers. Specifically, an ITS can provide, to a student performing in a simulated scenario, an automatic debriefing, tailored remediation to address deficiencies observed in his performance in the simulation, and automatic selection of the best scenarios for that student to allow him to practice his weakest areas.

This tutorial provides an introduction to ITSs and their benefits when combined with simulation. The major components that constitute an ITS will be described. The tutorial will also offer information on how to implement intelligent tutoring system technology. Issues dealing with integration with simulation will be addressed by explanation and example, including a discussion of the SISO draft ITS/Simulation Interoperability Standard (I/SIS).

The tutorial will utilize actual ITS examples to illustrate important concepts. These examples include systems where the ITS has been integrated with a simulator, demonstrating the synergies afforded by this union, videos will help to convey these benefits in action.

Finally a live demonstration will be conducted where a simple ITS will be constructed and interfaced to a simulation, thus showing the major development steps for an ITS.

ABOUT THE PRESENTERS

Dick Stottler has been working on Intelligent Tutoring Systems (ITSs) for the military since 1992 and has managed a large number of tactical ITS projects. His philosophy emphasizes the use of scenarios in training simulations to provide an active learning by doing type of instruction. Evaluations of student knowledge are performed automatically by the ITS while the students are performing scenarios that are as realistic and close to operational as possible. These ITS projects include the TAO ITS for the Navy, an ITS that teaches principles of counter terrorism intelligence analysis for the Army, the acoustic signal analysis ITS for the Navy, an ITS that teaches tactics and operations for the Navy' newest anti submarine helicopter, an ITS which teaches tank tactics and command and control system operations to company commanders, an ITS authoring tool tailored to military domains, the Dismounted Infantry ITS for the Army, the Army Medical Specialist ITS, an ITS authoring tool tailored to system operations, an F/A-18 Tactics ITS, a Battlefield Command Reasoning ITS, and an AWACS Weapons Director intelligent tutoring system (ITS) prototype for the Air Force. Additionally, Mr. Stottler has taught numerous Artificial Intelligence and Expert Systems courses. He has experience as a classroom instructor as well.

Dr. Eric Domeshek has been researching, developing and publishing in the area of Intelligent Tutoring Systems (ITSs) and other educational technologies since serving as a member of Research Faculty at GA Tech. He moved to Northwestern University's Institute for the Learning Sciences (ILS) as an Assistant Professor of Computer Science to pursue teaching and research in these areas. ILS was an interdisciplinary research and development laboratory dedicated to applying principles of cognitive science, computer science, artificial intelligence, and educational theory to improve the way people learn. At ILS, in addition to teaching undergraduate and graduate courses, Dr. Domeshek developed a pair of successfully fielded educational systems for university courses, and several other AI and multimedia systems for knowledge management. Dr. Domeshek's largest current ITS project addresses the problem of how to train teams of medical personnel to cope with situations involving weapons of mass destruction. In part, this is an application to medical problems of earlier work on Socratic tutoring of Army officers in high-level battlefield command reasoning skills. Where the command reasoning work focused on modeling Socratic interaction—question-driven discussions of their rationale that aim not to promote a particular "right" tactical answer, but rather to model appropriate modes of thinking—this new work emphasizes simulation of interaction with other team members.

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BACKGROUND

Intelligent Tutoring Systems (ITSs) fall under the Education Subcommittee because they are the application of instructional methods and theories. Specifically these are the pedagogical theories that relate to the importance of performing instruction in the context of operational tasks and (simulated) operational environment and the importance of accompanying simulation training with evaluation and feedback regarding the student's decisions and actions.

Historically, ITSs have not been widely applied outside of academic subjects and have specifically been only rarely applied to military training problems. However, this situation is changing. The term, "Intelligent Tutoring System" has begun to appear in solicitations for acquisition of training systems, both those relating to training simulations and those relating to interactive courseware. There are a number of reasons for this trend. Restriction of training funds in parallel with increasing tactical system complexity (and therefore increasing training required) is forcing the DOD to look at ways to automate functions normally performed by instructors. This is squarely in the realm of ITSs. Furthermore the increasing power and reduced cost of PC platforms has led to an increase in PC based training simulations. This has increased the number of students working in simulated scenarios (thus increasing the need for those students' actions to be evaluated) and made the data for automatic evaluation much more readily available than when the actual tactical equipment was used for training. As ITSs become considered for and applied to a wider variety of training applications it will become more important for a wider audience to be familiar with them. This includes training simulation developers, interactive courseware developers, DOD acquisition specialists, instructors, and trainees.

TUTORIAL AIM

This tutorial is aimed at the broad military training, simulation and education community. Increased application of ITSs will require increased awareness and familiarity with this technology throughout this community. Simulation developers will have to understand what an ITS is and what it needs from and will provide back to a training simulation and an understanding of how to integrate the two. Interactive courseware developers will have to understand how traditional IMI relates to and should be interfaced with an ITS. Instructors will have to understand an ITS's benefits, applicability, opportunities, and limitations and how best to utilize the technology. Training system acquisition personnel will have to understand the special requirements of an ITS, such as the need to integrate with training simulations and IMI, as well as the special development processes ITSs require. To address the ITS knowledge acquisition needs of the diverse military training, simulation and education communities, this tutorial will describe what ITSs are and their benefits, how they relate to and interface to training simulations and IMI, the typical ITS components and techniques for them, and the process used to develop an ITS. The concepts will be illustrated by videos and live examples of actual military ITSs.

LEARNING OUTCOMES

There are several learning outcomes for the ITS tutorial. After taking the tutorial, attendees should:

- Understand what an ITS is
- Know what the benefits are
- Understand how an ITS relates to and interacts with a training simulation and IMI
- Know what data an ITS needs from a simulation
- Know what data the simulation may need from the ITS
- Know multiple ways the two can be interfaced
- Know the typical components of an ITS along with techniques to develop them

- Understand the process used to develop an ITS

TUTORIAL DESCRIPTION

The content of the tutorial is described in this section and overviewed in the subsection immediately below.

Overview

The tutorial will start with a short overview which gives a preview of what will be covered over the course of the 90 minutes. The tutorial will first describe what an ITS is and give the high level context, which shows where an ITS fits in a larger training system with other more traditional training technologies such as simulations and IMI. The Benefits of an ITS will be presented. The individual components of an ITS will be first summarized then shown together in a typical ITS architecture. Each component will then be described in more detail along with different techniques and methods to implement it. One of these components is the interface between the ITS and the simulation. After the components are described, the typical process used to develop the ITS as a whole will be presented. This process will then be illustrated by executing it to develop a simple ITS at the end of the tutorial.

ITS Description

The primary goal of the ITS field is to mimic human tutors by adapting instruction to an individual student's performance, strengths and weaknesses, and other attributes. Although traditional ITSs applied to traditional domains often do not utilize simulations, military ITSs typically monitor a student's decisions and actions in simulated scenarios, then evaluate them, provide feedback, and infer the student's knowledge and skills and his/her ability to APPLY them when appropriate. An ITS typically includes a "Student Model," a set of estimates of the students mastery of his/her knowledge and skills and ability to apply them based on the student's performance in scenarios.

ITSs also often formulate instructional plans for the student. ITSs are based on Artificial Intelligence (AI) technology. Instruction is adapted to individuals from the Student Model, not directly from the student's actions (which would be a form of branching). Specifically, ITSs are not just a new form of Interactive Multimedia Instruction (IMI). They are often interfaced to IMI (as well as to the simulations in which they are monitoring a student's performance, of course) as shown in the next subsection.

High Level Context

The high level context in which the ITS usually operates is shown in the following figure. The student interacts primarily with a training simulation as shown. That interaction is monitored by the ITS which receives from the simulation the student's actions and decisions as well as the context in which the student is making those decisions. This allows the ITS to evaluate those decisions and actions, give the student feedback and formulate a plan of remediation. That remediation may involve highly focused portions of an IMI system, if present, to address misperceptions that the ITS has inferred that the student has. (IMI may have also been used to initially introduce concepts to the student prior to exercising them in the simulation.) The remediation plan often involves selection of scenarios to test the effects of remediation, to practice areas the student is weakest in, and to use as examples to illustrate points the ITS is making to combat deficiencies that it perceives the student has.

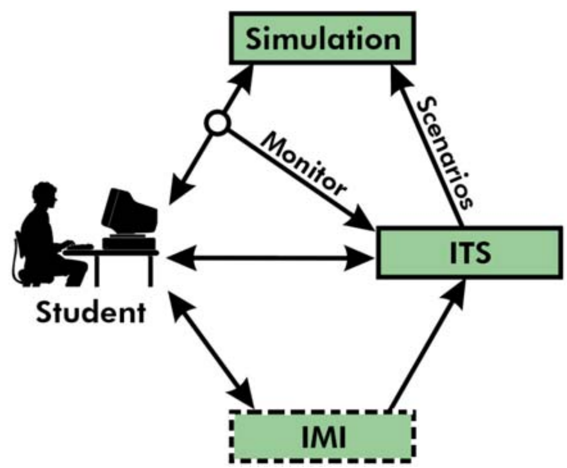

Figure 1. High Level Context

Benefits

There are many benefits associated with ITSs. They off-load instructors and can replace instructors in situations where they may not be present such as with an embedded training system which may be used out in the field. They automate the debriefing and after action review (AAR) process. By evaluating decisions instead of outcomes, they allow the use of lower fidelity simulations. By providing decision making practice with feedback they improve students' problem-solving skills. By offloading instructors, they allow for more tactical trainee practice. They often provide improved training outcomes when compared to classroom instruction and when compared to traditional IMI. Training and evaluation are more operationally realistic and relevant. Because training is tailored and customized to the individual student, more efficient student learning occurs. The knowledge incorporated into the ITS captures the expertise of best instructors and distributes it to all students. Finally, ITSs leverage the existing investment in simulators and/or IMI.

Components

An ITS normally consists of the components shown in the Architecture below. The student generally spends the majority of his time interacting with the simulation's user interface. This typically provides the student's interaction with the simulated environment, modeled and updated by the Simulation Engine. These two components constitute the Simulation System to which the ITS is interfaced. The Simulation/ITS Interface provides the student's actions, the trainee observables, from the simulation to the Evaluation Component. This interface, methods and techniques to define and implement it; and evolving standards for it will be described in detail in the tutorial. Specifically, the SISO draft ITS/Simulation Interoperability Standard (I/SIS) will be presented.

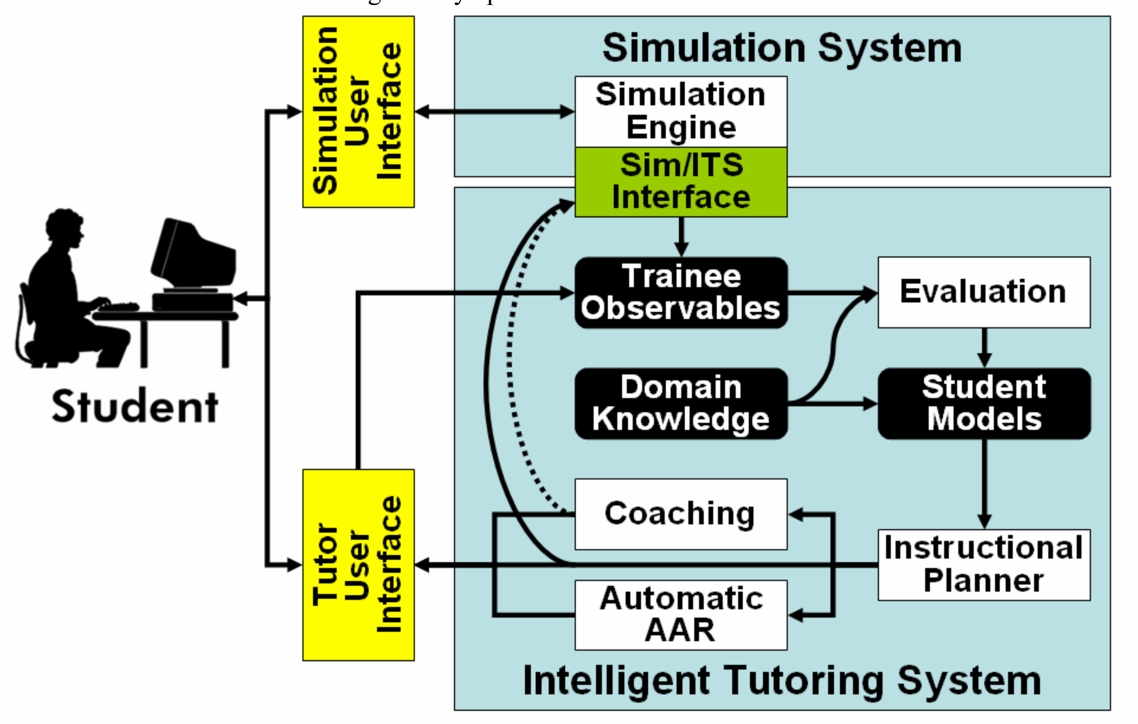

Figure 2. Architecture

The Evaluation component uses domain knowledge to examine the trainee observables and to determine which were correct and incorrect and to infer what these imply about the state of the trainee's knowledge and skills required for those actions and decisions. Different techniques for automatic evaluation and the representation of the required domain knowledge will be discussed. These new inferences of the trainee's knowledge and skills are folded into the student model, which is based on the trainee's entire history with the system. The Evaluation component's output is also used by the coaching and automatic AAR components to present feedback at the appropriate time. The Student Model information is used by the Instructional Planner to determine the next instructional events including appropriate scenarios for practice in the training simulation and the degree of hinting and coaching which are appropriate for the trainee's current state of development. Typical techniques used in the ITS's user interface are also discussed.

ITS Development Process

The tutorial will describe the proper ITS development process as well as tools to facilitate ITS development. The process will be illustrated with a small but complete example. The ITS development process is similar to the ADDIE process from ISD. First

Knowledge Engineering (KE)/Cognitive Task Analysis (CTA) is performed on both the tasks to be trained and on the process instructors use to train that task. This includes useful scenarios, methods to evaluate student's performance in those scenarios, the reasoning process used to uncover a student's underlying deficiencies, and remediation techniques to address those found. A scenario-based approach to KE/CTA is recommended, where the individual decisions required in the scenario are stepped through and discussed in detail.

The next two steps, ITS Design and Develop Scenarios, are typically performed in parallel. Design includes determining the basic instructional strategy, such as a practice – debrief loop, for situations where the trainee can be presumed to be knowledgeable, such as in refresher training. An instructional strategy for less knowledgeable students may include initial presentation of instructional material as well as real-time coaching and hinting when first performing in simulated scenarios. Design also includes determining the training simulation integration requirements including what data is needed and available for the ITS in order for it to evaluate the trainee's actions. Design also typically involves choosing evaluation techniques and applicable ITS development tools and determining the required budget (or conversely what can be implemented in the available budget).

The scenarios are developed while working closely with instructors and should be based on scenarios that they already use and have experience with in terms of how trainees normally perform in them. Of course the ITS has to be implemented and integrated and the result evaluated first by instructors then in concert with students. A spiral development methodology is more important with an ITS than most software systems because the instructors, the primary customers, will likely not have experience using ITSs before. Often delivery of the first iteration provides them with a significant learning experience of their own.

ITS Development Example

The entire process described in the previous section will be executed in a very abbreviated way in a military training domain to produce small versions of each of the components of an ITS system.

QUESTIONS

The following are questions that tutorial attendees will be able to answer:

- List 3 different benefits of a Warfighter Intelligent Tutoring System (ITS)
- List at least 4 components of a Warfighter Intelligent Tutoring System and describe each.
- List 2 types of software a Warfighter ITS is usually interfaced to.
- List at least 3 typical methods of interfacing a Warfighter ITS to a tactical training simulation.
- List 4 out of 5 steps in the typical Warfighter ITS development process.

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