ENHANCING SIMULATION EDUCATION WITH INTELLIGENT TUTORING SYSTEMS

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ABSTRACT

The demand for education in the area of simulation is in the increase. This paper describes how education in the field of simulation can take advantage of the virtues of intelligent tutoring with respect to enhancing the educational process.

For this purpose, this paper gives an overview of what constitutes the objectives and the content of a comprehensive course in discrete event simulation. The architecture of an intelligent tutoring system is presented and it is discussed how these sophisticated learning aids offer individualised student guidance and support within a learning environment. The paper then introduces a prototype intelligent tutoring system, the simulation tutor, and suggests how the system might be developed to enhance education in simulation.

1 INTRODUCTION

Simulation provides the pedagogical challenge of educating students in a wide range of problem understanding skills (Paul and Hlupic, 1994). A recent approach to the use of computers as tutors is that of intelligent tutoring systems (Kaplan and Rock, 1995). Intelligent tutoring systems provide helpful guidance and adaptation to the student by exploring and understanding the needs of the individual student. This paper proposes the use of intelligent tutoring to enhance education in simulation. For this purpose, we present an overview of what constitutes the learning objectives and content of a comprehensive course in simulation. The paper continues to describe the architecture of intelligent tutoring systems and how these sophisticated learning aids can provide individualised tutoring. The paper presents a prototype intelligent tutoring system, the simulation tutor, and suggests how the system might enhance the delivery of skills and knowledge in simulation.

2 EDUCATION IN SIMULATION

An example of a typical course in discrete event simulation is taught at the Department of Computer Science and Information Systems, Brunel University, England. The course is dedicated to the objective of educating the student in problem understanding, and is a final year option open to B.Sc. Computer Science and B.Sc. Computing in Business students. This is achieved through an overview study of simulation approaches, and aims to provide the student with practical experience in different simulation languages and environments used in industry. The main modes of delivery of the course are lectures and practical case studies. The underlying themes ask questions such as, 'How may a simulation model be built, using an appropriate simulation tool, which represents the best understanding of the system under study?' and 'Using such a model, how may we experiment with it to help us understand more about that system?' Accordingly, the course objectives include the management of the simulation process, the development of simulation skills and promotion of awareness of the place of simulation relative to other disciplines (orientation).

2.1 Management of the Simulation Process

This concerns the key educational themes of model development and experimentation. Model development addresses the means by which a simulationist can confidently develop and subsequently demonstrate to the owner of the system the validity of a model developed for that system. Experimentation concerns the formulation of the simulation experiments to be performed on the simulation model.

2.2 Development of Simulation Skills

The student is taught a variety of techniques for this purpose. For example, during the course, the student is in-

troduced to activity cycle diagrams, automatic program generators, visual interactive simulation modelling, simulation program structures, simulation software tools, the handling of stochastic input and output of the model, and issues relating to model confidence. This course of study is backed up with a workshop program to reinforce these practical skills, so giving the opportunity for the student to apply what he or she has learnt in order to concretise the knowledge delivered via the lecturing programme. For example, the student discovers activity cycle diagrams and then is given the opportunity to pursue a simple case study to model a system in terms of this technique. An automatic program generator is then introduced to give the student some experience in transferring the model into a simulator. Case studies of increasing complexity are introduced to address other aspects.

2.3 Simulation Orientation

Simulation Orientation is intended to present simulation as being part of a larger field concerning techniques relevant to decision making. The reason for this issue being addressed is exactly why simulation has found itself as part of other courses ranging from Operational Research to Management Science. It is important that the student is aware that simulation is not an isolated discipline and has strong links to other fields.

This course has proven to be extremely popular amongst undergraduates. While gratifying that this is the case, the size of the student cohort undertaking this scheme of study has increased the pressure placed on the educators responsible for course delivery. This is especially true for the practical case study elements of the course which require significant tutor-student interaction. These were some of the factors motivating a study launched to examine methods to alleviate this pressure. The most interesting possibility which arose from this study was that of a recent innovation in computer-based training which takes advantage of Artificial Intelligence. This is termed *intelligent tutoring systems.*

3 INTELLIGENT TUTORING SYSTEMS

The objective of intelligent tutoring systems (ITSs) research is to provide a new plateau of instructional capability by integrating artificial intelligence into computerised learning systems. Intelligent tutoring systems provide helpful guidance to the student and are intended to complement socalled conventional computerbased training systems with the features of an equivalent "online" human tutor. It is therefore the goal of an ITS to make the computer-based teaching process more adapt-

able to the student by exploring and understanding the student's special needs and interests, and by responding to these as a human tutor does. In order to provide this adaptability to the student an ITS makes use of three knowledge models. These are the *tutoring model*, which regulates the instructional interactions with the student, the *domain model*, which contains the knowledge about the domain to be taught, and the *student model*, which represents any information about the student. Adding the fourth component, the *user interface*, completes an ITS (Kaplan and Rock, 1995). To better understand the means by which ITS can aid education in simulation, we now review the four components.

3.1 The Domain Model

The domain model of an ITS contains the knowledge about the subject area to be taught. The ITS uses its domain knowledge to reason about and solve a problem which has been set for, or by, a student. This knowledge has to be represented in such a way that it supports reasoning that resembles the human problem-solving process within the teaching domain. Furthermore, different knowledge representations may be required to support the application of different teaching strategies. One rather pragmatic way of looking at what the domain model represents is to consider it as being a computer-based training tool and postponing decisions which have to be made concerning knowledge representation, etc. As will be seen, it is this approach which has given rise to our current implementation cycle.

3.2 The Tutoring Model

An ITS should exhibit the various tutoring characteristics encountered in the classroom. These are encapsulated in the tutoring model. It must therefore have control over the selection and sequencing of material to be presented to the student. The system must also be able to respond to questions concerning the subject material and must be able to apply learning strategies to determine when students need help and what kind of help is required. For this purpose the tutoring model incorporates different teaching strategies (O'Neil, Slawson and Baker 1991).

Teaching strategies are used to present material and depend on the subject matter and the instructional objectives of the ITS. A teaching strategy determines the style of material delivery that is employed in order to lead the student and to indicate the times at which intervention is required. Many ITSs apply different teaching strategies in different teaching situations. Reviews have been made by Siemer, Taylor, and Elliman (1995) and Elsom-Cook (1991).

An ITS should ideally include a selection of different

teaching strategies for intervention. The strategy may be chosen according to the peculiarities of a tutorial situation, such as the student's needs and preferences, experience and the domain of discourse (Angelides and Tong 1995).

3.3 The Student Model

To carry out intelligent tutoring a tutor has to have a good understanding of the student being taught. For this reason an ITS uses a student model to represent the student's emerging knowledge and skills of the subject matter. An ITS may use its student model to analyse the input of the student during tutoring interaction. The student's input may come in a variety of forms ranging from answers to questions posed by the ITS or moves taken in a game, to commands delivered within an editor. This information can sometimes be complemented by the student's educational history.

The most common approach is the representation of the student's knowledge in the form of an overlay model. Here the student's knowledge is represented as a subset of an expert's knowledge. As the student moves from his initial state of knowledge towards mastery, parts of knowledge are added to this expert knowledge subset. To determine the student's knowledge state the system generally refers to the same knowledge base using different interpreters. However, the overlay model allows only missing parts of knowledge to be represented. To represent misconceptions, i.e. a different conception of some part of knowledge, the overlay model is usually complemented by a educational bugs catalogue. The bugs catalogue is a library of common errors made by students. It represents typical deviations a student can make from the ideal expert behaviour. Student diagnosis is carried out by matching the student's faulty behaviour against the bugs in the bugs catalogue. From this remedial action can be taken by the system.

3.4 The User Interface

The user interface is generally recognised as a fourth component of an ITS architecture (Woolf and Hall 1995). As the student interacting with the ITS is working in an area he or she does not understand well the system has to ensure that any complications the student is exposed to when operating the system are kept to a minimum. A well designed interface can add considerably to the way in which the student will conceptualise the domain being taught (O'Malley 1990).

The user interface determines how students interact with the ITS (Bonar 1991). The teaching material may have to be presented in different formats, such as text, graphics, animation or video (Alpert, Singly and Carroll

1995) depending on the needs and requirements of the current situation, such as the teaching strategy employed or the nature of the material to be presented. A well designed human interface allows the ITS to present instruction and feedback to students in a clear way. At the same time it can provide students with tools and techniques to state problems and hypotheses to the ITS.

4 STUDENT-CENTRED TUTORING

An ITS employs the knowledge of its three models to provide studentcentred tutoring, i.e. the adaptation of the tutoring process to the student's needs and preferences. In order to provide this adaptability for a student, an ITS should apply suitable teaching strategies and presentations for each subject matter unit as needed, choosing the form that is most beneficial to the student for a particular instructional situation (Miller and Lucado 1992). The selection of an appropriate teaching strategy and its presentation requires knowledge about the needs of a student. The student model may provide information about the student's experience with particular remedial strategies and different ways of presentation. Accordingly, it may provide information on approaches that have proven to be successful or unsuccessful within earlier interventions, and the tutoring process may adapt accordingly.

A further common discriminating factor to consider in order to distinguish between students with different needs, at a stage where the creation of a full cognitive model has not yet been achieved, is the differentiation between student advancement stages. A system may, therefore, adjust its tutoring to the advancement stage of a student. A fundamental idea in education is that as students learn more about a subject, one can teach them progressively more advanced ideas. Accordingly, a novice may require different tutoring from an advanced student. Whilst the competent student may be able to appreciate and integrate shallow and subtle tuition, the novice student might require a detailed explanation of intermediate ideas (Silverman 1992).

A further issue of student-centred tutoring is the issue of proactive instruction and reactive instruction (Alpert, Singly and Carroll 1995, Silverman, 1992). An ITS may provide adaptability to the student by providing both help that may be invoked by the student or by the system. An advanced student, for example, may recognise his need for help and may decide to activate system help. However, when the student is a novice, or when the teaching domain is broader, system-invoked help seems more appropriate. The student may require intervention when the student makes a mistake without realising it, or when the student does not know what to do next. A student who has problems with the English language, for example, may appreciate a system-activated spellchecker

or grammar-checker that assists him incrementally during the task as each difficulty occurs. Similarly, the PAT (Pump Algebra Tutor) system (Barker 1995) offers student-invoked help. The student has to ask for intervention by the system when he feels that help is required for the mathematical problem he has to solve. Attempts have been made to bring the two modes together by establishing a balance according to the student's individual preference (Moyse and Elsom-Cook 1992, Winkels 1992, Milheim and Martin 1991). The MoleHill system which teaches Smalltalk programming (Singley, Carroll and Alpert 1993), for example, offers both active and reactive instruction to its users.

ITSs have been introduced thus far as a novel development in computer-based training. These offer individualised student guidance and support within the learning environment. In order to demonstrate how these educational benefits can be used to enhance simulation education the next section introduces a prototype ITS for simulation which has been developed as part of this research.

5   THE   SIMULATION   TUTOR: AN INTELLIGENT TUTORING SYSTEM FOR SIMULATION

The simulation tutor is an ITS currently under development at Brunel. Given the quite heavy investment in development that an ITS requires, a prototyping approach has been taken. This has used a "paper-ITS" to form the basis for evaluation and definition of ITS interaction and the simulation tutor. A paper-ITS is essentially the domain model and user interface implemented using conventional computerbased training technology (in this case Asymmetrix Toolbook (Asymmetrix Corporation, 1994)). The tutor and student models are emulated by using a research assistant. To provide a forum for discussion and ongoing development, the domain model has been decomposed into sub-components representing the major elements of the simulation course (Paul and Balmer 1993). These are:

1.   The need for simulation. This is first considered to make it clear to the student as to the reasons for when simulation should and should not be used. This follows the course text and uses examples generated by the educator and by the class in open discussion.

2.   Discrete event simulation. The goal of this lecture is to introduce the students to the key terminology of discrete event simulation and its constituents. Again the course text is used and is backup by worked examples indicating how each elements works and its consequences.

3.   Different modelling approaches. Following on from 2., different modelling approaches are considered. Worked examples are given.

4.   Activity cycle diagrams and the three phase approach. This modelling technique is selected as one technique to study in depth. Further terminology and examples are introduced.

5.   Case study I. The first of two case studies is introduced. Students are taken through different stages of model development via the first simple case study.

6.   Visual interactive simulation. A simple simulation environment and features are introduced with respect to the earlier elements of the course. The importance of animation in simulation is demonstrated.

7.   Model testing and validation. Following on from 6., issues of model testing and validation are covered.

8.   Case study II. A more complex case study is attempted. This is used to summarise the previous elements of the course.

9.   Discrete event simulation software and languages. This reviews the current state of the art.

10.   Sampling methods. Sampling methods are reviewed.

11.   Planning and interpreting discrete event simulation experiments. Again a review of the subject area.

12.   Summary. The course is pulled together with respect to the learning objectives.

Initial work performed on the simulation tutor concerned the first four elements. Essentially, the domain model was an animated version of the course text. This added an extra dimension to the usual forms of course support and focused on relating the components of the simulation program to the flow of entities through a system. Interaction with the tutor and student models was performed via a research assistant who discussed the learning needs with the representative student groups.

6   EVALUATION OF THE PROTOTYPE

The prototype was evaluated with a group of representative students who used the system. The students had recently completed part of the simulation course at Brunel University. They were asked to interact with the system under supervision. The experiment was supported by a questionnaire which was developed based on suggestions made by Schneiderman (1987) to gain feedback from the students about the way they perceived the needs of tutoring and learning.

The results of the evaluation show that the simulation tutor has the potential of offering adaptive tutoring to the student. The tutor coordinates the information from its knowledge models to provide adaptability to the needs and preferences of the players. In general comments alluded to good structuring and presentation of the teaching material. Informational content was adequate, given that it was supported by course texts and lecture notes. However, more effort should have been made in the pre-

sentation of the graphics. Video should be included in the next release. The use of animation to demonstrate the working of the simulation model and the simulation itself was good. Students were keen to have model elements linked to the physical system via video sequences.

In regard to the user interface users expressed a general liking of the use of a windows environment with easy to use, self-explanatory buttons and features. The context-sensitive help facility providing hints and analogues was useful as was the use of a mapping system; the students responded well to being able to see where they were in relation to the other parts of the course. There was, however, general dissatisfaction with the lack of response that the prototype provided. This was to be expected as the tutoring parts of the system had not been fully implemented. Once this was explained to the students, the response was that if the role of the tutor was documented correctly, then the intelligent tutor would be more than satisfactory.

The overall response to the system was encouraging, and the feedback provided by the students suggests ideas to be incorporated into the next version of the prototype.

6 CONCLUSIONS

This paper has reported on an attempt to introduce ITS techniques into simulation education. An initial investigation has shown that ITSs could improve the educational process by providing individual guidence and student centred learning. Further work is currently addressing other elements of the simulation course and the implementation aspects of the simulation tutor.

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