Intelligent Multimedia Tutoring for Manufacturing Education

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Abstract

This paper describes current work on the design and implementation of intelligent multimedia tutoring modules which are intended to supplement short training courses in Non-destructive Inspection for the Boeing Defense and Space group.

Introduction

Many of the drawbacks of traditional classroom-like training methods, namely, limited time spent on particular topics of interest to the student, limited instructor access, and difficulties in transferring lecture information to real world situations, are not unique to the manufacturing environment. In any ill-structured domain, which typically requires knowledge of multiple concepts and complex relationships, learning and instruction "cannot be compartmentalized, linear, uniperspectival, neatly hierarchical, simply analogical, or rigidly prepackaged" [5]. The desirability of new instructional media which allows students to interact with course materials in a more exploratory manner has become a dominant theme in current educational technology development. However, computer-based training already has a relatively long history and has been shown to positively influence the amount of material learned, the time taken to learn it, and the enjoyment of the learning experience (e.g., [2,3]). Furthermore, many of these training systems incorporate artificial intelligence techniques to provide deeper levels of interaction with the student. More recently, advances in putting powerful, inexpensive display systems on the desktop have led many to consider interactive multimedia solutions to the expanding demand for engaging and stimulating courseware. The sudden accessibility of high-tech graphics, animation, video and sound capabilities, and the proliferation of multimedia authoring software have made it very easy to quickly produce impressive presentations and interactive modules.

However, while typical multimedia systems for education allow users to navigate through subject-related resource

material in an attractive and informative manner, "it is well known that page turning or browsing does not ensure effective learning...flashy graphics and simulations are not enough; the experience has to be authentic and relevant to the learner's life" [6]. Therefore, a current technical goal is to utilize the solid foundation of intelligent tutoring systems as a platform for a more sophisticated control of multimedia objects in a learning environment. Such programs can pose interactive problem-solving situations appropriate to the level of the student, track the student's performance, and intervene where necessary to coach the student in particular principles. Through intelligent interaction, such tutors can help guide the student through the reasoning process, giving advice, or redirecting the student's focus of attention at appropriate times. The nature of the student's errors or misunderstandings determines the type of assistance provided, and the system employs its multimedia capabilities in a manner that is most helpful to the student at the time.

One of the major challenges to be addressed is the achievement of this integration of technologies. Unfortunately, much of the multimedia authoring software available today does not provide the level of control usually needed for an intelligent tutoring system, nor does it provide easy ways to link its products to externally developed intelligent programs. Thus, the development of an integrated intelligent multimedia tutoring system can be more costly in terms of time, effort and portability than current expectations will allow. Furthermore, the application of this technology to the design of courseware in the manufacturing domain, particularly for industrial training courses, introduces additional challenging issues.

Approach

The work described in this paper emphasizes the design and implementation of intelligent multimedia tutoring modules which are intended to supplement in-house technical training courses for the Boeing Defense and Space Group. In this project, there are two complementary goals: first, to explore the research issues involved in introducing educa-

tional technology into these types of training environments. These issues include knowledge acquisition, system design and implementation, and, ultimately, testing and evaluation of the effectiveness of these materials. The second goal is to produce rapid prototypes of some of the different modules in order to demonstrate proof of concept, and to justify the further investment in supplementing and/or replacing the traditional courseware with this new modality.

Our theoretical approach begins with the traditional components of intelligent tutoring: a student model, an expert knowledge component and a tutoring module. The student model tracks the performance of the student and maintains a profile of the student's level and accomplishments at that level. This includes information about the last lesson learned, a progress check through test evaluations, and an indication of the student's experience level (e.g., novice or expert). The domain knowledge is encoded in the expert component. In our model, this knowledge is encapsulated as a "collective of experts", each of which knows about a particular small aspect of the subject matter, and is capable of presenting it in one of four presentation modes, according to the current teaching strategy. This partitioning of the domain knowledge into very small pieces provides flexibility in the construction of the lesson plans (i.e., if a short review of a certain topic is desired, using a particular presentation mode, that expert can easily be invoked without bringing in additional material). The tutoring module controls the entire training session, and can be thought of primarily as a planner. It examines the student's profile, chooses the topics, and then creates an appropriate lesson plan. This lesson plan consists of a series of goals which are attained through the services of the corresponding experts.

In addition to these three components, our model also includes a multimedia interface world, which contains the individual multimedia objects (movies, sound bytes, simulations, etc.) that are utilized by the domain experts, and also encompasses the objects and relationships of the metaphorical "world" inside which the tutorial session is conducted. This is an extension of the notion of microworld which is common in artificial intelligence. The preliminary system design is illustrated in Fig. 1. This first version of the system gives all control to the tutor, which must devise the plan, search for the appropriate experts, and then invoke them. A drawback of this approach, of course, is that it may not be possible to do an exhaustive search of appropriate experts each time, and, therefore, the most effective solution might not always be found.

The next evolution of this design will give more autonomy to the individual experts, requiring them to "report" their capabilities, and to compete with each other for participation in the lesson plan. This will be done through a blackboard-style architecture, where the tutor posts current information in a common data area, known as the black-

board, and the domain experts respond to this information if they are able to make a contribution to the plan. The modular design of the collective of experts should facilitate this extension to a blackboard-based system, where the tutor may just post the current teaching goals to the blackboard, and the experts then compete for the opportunity to contribute the relevant piece of knowledge in the most desirable presentation style.

Application to Industry

The general subject matter for our project is Nondestructive Inspection (NDI), which involves the detection of cracks and flaws in various airplane parts, using techniques which do not disturb or destroy the part itself. Conventional NDI methods include radiographic, ultrasonic, eddy current and penetrant inspections, and our first project is focused on the training course for Eddy Current Inspection.

This course has a number of features, which are common to other NDI training courses, and which may impact the way in which the technology can be introduced into the course curriculum. First of all, these courses are often taught in very short periods of time (e.g., two days for the Eddy Currents class), and are extremely information-intensive. Trainees who take these courses can vary in expertise from vocational high school level who are just beginning their apprenticeships, to experienced engineers who wish to review and obtain a deeper understanding of the concepts. Any session of the course may contain students from all levels of experience, and typically there is one presentation for all. There are typically theoretical as well as practical aspects to the courses, which means that the students must try to master two different modes of material. For example, in the Eddy Currents training course, the theoretical part is concerned with explaining fundamentals of electricity and magnetism as well as the particular characteristics of eddy currents, and their effects upon the materials and instruments. These concepts are often invisible, inaudible, intangible, and abstract. On the other hand, the practical side of the course requires the student to physically assemble the equipment, grasp the probe, calibrate by moving the probe over small material "standards", observe the meter movements, and listen for audio signals that may be adjunct to the meter readings. Suddenly, the student's physical perception is at the forefront of the task, and yet, he/she must also try to connect the theoretical concepts to the physical results.

Another interesting characteristic is that these short courses often do not review or test the material learned. In the case of the Eddy Currents course, the student demonstrates mastery of the subject during certification testing, which is done at intervals throughout his/her career, and which typically looks at the trainee's effectiveness at the

Figure 1. Intelligent Multimedia Tutoring System

task itself (e.g., correct detection of surface cracks under a variety of conditions), rather than a formal understanding of the underlying theory.

In the Eddy Currents course, all of the theoretical subject matter is currently presented in the traditional manner of overhead transparency presentation with occasional demonstrations using hand-built teaching aids. The practical part of the course provides students with hands-on experience of detecting cracks using a number of different probes, meters, and materials in the classroom setting. The purpose of introducing educational technology into this course is twofold: first, to explore the effectiveness of adding interactions, simulations, and animations to the presentation of the theoretical material, and second, to provide stand-alone practice sessions in which the students can review the course information as often as desired, without requiring the presence of the instructor. It is felt that such supplementary technology may increase the effectiveness of the inspection process, and may provide a product which can be disseminated to the customers of Boeing, who must also train their personnel to perform such inspections.

Two preliminary prototype modules have been developed for the Eddy Currents course on the topics of conductivity testing and surface crack inspection. In designing these modules, a major goal was to avoid simply replicating the sequential transparency-based material in a more "entertaining" fashion. An alternative approach is to lead the student through the inspection process, zooming in to details which reveal hitherto unseen aspects of the objects (e.g., material, probe, meter, etc.) by utilizing the capabilities of multimedia presentations. This technique promises to be particularly effective in the demonstrations involving electric and magnetic properties, and should allow the student to experience the theory in the context of the task itself.

In the current implementation, the emphasis has been placed on development of the multimedia interface world objects and their relationships. For example, the Conductivity Testing module needs to contain objects representing: voltmeter, different types of metals, probes, electrons, alloys, heat, etc. These objects have relationships to each other that must be identified. For example, alloy added to a metal reduces conductivity; heat treatment of the metal with alloy will increase conductivity; each of these will change the meter reading when the probe is passed over the metal. The representations for the objects and their relationships can be textual, static pictures (graphics), animations, simulations, video clips or combinations of these. From these groupings, the experts can be identified. For example, one expert which "knows" about Factors Affecting Conductivity, invokes the following sequence: probe-simulation, add-alloy-simulation, probe-simulation, add-heat-simulation, probe-simulation. The simulation permits user interaction with the objects on the screen, and is appropriate for students who are first learning about this subject. On the other hand, a more experienced student might want to review the concepts, without having to physically execute each simulation. In this case, an expert which invokes the corresponding text objects would be more appropriate.

These first modules have been developed using commercial authoring software, which, unfortunately, has very little intelligent capabilities in it. This decision was taken primarily to match the software development environment available to our Boeing collaborators, and to explore the capabilities of the authoring tools. The package is excellent for developing the multimedia objects themselves, and incorporating interactions into the presentations. It also allows tests to be administered, and performs some elementary student tracking, which can be considered a primitive version of the student model.

Conclusion

Although a number of limitations of this approach have been identified, we have achieved part of our goal of producing rapid prototype materials which can be evaluated by the course instructors, and if approved, can be integrated into the current curriculum. Further extensions are planned to improve these prototypes, and to introduce increasing levels of intelligence.

Our second goal of producing stand-alone problem-solving modules will require not only the mastery of the subject matter together with a suite of more sophisticated simulations, but will need a more extensive model of how the student integrates perception and problem-solving in these inspection types of tasks [4]. This cognitive foundation will incorporate knowledge about what is seen, how that information can be perceptually enhanced (e.g., visually and aurally), how that knowledge fits into the generation of hypotheses, what additional information and/or evidence is needed to support or rule out a hypothesis, and how to represent the student's confidence in what is seen as well as what is decided.

As our work becomes integrated into the actual courses conducted on-site at Boeing, we plan to conduct studies with the trainees to determine whether this injection of educational technology supports the goals of improved performance of the task as well as increased understanding of the theoretical underpinnings.

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