DEVELOPING AN ADAPTIVE INTELLIGENT FLIGHT TRAINER

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ABSTRACT

Intelligent tutoring systems (ITS) seek to mimic the learning improvement provided in a one on one tutor/student relationship. In order to effectively teach to a student, the ITS must adapt to the student s current understanding. Many ITSs judge a student s knowledge by current and historic performance in a subject area. From this information, an ITS can determine a number of facts about the student relevant to tutoring.

This current/past performance view of tutoring ignores many aspects particular to a student, which would be useful in teaching to her (e.g. personality factors; preferred learning style; confidence/anxiety). We view an adaptive instructional system (AIS) as an extension to an ITS that also takes into account these types of individual trait and state differences.

The adaptations used by the AIS have been collected from both relevant literature and interviews with domain experts. Currently we are applying these techniques to extend an ITS for training new helicopter pilots in the Army, where the subject matter experts are helicopter pilots.

AUTHOR S BIOGRAPHIES

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Dr. Sowmya Ramachandran has a strong background in a wide variety of Artificial Intelligence techniques, including Intelligent Tutoring Systems, Machine Learning, and Case-based Reasoning. She has twelve years of experience in AI research and development. She also has extensive experience in developing educational software. Dr. Ramachandran is currently the senior person involved in developing an ITS for adult literacy enhancement, an ITS to teach Algebra to at-risk high-school students, and a simulation-based ITS for leadership training. She earned a Ph.D. from the University of Texas at Austin in 1998.

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INTRODUCTION

We envision an adaptive instructional system (AIS) as a natural extension of on intelligent tutoring system (ITS). In order to discuss how we are extending an ITS, it is first necessary to briefly cover the current ITS and its domain, as well as how we think it is deficient. We will then explain the AIS concept, which will address the deficiencies of the ITS. Next we will summarize some of the findings from our meetings with subject matter experts (SME) and describe how these results will be used by the AIS to improve automated instruction. The final section is devoted to the direction of future work in this area.

Overview of the Intelligent Flight Trainer

In current initial entry rotary wing (IERW) training, an instructor pilot (IP) is assigned two students. These two students train in the helicopter with the same IP until they complete the current training phase and check-ride. In this way, all of their in-flight training for any particular phase is given by the same IP. Currently, IERW students do not use simulators for any of the primary flight training.

Johnson, Hamby, and Stewart (1996) examined replacing some of the actual flight training with simulation instruction for beginning pilots within the 2 students to 1 IP structure. In their work, each pair of students had an additional IP for simulator training. For this training the students spent ten 45 minutes sessions in a TH-67 simulator with an instructor pilot. The results indicated that the experimental group performed at the same level as the control group on the first check-ride, but did so with less actual helicopter time than the control group. Further, the experimental group showed less variability in their check-ride scores than the control group. This study provides evidence that some flight training could be transferred to low-cost simulators, thereby lowering price of training without sacrificing results.

The main drawback of their work is that an IP is required for all simulator training. This supervision is required to ensure that students don t acquire any bad habits in the simulator, such as cross-controlling the aircraft or performing proscribed maneuvers. An instructor is also required to direct their learning experiences for maximized learning (Wagner, 1999).

The Intelligent Flight Trainer (IFT) takes the simulator s role in training a step farther. Rather than have IPs train students in the simulator, the IFT takes on the tasks of an instructor pilots. This means that in addition to simulating helicopter flight, the IFT must also perform as an instructor pilot.

The IFT consists of a helicopter flight simulator and an intelligent tutoring system (ITS) merged into a single system. This system was designed primarily to help teach hovering skills to IERW students. It is described in greater detail in previous papers (Krishnakumar, et. al., 1991; Zacharias, et. al., 1993). The skills taught by the IFT were later extended to include hover taxi, hover turn, traffic patterns, and standard approaches (Mulgand, et. al., 1995). An introduction to helicopter piloting, as well as detailed descriptions of the tasks above, can be found in Padfield (1992).

Simulator

Currently, the IFT aerodynamic model represents a generalized training helicopter. The cockpit consists of a frame, instrument panel, cyclic, collective, and pedals, all of which have been taken from actual helicopters and resemble those of the TH-67 training helicopter. A liquid crystal display screen presents a virtual instrument array and can be used for visual instructional feedback. Out-the-window view is accomplished using three PC-based image generators feeding rear projection systems resulting in a horizontal field of view of about 90 degrees. The entire simulator, excluding the image generators, runs on one PC under the Linux operating system.

Intelligent Tutoring System

In the IFT, the intelligent tutoring system attempts to provide the same types of training provided by instructor pilots. The two main components of the ITS are referred to as the *helper* and the *advisor* (Mulgand, et. al., 1995). *Helper* makes it easier for the student to fly the helicopter, akin to training wheels on a bicycle. It dynamically adjusts the flight model to correspond with the student s ability to complete maneuvers.

The student begins with an aerodynamic model that is very easy to control, but unrealistically unresponsive, and progressively approximates a realistic model as the student gains control proficiency. This allows beginning students, who tend to make large, impulsive cyclic movements, to be able to fly the helicopter. At the same time, proficient students are not given this freedom and need to make the small and controlled control inputs actually used in the helicopter. All of this is performed without explicit interaction of the student with the ITS. The only task the student needs to perform is to fly the simulator.

The second component requires more interaction since the *Advisor* communicates verbally with the student. Currently, this means that the advisor talks using text-to-speech software and the student listens. The advisor has four different informative roles, the first of which is to instruct the student on basic procedures (tutorial role), such as applying left peddle as the collective is increased. Performance monitoring is the second role, with instructions such as watch your airspeed . The third role is monitoring flight control manipulation, where comments on how the student is using the controls are given by the advisor (e.g. notifying the student when they are cross-controlling). The final feedback role is advisory, which verbalizes suggestions to control or correct flight. An example of this type of comment is descend by lowering the collective.

Evaluation

Mulgand, et al., (1995) evaluated the performance of the IFT with a single participant with a basic knowledge of helicopter flight but minimal flight experience. They found that the level of control assistance given could effectively allow the student to hover, and that the level of control assistance generally decreased with more time spent on the hover task. For the traffic pattern task alterations of the aerodynamic model by the *helper* did not improve skill acquisition. Generally, the student performed poorly on this task. They note, however, that the *advisor* did successfully guide the student through the traffic pattern.

This evaluation is extremely limited. Perhaps the most obvious problems are the very small study size, the lack of a control group, and the lack of a measure of success. The transfer of skills from the simulator to a real helicopter were also not studied. Finally, the evaluation seems to have taken place in a single session with breaks. Perhaps a more useful evaluation would be spread over several days to mimic helicopter training programs. This would provide more information about the ability of the student to improve over time. Despite these shortcomings, the evaluation does serve as an indicator that a variable flight model can help a student perform tasks and that the student can follow the verbal cues of the *advisor*.

Limitations

In discussing limitations, we are primarily concerned with the intelligent tutoring system portion of the IFT. To effectively teach to a student, the ITS must adapt to the student s current understanding. The IFT judges a student s knowledge by current flight performance. From this information, the ITS determines the level of flight realism and the content and frequency of verbal feedback.

This current performance view of tutoring ignores historical, trait, and state attributes of the student that would be useful in teaching to her. An example of a historical element is how the student performed on this maneuver last time. Student traits are slowly changing attributes such as personality or preferred learning style. Fatigue is an excellent example of a current student state. In fact, in the IFT evaluation by Mulgand, et al., (1995) the students were given breaks when the human instructor noticed that they were fatigued. We view an adaptive instructional system (AIS) as an extension to an ITS that also takes into account these types of individual differences.

ADPATIVE INSTRUCTIONAL SYSTEM

The use of a student s past performance in intelligent tutoring systems has already been well developed in both research and industry, so we will not be focusing on this aspect of student modeling. Instead, our adaptive instructional system is much more concerned with how to use knowledge of *trait* and *state* differences to improve the instructional experience of the student.

An example of a trait-based adaptation is making use of a student s preferred learning style. Work based on Kolb s learning style model contains four different kinds of instructors: *advisor, coach, mentor,* and *expert* (Willcoxson & Prosser, 1996). A motivator explains relevance of material and relates it to experience, an expert explains information in an organized fashion, an advisor lets students discover things for themselves, and finally a coach provides guided learning by trial and error. The AIS would then be developed to present material and direct the student in any of these four modes. Then the student is given a brief pre-test for preferred learning style, which is saved for later use, that provides evidence to the AIS about which mode to use when instructing this student.

Adapting to anxiety is an example of a state-based adaptation. Hudlicka and Billingsley (1999) found a wide variety of anxiety effects in fixed wing pilots. One specific effect is that anxious pilots tend to focus on what they perceive as the biggest threat and neglect other tasks. This is true for helicopter pilots as well. Some students, who are having difficulty completing a task, will focus all of their attention on one aspect of the maneuver and ignore others. For example, an anxious student concentrates on keeping a fixed heading to the detriment of altitude and airspeed. This fixation generally results in poor overall performance. The AIS could adapt to the anxious student in the example above by focusing the student s attention on all three aspects before the student has a chance to make a mistake.

Design of the AIS

The first step taken in the construction of the AIS was knowledge engineering. The purpose of this was to gain an understanding of how actual instructor pilots adapt their instruction to individual students. This provides a reasonable base of instructor adaptation to use in the design of the AIS.

We interviewed one civilian IP (with a previous military training background) in addition to five Army IPs who are currently involved in IERW training at Ft. Rucker, Alabama. These interviews ranged from two to eight hours in length. Klein Associates, a specialist in research on decision making processes, led the interviews. The goal was to elicit *episodes* where the IP altered instruction in order to help a student succeed, as well as the role of the IP during normal training. An episode consists of a particular interaction with a student rather than a generalization. We collected episodes on how IPs deal with exceptional students as well.

Preliminary Knowledge Engineering Results

The IP is responsible for demonstrating the maneuvers outlined in the curriculum (U.S. Army Aviation Center, 1999) and to maintain control of the helicopter while simultaneously letting the student use the controls. This alone is a difficult task, but the IP must also try to make sure that the student is learning during a flight. It is in trying to help the student learn that the IPs show most of their adaptations.

Our preliminary results indicate three areas of adaptive instruction to focus on in the AIS: anxiety/confidence, fatigue, and visual cues. As anxiety increases, the cognitive ability of the student becomes greatly diminished (Hudlicka & Billingsley, 1999). Anxiety also manifests itself physically, such as a death grip on the cyclic with tense, jerky, movements. Not surprisingly then, every pilot mentioned dealing with student anxiety as a primary concern. They noted that a student could not learn or perform well when she is overly anxious, and had varying techniques for building confidence. Additionally, several of them mentioned that they made tasks more difficult for exceptional students in order to produce some anxiety. These interviews indicated that pilots try to keep the students state in the middle of an anxiety/confidence continuum.

Fatigue was also a major concern for most IPs. In the interviews, they discussed how students performance would rapidly decline as they became more fatigued. Mulgand (1995) found similar results, with the evaluation student needing to take a break after attempting a maneuver for 18 minutes in the simulator. The IPs maintained that effective flight control is essential for learning, and that fatigued students simply don t fly as well.

In addition to keeping hands (and feet) near the controls to feel what a student is doing, they also watch where students are looking. Several IPs gave examples of students unable to perform tasks, or performing them poorly, because of where they were (or were not) looking. In one example, a student was unable to correctly perform an auto-rotation approach, despite being able to correctly control the helicopter in other maneuvers. When given a progress ride for her deficiencies, the IP noted after four or five attempts that the student was looking out the bubble window near her feet. When instructed to instead look outside the helicopter through the front, she was immediately able to complete the maneuver. Instruction on where to look is generally not part of the training but something that the student usually develops automatically.

These results are very encouraging and provide a strong set of state-based adaptations for the AIS. We did not find much support for trait-based instruction (such as personality) in the interviews. While some IPs mentioned that students might perform differently with different IPs, there were not enough episodes to draw any conclusions. Therefore, trait-based adaptations will need to be determined from relevant literature rather than from subject matter experts.

FUTURE WORK

The knowledge engineering results discussed above provide us with some of the what to adapt to for the student. The next step is to determine how the system will carry these adaptations out. We are currently working on methods to determine or infer student states such as anxiety and fatigue, and to track physical expressions such as eye movements. Once we are able to successfully identify adaptation points, we will begin the process of augmenting the ITS to respond to these cues. The final stage of this work will be an evaluation of the system s ability to adapt to individual users and the overall effectiveness of the training tool.

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