DEVELOPMENT AND FIELDING OF INTELLIGENT TUTORING SYSTEMS FOR AIRCRAFT TECHNICIANS

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ABSTRACT

The Human Systems Center of the United States Air Force is developing and fielding a new generation of computer based training systems. These Intelligent Tutoring Systems (ITSs) capitalize on knowledge engineering, cognitive learning theory, system simulation and advances in artificial intelligence to rapidly teach expert troubleshooting strategies to F-15 and F-16 aircraft maintenance technicians. Laboratory testing with ITS prototypes indicated that the development of troubleshooting expertise on complex systems was dramatically accelerated. The current program is developing a series of 11 ITSs for the United States Air Force Air Combat Command. Each will be fielded as a software application for 486 class PC platforms.

The development of these tutoring systems addresses a critical need in today's military environment. Weapon systems are becoming increasing complex and sophisticated. While these advances often lead to reduced normal maintenance, unusual or uncommon problems do develop which require very high levels of diagnostic skills. Development of excellent diagnostic skills traditionally occurred through the on-the- job training and mentoring technicians received over years of service. However, because of force downsizing and other concerns, the traditional approach to troubleshooting skill development is no longer acceptably efficient. The ITSs supplement normal on-the-job training with a high technology learning environment. The use of artificial intelligence, within an instructional framework reflecting cognitive learning theory, custom tailors instruction to the specific needs of each technician as he gains an understanding of the reasons for and applications of expert troubleshooting strategies.

The first ITS teaches troubleshooting strategies for the F-15 off-aircraft avionics test station and will be fielded in the spring of 1994. Additional ITSs will be fielded at 8-10 month intervals over the next several years. A detailed description of the ITS development program will be provided at the conference.

INTRODUCTION

A dichotomy between two current societal trends serves to make the advent of Intelligent Tutoring Systems (ITS) appealing to a diverse population of potential users. First, the learning that typically takes place during the formalized education process is becoming continually more abstracted from the manner in which that knowledge is applied in the "real" world. Second, as our technological sophistication increases, more specialized knowledge is demanded of the individuals responsible for using and maintaining this new technology.

The early answer to this problem seemed to lie in Computer Based Training (CBT). In theory, CBT would bridge the gap between technology and education by allowing many individuals to experience the benefits of an expert's knowledge in a particular domain. Designers were able to encode a static representation of an expert's knowledge of a particular domain allowing the student to follow along a well-defined, procedural, decision-making process. However, use of computers in computer-based training is in many ways similar to the presentation of information via traditional text books. Both can be sophisticated and offer the student useful features to facilitate the learning process. Unfortunately, neither CBT nor traditional text books have the ability to answer unexpected questions, draw relevant and novel inferences or adapt their presentation to adapt to a particular student's learning style (Wenger, 1987). Computer-based training might be computationally complex, but it is not "smart."

The natural extension to CBT is the continuing development of Intelligent Tutoring Systems (ITS). Whereas, in a CBT, expertise is pre-stored and displayed

The first step in actually developing an ITS is the collection of the basic data. These data will be used to develop all facets of the tutor - from the expert model and coaching messages to the student interface (Hall, 1993). The Armstrong Lab of the Human Systems Center has developed a data collection technique known as the PARI (Procedure, Action, Result, Interpretation) process. The PARI procedure involves situated problem solving sessions where experts apply their knowledge to particular problem contexts and task demands. As they attempt to solve troubleshooting problems, the experts are probed for the reasons behind the actions the choose to take and for their interpretations of the results of their actions. In this way, each experts' reasoning processes, those responsible for their applied knowledge, are made apparent. The probes are part of a structured interview process, designed to reveal a technicians' knowledge and skill in the context of their use. During the course of the PARI interviews, technicians experience the "full functional context" of complex problem solving so that the various intended uses of particular skills and knowledge structures (i.e., the reasons behind the procedures) are made explicit (Hall, 1993).

The PARI data collection process is composed of nine stages. In general, the first four stages determine the group of experts that will further contribute to the task analysis and identify at a general level the problem solving tasks and associated cognitive skills that are to be considered as instructional targets. These tasks and skills serve as the initial focus in the development of specific problems to be solved during the PARI interviews. The final five stages involve the basic expert, intermediate, and novice interview sessions, the follow-up rehashes, and review and analysis of the data.

The cornerstone of the PARI methodology is the Subject Matter Expert (SME)-problem solving pair. One expert poses a problem and simulates equipment responses to a second expert. The second attempts to verbally isolate the fault conceived by the first expert. The SME-pair format is then extended by pairing intermediates and novices with the SME who continues to pose problems and simulate equipment responses. During each interview, the role of the researcher is to record the problem solvers' solution steps as discrete operations or Actions. The problem solver is then probed by the researcher to express the reasons, or Precursors, for each action. The reasons, or Precursors, reveals the problem solvers top level plan or goal structure. The researcher also probes the problem solver for an Interpretation of the system response provided by the SME. Finally, the problem solver is asked to draw a block diagram of the relevant equipment to illustrate each solution step.

The following series of stages details the data collection process.

<u>Stage 1 - Subject Matter Expert (SME) Selection & Orientation of Researchers</u>. On-site SMEs are identified by the research team and asked to describe their job specific training and experience. SMEs then orient researchers to the job specific equipment systems, relevant TOs, site-specific maintenance practices, and problems they have encountered while training technicians of different skill levels.

<u>Stage 2 - Determine Focus of Training</u>. SMEs determine the training foci for their job area by listing specific maintenance tasks and equipment systems that they consider to be "cognitively complex" as well as provide specific examples of equipment malfunctions.

<u>Stage 3 - Generate and Consolidate Problem Types</u>. SMEs independently generate exhaustive lists of potential faults using the foci from Stage 2 and collectively consolidate the faults into categories based on similar knowledge and skills required for problem solution.

<u>Stage 4 - Specific Problem Design</u>. SMEs are assigned to problem categories developed in Stage 3 and individually generate representative problem descriptions and statements. The problem description describes the specific location of the fault in the system, symptoms related to the fault, and alternate fault locations (i.e., locations in which a fault may be placed and continue to manifest the same symptoms). The problem statement describes the symptoms of the fault as they would be presented to the technician on the job. Researchers describe and discuss with SMEs:

a. criteria for good problems
b. example problem descriptions and solution paths
c. upcoming PARI sessions
d. PARI rehashes

<u>Stage 5 - Development of Problem Generator's Solution Path and Alternate Paths</u>. Each SME works one-on-one with a researcher to document, in PARI format, his/her preferred solution path to each problem that s/he has generated, step-specific block diagrams, and