INTELLIGENT SIMULATION FOR MAINTENANCE TRAINING

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1.0 ABSTRACT

Over the past decade, computer hardware and software advances have been astounding. As these hardware and software systems become more sophisticated, so do the expectations of the computer users. To be accepted, training systems must provide sufficient fidelity to satisfy users' expectations. This paper describes how Intelligent Simulations and Intelligent Tutoring Systems attempt to provide sufficient simulation and interface fidelity. It also provides pragmatic examples of training systems that effectively use varying levels of fidelity.

2.0 INTRODUCTION

Computer users are becoming increasingly sophisticated. They interact with high-technology devices daily such as compact disc players, camcorders and cellular telephones. They also play interactive video games with high resolution graphics. As a result, they are bored by anything that doesn't have the same "curb appeal". Training and job aiding for technical devices should provide sufficient visual appeal to capture the user's attention.

However, a flashy interface is not enough. Once the user accepts the visual appeal of the system, the training system must be engaging enough to keep the user's attention. Without adequate simulation and remediation, the student is not motivated to learn. Intelligent Tutoring Systems and Intelligent Simulations provide a framework in which students can learn by doing.

3.0 INTELLIGENT TUTORING SYSTEMS AND INTELLIGENT SIMULATION

The term "Intelligent Tutoring System" (ITS) gained popularity in the eighties (Sleeman and Brown, 1982, Polson and Richardson, 1988, Psotka, et al, 1988). It describes an architecture around which training systems are built. As shown in Figure 1, an ITS contains an instructional environment, interface, and models of the student, expert and instructor.

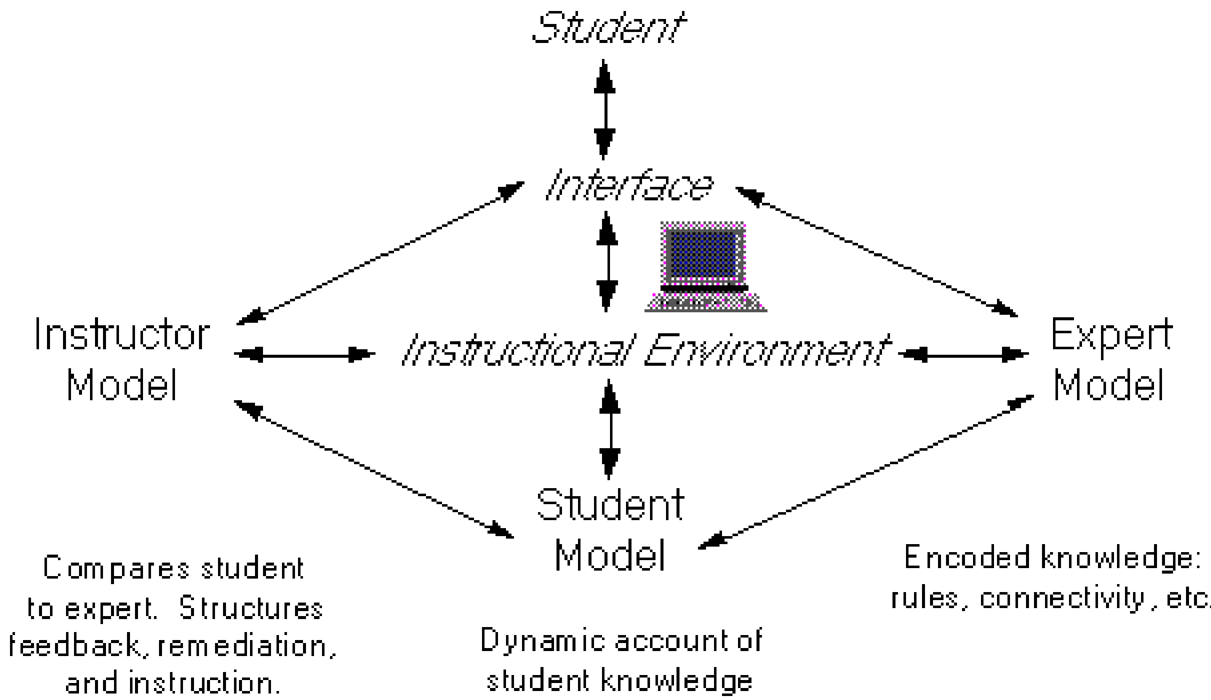

Figure 1 Intelligent Tutoring Systems

The instructional environment is at the heart of the diagram. This environment can range from drill and practice to tutorials to complex mathematical simulations (or any combination thereof). This paper concentrates on the use of simulation as the instructional environment for troubleshooting in technical domains.

The student sees the output of the instructional environment via the interface. The interface media can range from only text, to text and graphics, to digital photographs, to video and sound. Obviously, the type of interface depends upon the limitations of the computer hardware. Later sections will show how varying levels of interface presentation can be effective.

The "intelligent" portion of ITS revolves around models of the instructor, student, and expert. The ITS keeps tracks of the current state of the student's knowledge and actions (the student model). The ITS compares this model with what and expert would do (the expert model), and provides appropriate remediation to the student (the instructor model).

Intelligent Simulation (Johnson and Norton, 1991) still uses the ITS framework, but places greater emphasis on the simulation and the interface. While the student, instructor, and expert models are still very important, the *perceived* fidelity of the simulation and interface is equally important. The term "perceived" is significant here. The *actual* complexity of the simulation is insignificant, as long as the student *perceives* it to be adequate. For example, data values that appear on a test panel can originate from a complex simulation or a simple look-up table. As long as the data values are timely and accurate, the student does not care how they were generated.

Research indicates that the required level of fidelity varies depending on the type of task being taught (Hays and Singer, 1989). The intelligent simulations described below are generally more concerned with the cognitive tasks of troubleshooting, rather than with the psychmotor skills. Therefore, these simulations require more functional fidelity than physical fidelity.

4.0 PRAGMATIC EXAMPLES OF INTELLIGENT SIMULATIONS

The author and his colleagues have developed a wide spectrum of intelligent simulations over the past decade. This section will identify several training applications that adhere to the ITS and Intelligent Simulation structure. It will describe how each training system effectively integrates various levels of fidelity in each application.

4.1 ENVIRONMENTAL CONTROL SYSTEM (ECS) TUTOR

The Environmental Control System (ECS) Tutor is an intelligent simulation for maintenance training of the ECS on the Boeing 767-300, as shown in Figure 2. The ECS Tutor, developed for the FAA Office of Aviation Medicine, lets the student troubleshoot malfunctions of the air conditioning portion of the ECS.

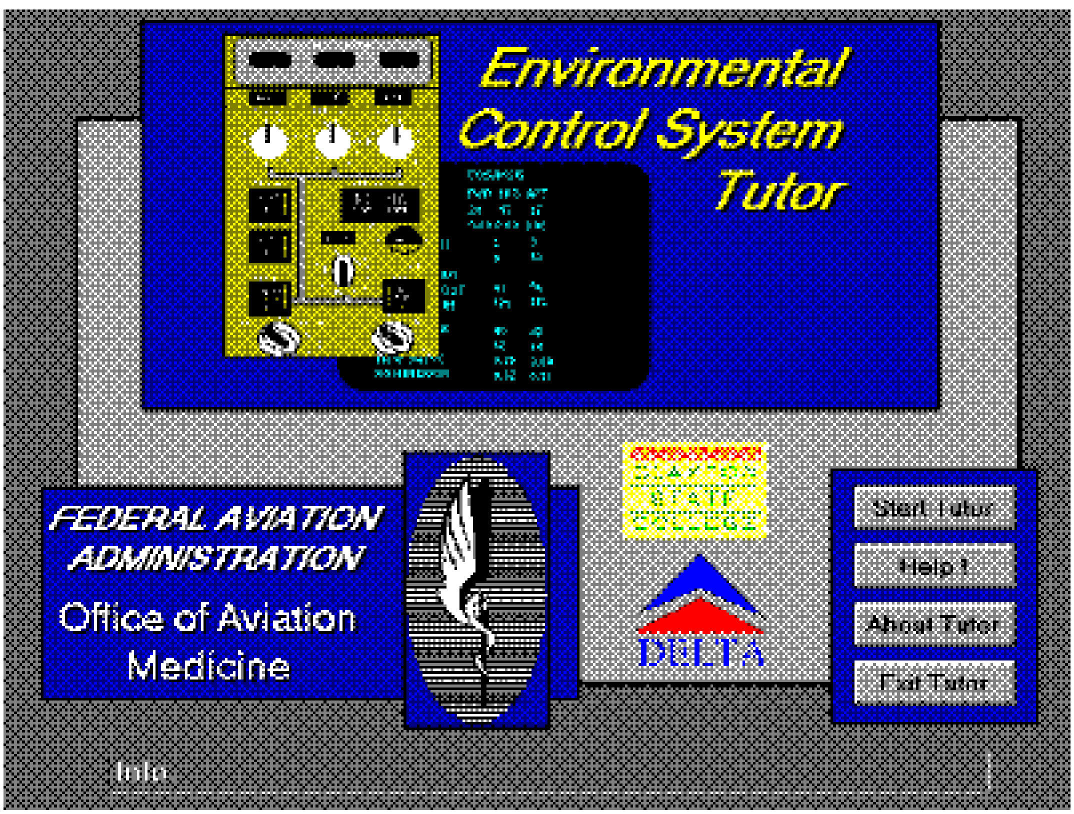

Figure 2 The ECS Tutor

The instructional environment and interface present the student with an interactive simulation of the aircraft maintenance environment. The student accesses the Overhead Panel to affect changes that are then shown on the Engine Indicating Crew Alerting System (EICAS) Display, as shown in Figures 3 and **4**. The student also accesses the Fault Isolation Manual (FIM) during the simulation. The FIM is the aircraft mechanic's decision tree during troubleshooting.

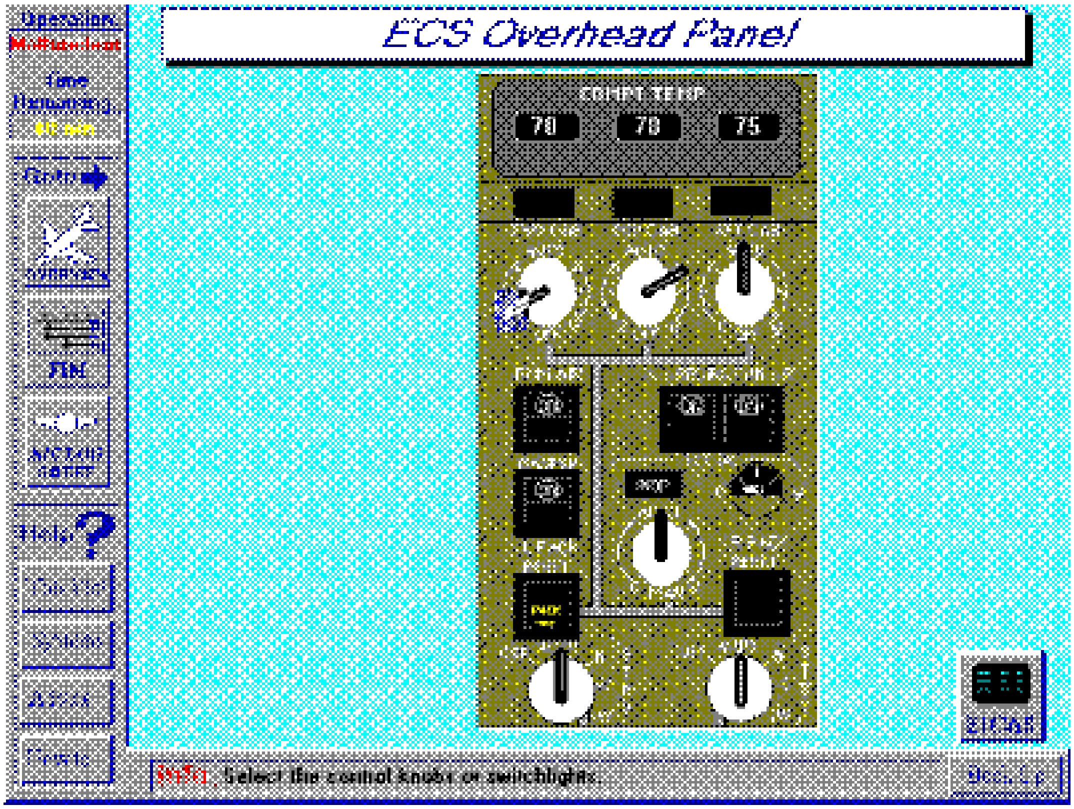

Figure 3 The ECS Overhead Panel

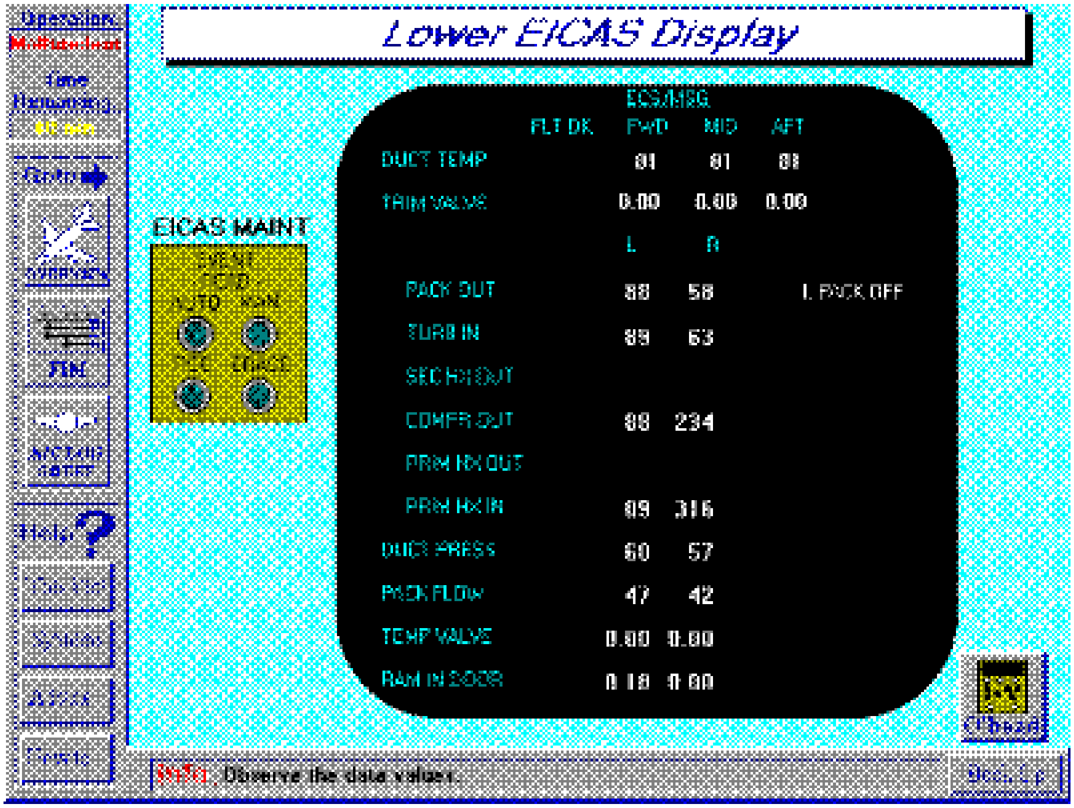

Figure 4 The ECS EICAS Display

The student may ask for troubleshooting advice at any time. Also, the system detects when the student appears to be floundering, and offers unsolicited advice. The system gradually gives more specific help each time it recognizes that the student needs help in the same area. For example, the unsolicited advice may first suggest that the overheating problem may be caused by a problem in the control system. If the student still has trouble, the system may then suggest that the student look at the temperature control valve.

The simulation of the ECS focuses on the inputs and outputs of each component. If a component fails, it produces an erroneous output value. Each subsequent component propagates this error through the system. The student interacts with the EICAS display and the Overhead Panel to see the effects on the air conditioning system. If the student replaces a malfunctioning component, the data values on the EICAS display immediately reflect the correction.

The student may choose to solve the problems by using the FIM exclusively, by using a schematic of the cooling pack, or both. Regardless of the method chosen, the simulation reacts as described above. Solving the problem via the FIM forces the student to go "by the book". Solving the problem via the schematic allows more flexibility for more proficient students. Both methods give the student access to various troubleshooting tools and procedures (e.g. visual inspection, voltmeters, built-in test equipment, replacement, etc.).

Preliminary evaluations of the ECS Tutor, with an airline and an aircraft maintenance school, have been very favorable. In order to obtain "hard" numbers, the ECS Tutor will undergo a complete cost-effectiveness and training-effectiveness evaluation in the Summer of 1992.

4.2 AIR TRAFFIC CONTROL BEACON INTERROGATOR (ATCBI-4) TUTOR

The Air Traffic Control Beacon Interrogator (ATCBI-4), shown in Figure 5, is a complex electronics system used by air traffic controllers. The ATCBI-4 Tutor, sponsored by the FAA Technical Center, allows Airways Facilities maintenance technicians to troubleshoot simulated malfunctions with the help of an expert advisor.

The simulation of the ATCBI-4 represents each component in the system via different operating states. When a malfunction is introduced to the system, the simulation determines whether each component is normal or abnormal - based upon the functional connectivity of components in the system. Each component has default data values for both a "normal" state and an "abnormal" state. If required, the simulation may override the default "abnormal" data values with values that are more specific to a given malfunction.

The ATCBI-4 Tutor also allows the student a variety of ways in which to troubleshoot the system. The student may use either functional flow diagrams or simulation displays. The student uses functional flow diagrams to get a solid theoretical basis for troubleshooting. These diagrams present the information about components in the most basic form: normal or abnormal.

Once students establish a baseline proficiency, they may opt to interact with the simulation displays for a more realistic, interactive instructional environment. The student accesses displays which represent oscilloscope wave forms and instrument panels. Simulation displays replicate the physical troubleshooting environment more realistaclly than the logical troubleshooting environment.

4.3 GAS TURBINE INFORMATION SYSTEM (GTIS)

The Gas Turbine Information System (GTIS), sponsored by the Electric Power Research Institute (EPRI), is an Integrated Information System for gas turbines, as shown in Figure 6. This system combines training, job aiding, and intelligent information retrieval. The intelligent tutoring system lets the student diagnose failures on a gas turbine engine. The job aid assists with on-the-job troubleshooting. The GTIS information retrieval system provides access to schematic diagrams and other system information.

The GTIS simulation uses a static "look-up table" scheme to generate data values. Data values are pre-defined for each malfunction. The simulation uses a "snapshot" of the state of the gas turbine at the time of the failure for data values.

The GTIS student obtains diagnostic information via tests, observations, calibrations and replacements. The GTIS uses still digital photographs of the equipment while troubleshooting, but uses digital video interactive (DVI) sequences to describe equipment and to teach general gas turbine principles.

4.4 MICROCOMPUTER INTELLIGENCE FOR TECHNICAL TRAINING (MITT)

Microcomputer Intelligence for Technical Training (MITT) permits technicians to operate and diagnose technical systems. It tracks trainee's actions and provides feedback using an embedded expert system. MITT runs on 80286-based DOS machines with the default 640K of memory (Norton, et al, 1992).

The MITT Writer Authoring System permits training developers to build expert system-based tutors (MITT Tutors) without the use of a programming language. The developer simply enters a description of the training domain. The developer may make changes to this training description as modifications to the target system warrant. To date, some of the MITT Tutors include: Auxiliary Power Unit (APU) Tutor (see Figure 7), Message Processing System (for Minuteman Missile) Tutor, Electric Power Distribution System for the Space Shuttle (Fuel Cell) Tutor, and Automobile Engine Tutor.

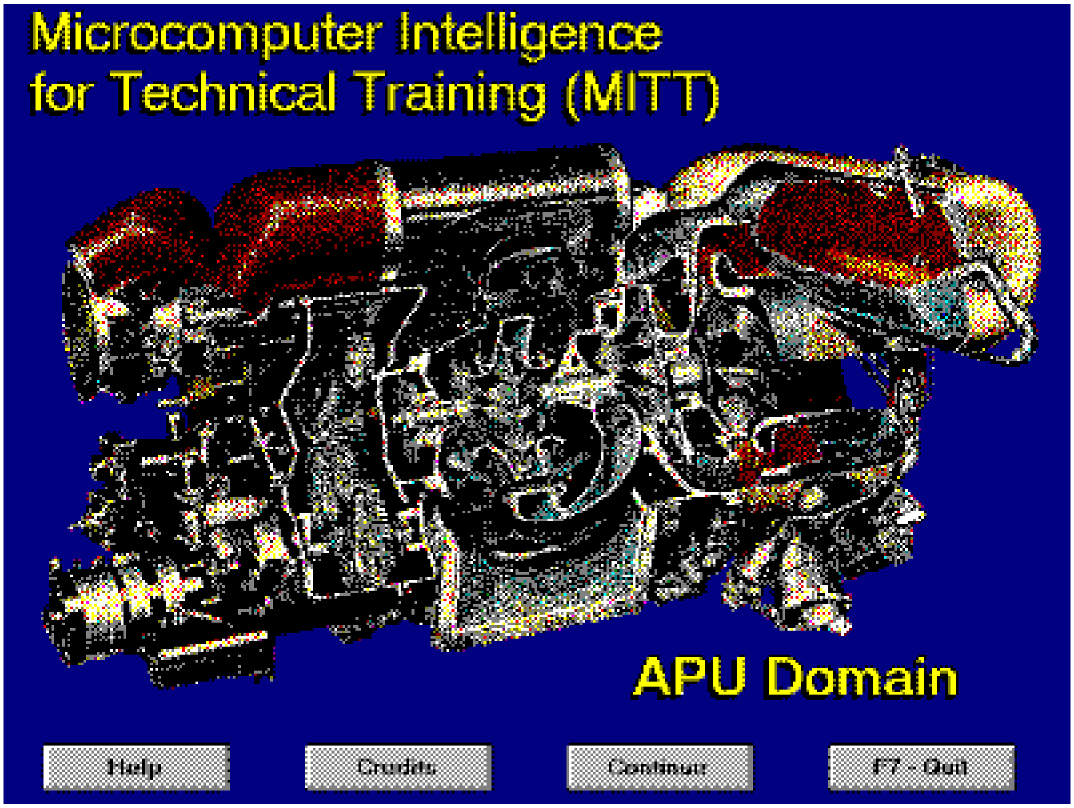

Figure 7 MITT APU Tutor

The MITT Tutor simulation relies on a simple, but effective "look-up table" to supply necessary data values to the student. With MITT Writer, the training developer provides a description of sensor behavior for each malfunction. The training developer specifies discrete data points for the duration of the malfunction. By using this method, the MITT Tutor supports dynamic data values. The simulation also extrapolates from data point to data point to give the student the effect of a continuous simulation.

5.0 CONCLUSION

The Intelligent Simulations just outlined encompass the spectrum of simulation fidelity and visual appeal. The ECS Tutor uses a deep simulation model, while MITT uses a dynamic look-up table. GTIS uses a surface-level, static simulation. These systems also use a host of interactive displays: from EGA, scanned graphics in MITT, to digital photographs in ATCBI-4, to digital video interactive in the GTIS.

Each of these technologies requires different levels of resources for development. While many people always want the highest fidelity simulations and greatest resolution images, it is impractical, and also unnecessary, for every system to require such parameters. The systems described above show that different combinations of fidelity can be quite effective.

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