A Computer-based Training System Combining Virtual Reality and Multimedia*

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Abstract

Training new users of complex machines is often an expensive and time-consuming process. This is particularly true for special purpose systems, such as those frequently encountered in DOE applications. This paper presents a computer-based training system intended as a partial solution to this problem. The system extends the basic virtual reality (VR) training paradigm by adding a multimedia component which may be accessed during interaction with the virtual environment: The 3D model used to create the virtual reality is also used as the primary navigation tool through the associated multimedia. This method exploits the natural mapping between a virtual world and the real world that it represents to provide a more intuitive way for the student to interact with all forms of information about the system.

1. Introduction

DOE applications, such as Environmental Restoration and Waste Management (ER&WM) and nuclear weapons dismantlement will require complex, special-purpose robotic systems. Training the operators of such systems will be both expensive and time-consuming. This is due to limited access, the expense of duplicating the system for training, and the negative consequences of making a mistake while learning. This paper presents a computer-interactive training system that combines virtual reality (VR) with multimedia and artificial intelligence (AI) to provide an extended training environment for such applications. Virtual reality is used as the primary training tool, in much the same way that it has been used traditionally for flight simulators and other similar applications. A multimedia component, containing additional information about the application and equipment in the form of video, text, voice, and audio may also be accessed during interaction with this virtual environment. The 3D graphical model used to create the virtual reality is also used as the primary navigation tool through the associated multimedia. In addition, AI techniques are incorporated to aid in creating realistic simulations, in navigating the hypermedia and, eventually, in tutoring the student .The rest of this paper describes the prototype system. Section 2 presents the application and the virtual training environment in more detail. Section 3 presents the multimedia component. Section 4 discusses the addition of intelligent agents for both training and media navigation.

2. Virtual Reality for Training

The initial application of this work will be in conjunction with the in-house Underground Storage Tank (UST) demonstration being developed at Sandia National Laboratories. This demonstration will provide a testbed for a number of technology development activities related to the retrieval of hazardous radioactive waste from

underground storage tanks. Because of the hazardous nature of these tanks, robotic systems will be used to retrieve and store the radioactive materials. This provides special challenges for robotic technology development: Tanks found in Hanford WA., for example, contain waste in the form of liquid, sludge, and hard salt cake. They also contain risers, pumps, cooling pipes, debris, and other obstacles. Obviously, the systems ultimately used for such work will be complex, consisting of many tools, sensors, and manipulators. Operating such systems will be a difficult task at best.

The in-house UST demonstration testbed provides a mock-up of a UST environment. It consists of a variety of robots, sensors, and tools. This entire robotic system is under computer control. At the highest control level, human operators use graphical programming techniques to provide commands to the system. Flat screen displays provide feedback concerning the status of the devices and sensors[Christensen 92].

An on-going development effort is underway to provide a virtual reality-based interface to this system. This interface provides a VR model of the UST testbed, including simulation capabilities for the manipulators and tools. The operator may move around in this virtual environment, using voice commands and hand gestures to program accurate graphical models of the actual robots. These task-level commands then automatically generate device-level programs to be down-loaded to the robots. The operator may also preview these operations for correctness via simulation and edit them interactively before sending them to the robotic devices. During operations, the simulation is driven by the positions of the robotic devices and the readings from the various sensors to allow the operator to monitor the state of the operations. The positions and states of the manipulators, tools, and sensors are accessed and used to upgrade the graphical models in the virtual environment.

The virtual reality testbed for this work consists of a Fakespace, Inc. mechanically-tracked stereoscopic viewer (BOOM), a Polhemus FastTrack wrist tracker, a Dragon Systems voice recognition system, and a Silicon Graphics Inc. workstation with audio. The software platform is the Cim-Station robot modeling and simulation package from SILMA, Inc. The VR interface will be used both for training the operators of the system (simulation mode) and during actual operations (command and monitoring mode). The primary difference between these two modes is whether the actual robotic devices are in the loop or not. Figure 2 conveys the idea behind this work. The figure shows an operator in the Fakespace BOOM, the CimStation model of the UST testbed, and the actual testbed.

3. The Multimedia Component

The operator may access additional information about the devices from the virtual environment by putting the system into training mode. In this mode, a selected object provides an access point into a hypermedia system containing information in the form of video, text, and still photos. The hypermedia structure is a graph containing *menu* nodes for navigation and *action* nodes for accessing the media. In the case of the UST application, additional information is associated with each of the robots and with a 3D icon which represents the underground storage tank application itself. An object is selected by "touching" it with a 3D pointer driven by a joystick and pressing the joystick button. This device will soon be replaced by a hand-held, magnetic-based position tracker. Spoken commands will be used for making selections. Figure 3 shows the system with the various devices used for viewing the information.

Information associated with each robot includes still photos, system diagrams, video of the actual device in operation, and the manuals for that device. Manuals are divided into reasonable chunks based upon the structure of the original text. Any figures associated with the text are also available. The UST icon invokes a text report on the Hanford site, photos of actual tanks, diagrams of remediation plans, and a DOE video describing the problem. Menus allow the user to navigate through the information for a particular device or icon.
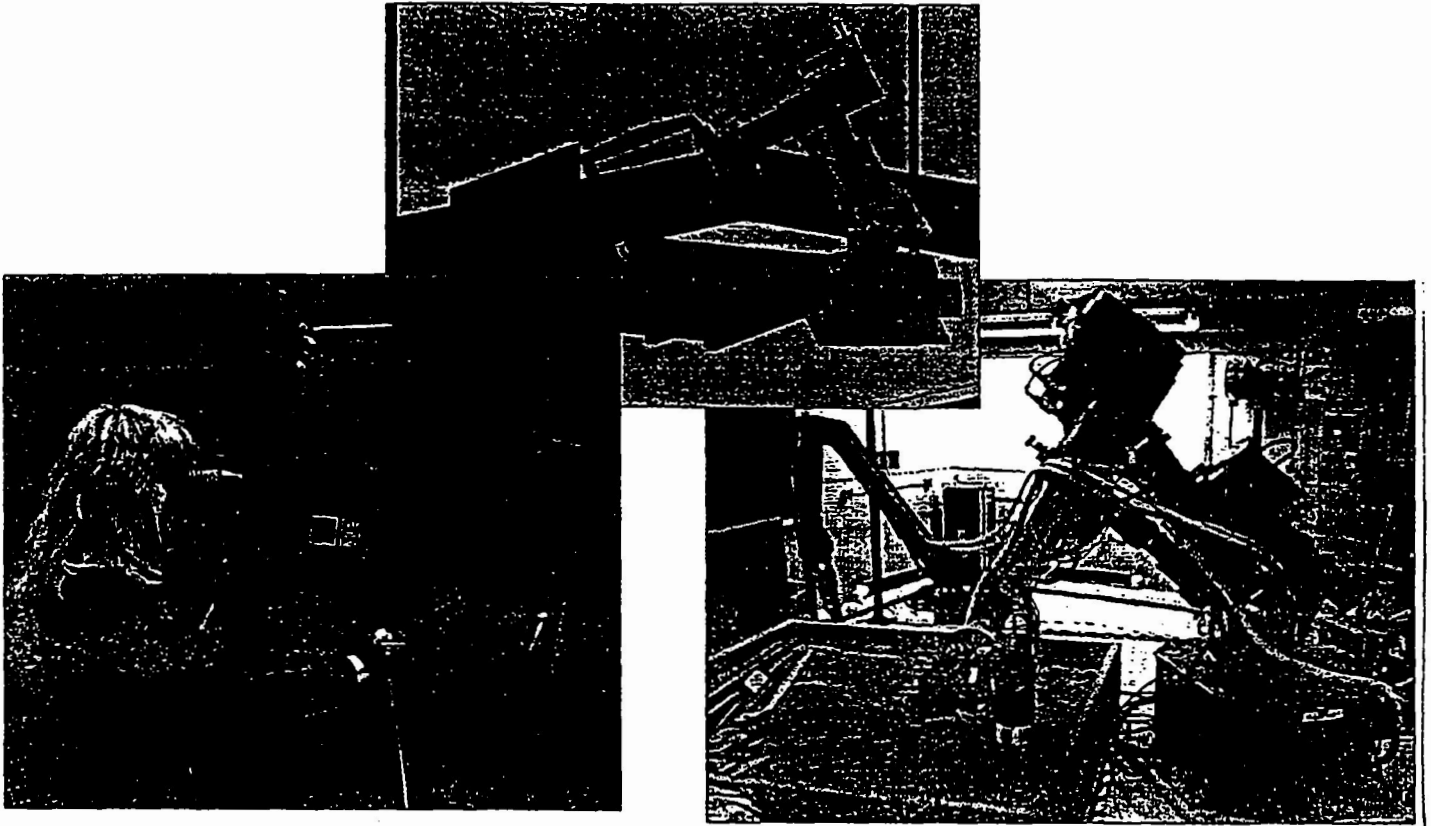
Figure 1: VR for robot operator training.

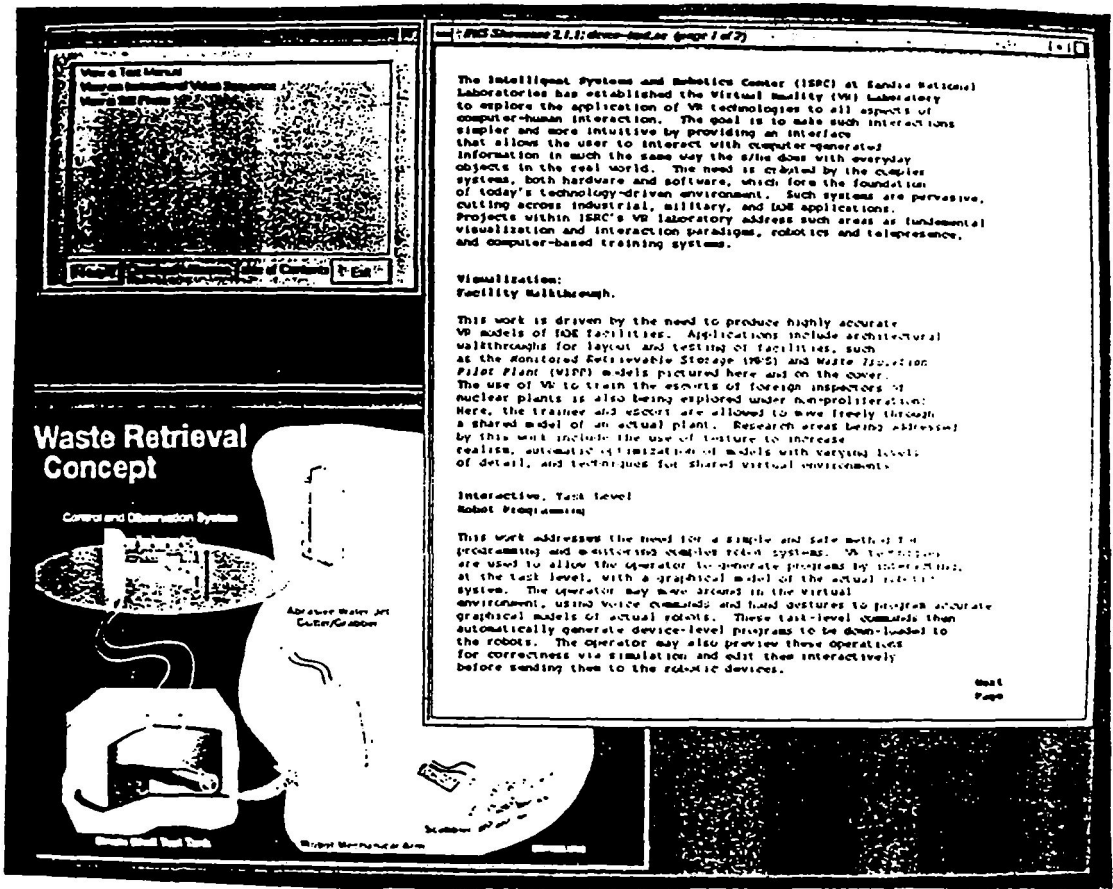Figure 2: The VR-based multimedia training system.

Figure 3: A representative screen.

Spoken word audio also provides guidance. A near-term addition will allow the user to speak preferences as well as to select them with the mouse. Figure 3 shows a representative screen for the multimedia component.

4. Adding Intelligence

Ultimately, the training system will embody intelligence in three forms: Intelligent behaviors during simulation, intelligent navigation tools for moving through the hypermedia component, and intelligent tutoring. Current emphasis is on the first two. The fundamental representation of an object is being extended to allow the invocation of intelligent behaviors for that object based upon the state of the simulation. For example, a pipe obtains the knowledge that it has been cut and behaves accordingly: it becomes two pieces, one of which falls to the ground. Likewise, waste contains the knowledge that it is radioactive and can communicate this state to the sensor object which can behave accordingly by creating the proper readings. Such intelligent behaviors add realism to the training simulator by allowing the user to run different scenarios. Emergency situations and equipment failures may also be invoked to train the operator to handle them.

Intelligence will be added to the hypermedia component to aid in navigation. Initially, this intelligent navigation tool will utilize typed, weighted links and a set of simple rules to allow the system to provide a list of prioritized suggestions as to other, related information that the user might also be interested in accessing. Future work will enhance this navigation tool by integrating machine learning techniques. Learning algorithms will be applied to allow the system to learn from the behavior of previous users. The system will then use this knowledge to guide current users through the hypermedia information .

Future work also includes the addition of an intelligent tutoring component that will interact with the student during training. In addition to information about the environment and tasks, the student will be able to access

interactive tutorials concerning the operations being t   ed. The system will also be capable of monitoring the
student's performance during a training session and   logging this performance. The system will then offer
critiques and advice concerning where additional train: nd/or study is needed and where the relevant material
may be found.

5. Summary

This paper has provided an overview of the intelligent, c   puter-based training system being developed at Sandia
National Laboratories for use in training the operators   complex, automated machines. This system combines
virtual reality with multimedia and artificial intelliger.   to extend the basic VR training paradigm to a more
complete teaching tool. The virtual environment provide   he underlying simulation for training the operators of
robotic systems, such as those used for remediation of   derground radioactive waste storage tanks. The VR
model also provides the primary access points into rela   information about the system and application in the
form of video, text, still photos and sound. AI technique   e used to create more realistic simulations and to help
the user navigate through the multimedia. Future wor: ill incorporate an automated tutoring component to
assist the student in learning about the system and tasks.

References

[Christensen 92] Christensen, B. K., Drotning, W. D., and T   borg, S. "Model Based, Sensor Directed Remediation
of Underground Storage Tanks", *Journal*   *obotic Systems*, pp. 145-159, 1992.