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Virtual Reality Applications to Automated Rendezvous & Capture

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Virtual Reality (VR) is a rapidly developing Human/Computer Interface (HCI) technology. The evolution of high-speed graphics processors and development of specialized anthropomorphic user interface devices, that more fully involve the human senses, have enabled VR technology. Recently, the maturity of this technology has reached a level where it can be used as a tool in a variety of applications. This paper provides an overview of: VR technology, VR activities at Marshall Space Flight Center (MSFC), applications of VR to Automated Rendezvous and Capture (AR&C), and identifies areas of VR technology that requires further development.

VR is a computer generated three-dimensional graphic environment that senses a user's behavior and updates the display of that environment accordingly. Head-mounted color monitors with wide-angle binocular optics displays the environment to the user. Changes in hand and head position and attitude are the basic user inputs sensed by a VR system. When the user moves or turns his or her head, the computer generated view shifts accordingly. With a hand gesture, the user can "fly" his/her point-of-view to another location within the virtual environment and "grab" virtual objects to move or re-orient them.

Ames Research Center (ARC) developed a prototype VR system, the Virtual Interface Environment Workstation (VIEW). It consists of a DataGlove and a Head Mounted Display (HMD). Thomas G. Zimmerman and L. Young Harvill created the DataGlove at VPL Research, Inc. Fiber optic cables, embedded in the glove, bend with the fingers and produce varying light levels, much as a bend in a water hose will decrease the flow of water [1]. The varying light levels provide the positional data for the fingers. In 1987, VPL Research extended this concept to the whole body with the DataSuit [2]. Polhemous Navigation Sciences Division of McDonnell Douglas Corporation created the sensor that tracks the position and orientation of the hand and head. Head mounted computer graphics display systems were first developed by Ivan Sutherland at MIT in 1967 [2]. Scott Fisher developed the VIEW HMD at the ARC [1]. Other ARC VR activities include the Convolvotron, a 3-D audio system. [4]

MSFC is currently developing the capability to apply VR as a tool in Human Factors analyses, hardware development, operations development,

training, and mission operations. The VR system consists of the VPL DataGlove and Eyephones, a Silicon Graphics 4D/310 VGX, and a Macintosh II computer. MSFC has developed a low fidelity virtual mockup of Space Station Freedom.

Virtual Reality has a number Automated Rendezvous and Capture (AR&C) applications. Primary applications are in the areas of system development, operations development, training, and mission operations.

During the development phase of the AR&C system, designers, reviewers, and users can "enter" the 3-D graphic models of the system. Hardware configuration concepts and designs can be evaluated in this Virtual World. Form and fit for assembly and both Orbital and Line Replaceable Unit (ORU and LRU) changeout can be tested. Haptic and tactile feedback devices will enhance these analyses by providing the user with the sense of touch. VPL and UNC have both developed this type of user interface. [1,3] This virtual mockup can also assist in the analysis of viewing, dynamic work envelopes, and restraints and mobility aids.

Operations concepts can develop concurrently with hardware design development. This ensures operations input to early hardware design, where it is most effective. A person can monitor an unpiloted Cargo Transfer Vehicle (CTV) as if he/she were on the vehicle or the target. An observer could view an AR&C task from inside or outside the activity. In "Project Grope", a molecular docking system at UNC, the team determined that "the most valuable result from using Grope III for Drug Docking is probably the radically improved situational awareness" [3].

Techniques and technologies developed during the systems and operations development phase could also be utilized during mission operations to enhance situational awareness. The Stafford committee report identified VR techniques in conjunction with robotic precursor missions. Telemetry from the remote system would allow the operator to see through the eyes of the robot, use the end effectors as if they were their own, and feel the objects that the system manipulates. A person could also rehearse an AR&C maneuver, in a real-time simulation, and record the command sequences for later uplink and execution on an autonomous AR&C mission.

Interfaced with training simulators, VR can add a new dimension to the training environment. Trainees can gain insights into how the system functions from the CTV, target, or 3rd person point-of-view. UNC reported a two-fold increase in task performance, using VR, over traditional graphic systems. [3]

More than one person can enter the same Virtual World at the same

time without necessarily being in the same physical location. For example, a designer at a remote location might call a reviewer at MSFC and say, "Put on your Eyephones, I have a design modification I want to show you." Both could then view the same design, the reviewer could watch as the designer manipulates the virtual mockup, then the designer could watch as the reviewer manipulates the object. Each participant is able to interactively control aspects of this mutual world. Operations development, remote training, and even teleconferencing can benefit from shared virtual worlds.

Key areas of VR that require further development include: 1) An ability to model and render object behavior and dynamics attributes, with greater accuracy, 2) Refinement of user interfaces that more fully incorporate the user's senses (e.g., force-reflective/tactile feedback, improved visual resolution, 3-D audio), 3) A capability to translate existing CAD databases into VR databases, and 4) Full utilization of state-of-the-art graphics engines' capabilities (e.g., illumination and reflections, textures, "realism") while, at the same time, reducing time delay and increasing frame rate. Developments in these areas should lead to VR graphic libraries, tools, standardization, commonality, and communication protocols.

This paper has demonstrated that VR is a technology that is ready to be incorporated into space systems development and operations. It has described applications of VR to AR&C projects. Also, it has identified required development efforts that would refine VR techniques and technologies to increase the fidelity of these AR&C applications.

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