Title of Investigation:

Real-Time 3-D Virtual Graphical Interface for Telerobotic Control

Principal Investigator:

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Initiation Year:

FY 2004

Aggregate Amount of Funding Authorized in FY 2003 and Earlier Years:

$0

Funding Authorized for FY 2004:

$35,000

Actual or Expected Expenditure of FY 2004 Funding:

In-house: $15,000 for robot electronics and fabrication; Grants: $20,000 to the University of Maryland

Status of Investigation at End of FY 2005:

Transitioned to FY 2006 IRAD funding for Tetrahedral Robotics Development

Expected Completion Date:

September 2006

Purpose of Investigation:

The objective is to develop a 3-D graphical virtual reality (VR) interface to control a radio-frequency-addressable Tetrahedral Walker (TET). The TET is an innovative robotic platform developed jointly by the Goddard Space Flight Center's Codes 695 and 544. Designed for the NASA Exploration Initiative, the TET walks by tumbling. The "click and drag" of a 3-D mouse will control TET's motion. Development of such an intuitive and efficient human-robotic control interface, with real-time 3-D imagery and other sensory feedback, is crucial for ensuring Exploration mission successes. Robots increasingly will be used to assist, amplify, and augment humans to perform complex tasks. The traditional "blind" tele-control method may not be sufficient, as it does not fully use a human operator's strong cognitive and pattern-recognition abilities to understand, analyze, and solve problems given *in situ*, real-time 3-D data. The other consideration is that we do not wish to encumber the operators with the details of robotic system constraints or require them to learn customized robot interfaces. Therefore, the development of the VR control system will make use of the latest Web-based, platform-independent software standards and technologies. That way, operators can use the same interface to command and control different robots.

Accomplishments to Date:

Three parts make up the system design and development (Figure 1): the VR graphical interface; the definition of high-level commands in standard interface languages; and the integration of the interactive software to the low-level controller commands that control the TET actuators and servo mechanisms with real-time feedback.

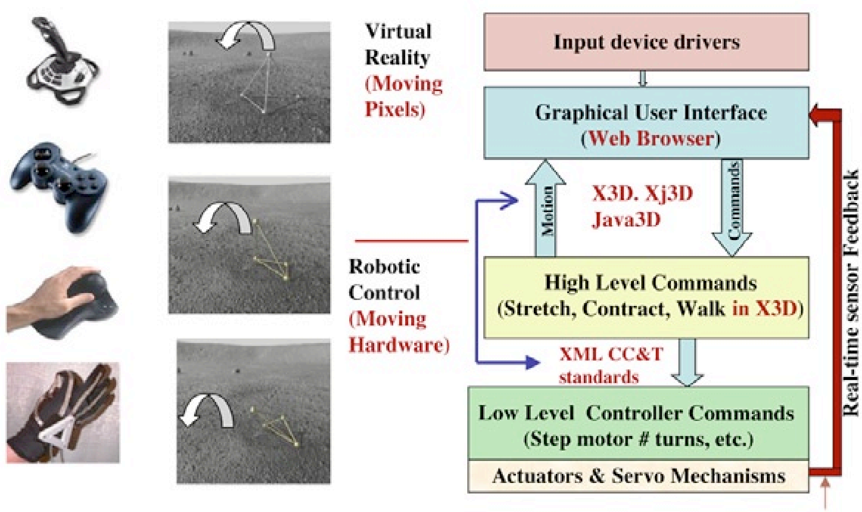

Figure 1. System Concept for 3-D VR Telerobotic Control Interface

We started by converting an X3-D tetrahedron model from a Virtual Reality Markup Language (VRML) model. We then designed and developed the manipulation and interaction software, using a kinematics-only approach coded entirely in Java 3D. We added user interactivity to the VR graphical model of the TET Walker so that the user could click on any ground-node to initiate walking in the direction opposite of the selected node (figure 2). With the graphical model, the user also could pan and zoom in 3-D space to make the walking viewable from any desired perspective.

Figure 2. One small step for a TET

We used the free Java Astrodynamics Toolkit (JAT) (http://jat.sourceforge.net/) to model dynamic forces and their interactions. JAT is used in Goddard research on and simulation of formation flying and neural-systems control, opening up the possibilities for cross-fertilization, new research directions, and more rapid progress through technology-readiness levels. These JAT simulations are used to generate the parameters for the low-level controller commands. The use of physics-based dynamics in a standards-based VR system allows the incorporation of new technologies built to those standard interfaces. For example, complex dynamic control simulations requiring advanced computational capabilities like Beowulf clusters can be developed and used to achieve close-loop control.

We integrated these 3-D control and navigation capabilities with the Goddard-developed Instrument Remote Control (IRC) software to enable high-level commanding. Using IRC, the VR 3-D interface sends commands to the physical TET Walker over a wireless Bluetooth connection. Feedback telemetry is relayed from the sensors to inform the user of the actual state of the walker. Currently, this information is displayed in a tabular format in the user interface. In future, the 3-D VR interface will mirror the actual steps that the physical walker performs.

With students in the JASON Education Foundation Expedition to Meteor Crater in Arizona on September 12–13, 2005, we successfully demonstrated how easy it was to use the 3-D VR interface. The purpose was to film student experiments using the TET Walker as an example of next-generation rovers for the series: “Mysteries of Earth and Mars” in the 2005–2006 curriculum package. The student “Argonats” used the 3-D VR interface to command the TET to traverse terrains that would defy conventional wheeled rovers. The TET performed well and took 10 steps down a rocky slope of about 12 degrees without difficulty. (http://www.jason.org/jason_html/expeditions/mars/getting_started/using_your_resources.htm)

Planned Future Work:

The 3-D graphical control software will be modified to accommodate feedback telemetry and to reflect in real time the true configuration of the TET on the screen. The 3-D model will be enhanced for command and control of a 12-TET walker with payload.

Key Points Summary:

Project's innovative features: This proposed work is a first attempt to connect VR to reality. We used the latest Web-based 3-D graphics technology to provide an intuitive human-robot interface to control operational hardware in real-time. Instead of moving pixels on a screen in VR, we are teleoperating hardware that may be deployed on planetary surfaces.

Potential payoff to Goddard/NASA: NASA will benefit because of: (1) reduced personnel training and operational costs due to ease of robotic control; (2) reduced mission risk because hardware constraints and restrictions can be built into control sequences through the model-based interfaces, and (3) use of extensible and generic Web-based technologies will make it easier to upgrade interface technology. This effort will support Goddard's bid for the Astrobiology Science and Technology for Exploring Planets (ASTEP) proposal for operation of the Tetrahedral Walker in the Iceland field campaign. Goddard is currently the lead in the standards effort for satellite XML Command and Control in the Space Domain Task Force in the Consultative Committee for Space Data System. This effort will lay the foundation for inter-robot communication by creating a potential standard for space robotics control. In addition, the graphical 3-D interface will be excellent for educational outreach for the Exploration Initiative. It will enable the public to "drive the robot" remotely.

The criteria for success: By the end of the performance period, we will demonstrate a VR 3-D graphical interface to control a Goddard-built robot—the reconfigurable tetrahedral walker proposed by Dr. S. Curtis. The software toolkit will be delivered with relevant documentation.

Technical risk factors: Internet-based interface technology is not designed for real-time operation. The system's "real-time" performance needs to be evaluated and analyzed against mission-critical tasks. Issues of live feedback from the robotic control electronics to the VR screen to reflect reality would be investigated in a future follow-on effort.