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Advanced Sensing and Control Techniques to Facilitate Semi-Autonomous Decommissioning

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Research Objective

This research is intended to advance the technology of semi-autonomous teleoperated robotics as applied to Decontamination and Decommissioning (D&D) tasks. Specifically, research leading to a prototype dual-manipulator mobile work cell is underway. This cell is supported and enhanced by computer vision, virtual reality and advanced robotics technology.

Research Progress and Implications

This report summarizes work after approximately 1.5 years of a 3-year project.

The autonomous, non-contact creation of a virtual environment from an existing, real environment (virtualization) is an integral part of the workcell functionality. This requires that the virtual world be geometrically correct. To this end, we have encountered severe sensitivity in quadric estimation. As a result, alternative procedures for geometric rendering, iterative correction approaches, new calibration methods and associated hardware, and calibration quality examination software have been developed.

Following geometric rendering, we have focused on improving the color and texture recognition components of the system. In particular, we have moved beyond first-order illumination modeling to include higher order diffuse effects. This allows us to combine the surface geometric information, obtained from the laser projection and surface recognition components of the system, with a stereo camera image.

Low-level controllers for Puma 560 robotic arms were designed and implemented using QNX. The resulting QNX/PC based low-level robot control system is called QRobot. A high-level trajectory generator and application programming interface (API) as well as a new, flexible robot control API was required. Force/torque sensors and interface hardware have been identified and ordered. A simple 3-D OpenGL-based graphical Puma 560 robot simulator was developed and interfaced with ARCL and RCCL to assist in the development of robot motion programs.

Planned Activities

Integration of the 3 subsystems (virtualization, virtual reality and robotics) is anticipated in the Fall of 1998. Following successful completion of this, the first demonstration will be scheduled. In order to expedite the virtualization effort, we are bringing in Dr. Khaled Shaaban from Assiut University as a visiting researcher.

Work continues in efforts to segment the passive image into regions corresponding to individual light stripes, and to establish correspondence between those regions and the projected lines. Complex geometries in unstructured environments yield objects with many parts, limited extent, self-occluding surfaces, and sharp or discontinuous surface boundaries, thus presenting a challenge.

In the development of the new color and texture recognition techniques, it became apparent that an iterative (closed-loop) approach was feasible and likely to provide both further improvements to environment replication and a facility for easily integrating multiple passive camera images into a single environment model. Work is underway on this iterative radiosity. Furthermore, efforts are underway to approximate gaze-dependent rendering.

Near-term robotics objectives include the development of QNX interface software for the force/torque sensors, as well as design and implementation of a low-level force feedback controller for the robots. Tools and tool changer hardware must also be selected and interfaced with the robot control system. A simple disassembly will then be performed using ARCL as the high-level API. Design and implementation of a general-purpose high-level robot control API to replace ARCL is the next major milestone. Furthermore, an operator console must also be designed and interfaced with the system.

Other Access To Information

The following papers have been published as a result of this research effort:

1. "Autonomous Virtualization of Real Environments for Telepresence Applications", Geist, R., Stinson, T., Schalkoff, R.J., and Gurbuz, S., Presence, Vol. 6, No. 6, December 1997, p. 645-657.
2. "Rendering Inversion in the Automated Construction of Virtual Environments", Geist, R., Vernon, D., and Schalkoff, R., Proc. 3rd ASCE Specialty Conf. on Robotics for Challenging Environments (ROBOTICS '98), Albuquerque, New Mexico, April 1998, pp. 85-91.
3. "Geometric Elements of the Direct and Autonomous Virtualization of Quadric Environments", Schalkoff, R.J., Proceedings Robotics '98, American Society of Civil Engineers, Albuquerque, NM, April 1998, p.71-77.
4. "QRobot: A Multitasking PC Based Robot Control System", N. Costescu, M. Loffler, E. Zergeroglu and D. Dawson, IEEE Conference on Control Applications, Trieste, Italy, September 1998.
5. "QMotor 2.0: A PC Based Real-Time Multitasking Graphical Control Environment", N. Costescu and D. Dawson, IEEE American Control Conference, Philadelphia, Pennsylvania, June 1998.
6. "Tracking Control of Robot Manipulators with Bounded Torque Inputs", W.E. Dixon, M.S. de Queiroz, F. Zhang, and D.M. Dawson, Proc. of the 6th IASTED International Conference on Robotics and Manufacturing, Banff, Canada, July, 1998, to appear.
7. "Global Adaptive Output Feedback Tracking Control of Robot Manipulators", F. Zhang, D. Dawson, M. de Queiroz, and W. Dixon, Proc. of the IEEE Conference on Decision and Control, San Diego, CA, Dec. 1997, 3634-3639.