Progress Report

Project Title: Remote Manipulation for D&D Exhibiting Teleautonomy and Telecollaboration
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Research Objective: The purpose of the work is to enhance remote operations of robotic systems for D&D tasks by extending teleoperation with semi-autonomous functions. The work leverages the $1.2M dual-arm work platform (DAWP) developed with broad participation for the CP5 D&D, as well as 2,000 hr DAWP D&D operational experience. We propose to develop a reactive, agent-based control architecture well suited to unstructured and unpredictable environments, and *cobot* control technology, which implements a virtual fixture that can be used to guide the application of tools with force-feedback control. Developed methodologies will be implemented using a structured light sensor and cobot hand controller on the dual-arm system.

Research Progress and Implications: This report summarizes work after one year of a three year project. The first year's work focused on the system design. The work was conducted as a joint research of Argonne National Laboratory and Northwestern University, and the following progress was made.

<ins>Design of reactive behaviors</ins>: Previous remote operation tasks were analyzed and modeled as a discrete event system composed of large grain motor behaviors: inspect, move_to_goal, apply_tool, grasp_tool (Figure 1). These motor behaviors are implemented as assemblages of primitive motor agents. The motor behaviors are initially tested through simulation, and then tested on mobile manipulator kits. Upon successful demonstration and verification for reliability, they will be implemented on the hydraulic manipulator systems.

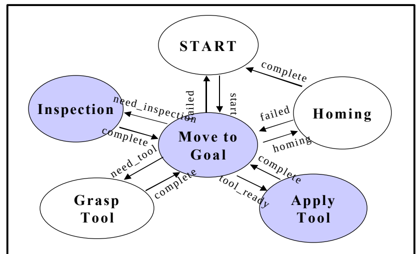

Fig.1. Motor behaviors of D&D

<ins>Development of sensory basis</ins>: A motor agent takes perceptual inputs from a sensory module and generates action. A structured light system has been adopted for the sensory module that consists of a laser grid beam projector and camera. The projected beam pattern may provide effective visual reference during tooling operation. Also, by analyzing the location and distortion of the beam pattern, the location and orientation of the task object can be determined (Figure 2). Also, compound sensing mechanisms such as sensor fusion, as well as active sensing, have been adopted to obtain more detailed environmental interpretations.

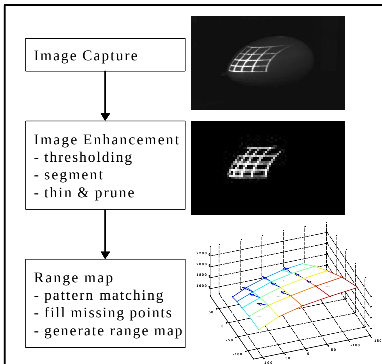

Fig.2. Sensor range mapping

<ins>Implementation of a single arm teleoperation testbed</ins>: Since the dual-arm work platform is contaminated, we have established a testbed teleoperation system with a Schilling Titan 7F manipulator. Test operations are performed to investigate sensor-guided teleoperation of tool handling for assimilated D&D tasks (Figure 3). Currently, the existing hand controller is being replaced with a PC based control system. This control system will facilitate demonstration of low speed reactive behavioral control.

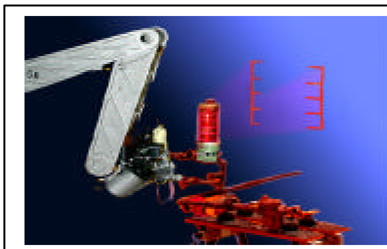
Fig.3. Single-arm manipulator (testbed)

<ins>Design of integrated control system for dual-arm robot</ins>: The enhanced teleoperation methods will ultimately be demonstrated with the dual-arm work platform (DAWP). This requires integration of various control systems: slave robot controller,

motor behavior computer, machine vision system and the hand controller. A VME host computer running on VxWorks controls the two Schiling Titan III manipulators. A low speed event-driven communication interface has been established with external computers using EPICS (Experimental Physics Instrumentation Control System). EPICS also provides convenient tools for implementing a graphic user interface. Also, a high-speed data transfer channel has been provided by directly sharing the memory of VME host and PCI memory of PC. The designed system provides a flexible, yet powerful interface for system integration between VME and PC based control systems.

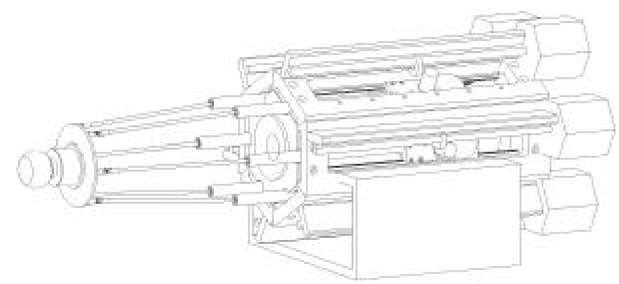

Fig.4. Cobotic Hand Controller Design

Design and construction of a six degree-of-freedom cobotic hand controller is underway (Figure 4). To date, a specification (including workspace dimension and force/torque capability) has been developed, and one of the six leg assemblies has been prototyped. Design revisions are now underway, and a fully functional prototype is expected in the fall of 2002. Initial plans have also been made for interfacing this hand controller to the single arm and dual-arm control systems at Argonne. We should be in a position to use the hand controller in system tests by late 2002 to early 2003.

Virtual fixture: Work has begun on the design of virtual fixtures. This effort began with observation of an experienced user of the Dual-Arm Work Platform, and with the research team members using the single-arm system. These experiences elucidated a number of areas in which virtual fixtures can be expected to be valuable. One such area involves “attention shifts.” The operator of the DAWP has a large number of camera views at his or her disposal. When shifting attention from one to another, the operator must re-establish hand-eye coordination because motions executed at the master end may not map in an obvious way to motions observed by the newly selected camera. As a consequence, a high level of cognitive activity is required that would simply not be necessary if the operator were present at the remote site. The focus of this work is to develop virtual fixtures that decrease the cognitive load during attention shift. These fixtures will include motion constraints implemented via the cobotic hand controller, as well as visual cues implemented via graphic overlay on video. Currently, a system is being developed for graphic overlay.

Planned Activities:

- Enhance sensor module for faster processing (Oct. 2002)
- Demonstrate graphic overlay, and operator creation of a virtual fixture (Nov. 2002)
- Complete Cobot hand controller (Nov. 2003)
- Test low speed reactive control with single-arm manipulator (Dec. 2002)
- Demonstrate generation of virtual fixture with single-arm manipulator (Jan. 2003)
- Complete dual-arm control system (Mar. 2003)
- Implement and demonstrate tele-autonomous operation of dual-arm robot (July. 2003)
- Interface Cobot with Dual-arm system, and demonstrate virtual fixture (Sept. 2003)
- Develop reactive behaviors and virtual fixtures for more D&D tasks (Feb. 2004)
- Develop meta behaviors combining virtual fixture and motot behaviors (Sept. 2004)

Information Access:

http://www.td.anl.gov/Programs/ti/robots/index.html
http://www.mech.northwestern.edu/dept/research/lims.html