**University of Florida
University Research Program in Robotics**

**U. S. Department of Energy
Robotics Technology Development Program**

**Annual Technical Progress Report
Project Period June 1, 1994 to May 31, 1995**

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The University of Florida supported three technical areas within the U. S. Department of Energy's Robotics Technology Development Program (RTDP) during this project period: Tank Waste Retrieval (TWR), Contaminant Analysis Automation (CAA), and Cross-Cutting and Advanced Technology (CC&AT). This report summarizes the technical progress made on the tasks for each of these three areas. Detailed reports will be sent to the RTDP coordinator and the project area coordinators at the end of the project period.

Tank Waste Retrieval

Task 1: Waste Retrieval Path Planning

A graphical front end for the Spar 2500 low level controller is currently under development. A stand alone graphical user interface has been completed that incorporates the forward and inverse kinematics of the Spar 2500 manipulator. The interface includes the ability to specify the global position of the end of the manipulator and a linear path generated to that position. Path planning for contour following is almost complete. Work continues on the interface to the Spar 2500 low level controller.

Task 2: Review of Robotic Removal of Waste Material to Meet 1% Removal Requirement

Decontamination methods for the removal of the waste from Hanford Tank C-106 have been investigated. A simulation of the radiation field arising from the waste in the tank using the Interactive Graphics Robot Instruction Program (IGRIP) has been performed and analysis of the resulting radiation fields after 99% of the volume of the waste had been removed was accomplished. Waste material was simulated based on the formulation specified by the Waste-Management Education & Research Consortium and was tested for removal properties.

Task 3: Low Level Controller for Spar 2500 Manipulator

Personnel at the University of Florida developed a replacement low level controller for the Spar 2500 manipulator located at PNL. The controller consisted of hardware and software to control the first three joints on the manipulator. The controller was desired by PNL personnel to provide a commonality of computer architecture between a robot attached at the end of the Spar 2500 manipulator and the Spar 2500 manipulator itself. The VxWorks operating system on a VME bussed backplane computer was chosen as the computer system of choice. Other computer hardware was selected for compatibility with manipulator hardware and commonality with current projects. The low level controller software was developed to communicate with computer hardware that was physically attached to robot joint sensors and actuators. The Spar 2500 low level controller was installed and has successfully

been utilized by PNL personnel for demos and during tests on the flexible structure control work. Future enhancements to the low level controller include a user interface on the Silicon Graphics workstation and incorporation of path planning routines.

Task 4: Application of a Planar Parallel Actuation Mechanism to the Gross Positioning Manipulator System

Previous work at the University of Florida has been aimed at developing an articulated mobile robot. Features of the articulated structure are the ability to make large changes in elevation and avoiding obstacles. Joint configuration between segments and actuation schemes were examined in an attempt to improve expected performance. The result of this effort was a mobile robot concept comprised of articulated segments attached by parallel actuators. Several prototype segments have been developed. The joint actuation scheme, planar parallel actuation (PPA), developed for this mobile robot has some merit in other applications. One application of interest is in the development of a long reach or gross positioning manipulator system (GPM). The GPM system is proposed to do gross positioning of a smaller dexterous manipulator for the DOE's Tank Waste Retrieval (TWR) program. The remediation process involves removal of the liquid and solid waste that is inside single walled underground storage tanks. The PPA has been examined with respect to its applicability to the GPM system. It was concluded that the PPA is applicable to the GPM system. It allows a shorter mast length to be incorporated in the design. The PPA based GPM is a polar based robot and as such would be well suited to the polar workspace of the underground storage tanks. The control system would be similar to other large manipulator control systems. The kinematics of the system are such that the mechanical advantage of the mechanism can be tailored to the expected gravity based joint loads. The PPA based GPM does have several drawbacks. The most significant would be an increase in system complexity. Considering redundancy, each PPA would need four hydraulic cylinders and their associated hardware. The implementation of the slider degree of freedom, along with a mechanical lock, greatly increase the system complexity. The cross-coupling between the slider and the rotation of the PPA also induce more complexity into the controller.

Task 5: Merging of Virtual and Real World Models

A. Surface Reconstruction. Three-dimensional (3D) stereo and laser range data was used to reconstruct visible surfaces. "Thin-plate" and "membrane" finite element models were used to reconstruct a piecewise-smooth surface of the object of interest. Multigrid surface reconstruction was used to accelerate the convergence process. An improved initial approximation method was investigated, but caused less improvement than expected.

A C-language code was written to convert the raw surface data into a format to visually display the reconstructed surface. This visualization was accomplished in both IGRIP and the Silicon Graphics Inventor program. Surfaces with approximately 8000 points and 16000 polygons require approximately 4-5 minutes to import into IGRIP and approximately 2-3 minutes to import into Inventor.

B. Image Comparison. This task has resulted in a method to compare two frames of images of a scene to determine which objects, if any, are missing or added. The two image

frames may be different due to translation, scaling, or rotation. The real world image of the scene generated from a vision system is designated as the object view, and the real world image is designated as the template view. A correlational approach was used to develop the C-language code for image registration between the object and the template. The keys to this approach are the construction of a four-dimensional hyper-image space and the creation of a measurement function for subspace correlation using a phase-only filter. In the hyper-image space, the four dimensions correspond to translations along the x and y axes, rotation and scaling, respectively. Rotation and scale changes are converted to linear shifts using "conformal mapping." The measurement function is defined as the maximum value of the subspace correlation coefficients obtained using phase-only filtering. This function provides a reliable judgement to detect the translation, rotation and scaling parameters simultaneously.

CONTAMINANT ANALYSIS AUTOMATION

Task 1: Development of a Soil Sample Preparation Standard Laboratory Module

The Soil Sample Preparation Module (SSPM) is a Standard Laboratory Module (SLM) that prepares a raw soil sample for sonication or soxhlet extraction. The SSPM will become part of the Standard Analysis Method (SAM) as developed by the Department of Energy under the control of the Los Alamos National Laboratory (LANL). At the top level, the conceptual functionality for the SSPM was to accept an input beaker with a soil sample and eventually place a specified mass of the soil sample in an output container. In between the input and output of the soil sample to the module, several processes had to be done. Most of the components of the SSPM have been designed and various components are currently under production. Various components include horizontal and vertical transports for sample conveyance, a grinder for soil pulverization, a mixer unit, and a scale. The horizontal transport, vertical transport, grinder, and sieve tunnel design represent the bulk of the design effort. All parts have been or are currently being manufactured in a machine shop and all catalog hardware has been ordered. System integration is currently underway. Work on the control and synchronization of the various mechanisms in the system will soon commence. Electronic devices and additional computer components that will be needed for the control of the SLM are being ordered.

Task 2: Development of a Multimedia Training/Maintenance Module

A prototype multimedia Training/Maintenance Module (T/MM) was developed to aid in the use of the Sonication Standard Laboratory Module (SLM). The T/MM was implemented using the World Wide Web (WWW) and the Mosaic viewer on both a Sun workstation and pc hardware platforms. The WWW/Mosaic platform was chosen because of its inexpensive cost, availability, extensibility, ease of distribution and ease of utilization. The prototype T/MM contains textual information about the Sonication SLM and sensitive maps providing visual information for training and maintenance tasks. Interface windows from the Human Computer Interface for the Sonicator are also included in the T/MM. A remote control program was developed to allow for the launching of the Mosaic program on demand. This feature will allow the T/MM to be interrupted by the control software of the SLM to notify the operator of an error in the operation of the equipment.

CROSS CUTTING & ADVANCED TECHNOLOGY

Task: Vision System Model

A Virtual Video Camera (VVC) system was developed to create a simulated video camera output. The VVC allows accurate testing and evaluation of robots or vehicles which use machine vision systems as sensors for navigation or other control operations. The VVC is a translator which organizes, analyzes and processes IGRIP simulation and modeling data for rendering output in the Pixar RenderMan software. Features of the VVC include the provision of automatic interpretation of IGRIP simulation data, automation generation of scene data not included in IGRIP's database, accurate modeling of real cameras based on empirical measurements of camera parameters, interactive light and texture modeling, and push-button operation.