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OVERVIEW OF ROBOTICS FOR MIXED WASTE OPERATIONS

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OVERVIEW OF ROBOTICS FOR MIXED WASTE OPERATIONS

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ABSTRACT
The Mixed Waste Operations Robotics program is developing robotics technology to make the handling and treatment of Department of Energy mixed waste; better, faster, safer and cheaper. This technology will provide remote operations and not require humans to be in contact with this radioactive and hazardous waste. The technology includes remote handling and opening of waste containers, remote removal of waste from the containers, remote characterization and sorting of the waste, and remote treatment and disposition of the waste. The initial technology development program culminated in an integrated demonstration in November, 1993 and each aspect of this technology is described.

INTRODUCTION

The Department of Energy's Office of Technology Development (OTD) is developing technology to aid in the cleanup of DOE sites. The Robotics Technology Development Program (RTDP) is part of the OTD program and has several teams. There are over 240,000 cubic meters of mixed low level waste accumulated at DOE sites and the cleanup is expected to generate about 900,000 cubic meters of mixed low level waste over the next five years. This waste must be monitored during storage and then treated and disposed of in a cost effective manner acceptable to regulators and the states involved. The RTDP is developing robotics technology to make these tasks; safer, better, faster and cheaper through the Mixed Waste Operations team. The Mixed Waste Operations team includes: Fernald Environmental Management Site (FEMP), Idaho National Engineering Laboratory (INEL), Lawrence Livermore National Laboratory (LLNL), Oak Ridge National Laboratory (ORNL), Sandia National Laboratories (SNL) and Savannah River Technology Center (SRTC). A demonstration at the Savannah River Site on November 2-4, 1993, showed the progress of this technology by DOE, universities and industry over the previous year. Integrated, state of the art robotics technology was applied to the handling, characterization and treatment of mixed waste as well as monitoring of stored waste.

BACKGROUND

Facilities will be built at many sites to receive containers of DOE mixed waste, remove the contents, characterize the waste, treat the waste and place it into a final form for shipment from the facility. All or most of the material handling and some of the treatment processes in mixed waste facilities could be accomplished by humans in direct contact with the waste. However, humans would have to be dressed in protective clothing, which becomes additional (secondary) waste after use. The protective clothing also takes considerable time to put on and take off and is cumbersome, which reduces the efficiency of manual operation. The handling of heavy containers manually or with manual operation of overhead cranes or other equipment and the manual opening of containers with powered tools and exposure to

BACKGROUND ON THE TELEROBOT

The Telerobot is a unique gantry robot in that it has both teleoperation and robotic capabilities, and it has 8 degrees of freedom (DOF). The extra 2 DOF allow the robot to reach inside, around and under objects, which is not possible with a standard 6 DOF gantry robot. It was built by PaR Systems to SRTC specifications. It has 3 DOF on the gantry and 5 DOF on the jointed arm. The lifting capacity at the wrist is 300 pounds. A JR3 force/moment sensor is mounted at the wrist and attached to it is an Applied Robotics tool changer. A second Applied Robotics tool changer is mounted on the shoulder of the Telerobot and has a lifting capacity of 1,000 pounds. The tool changers are unique, in that they are electrically-actuated. The wrist tool changer allows the Telerobot to pick up many standard electric powered hand tools including a gripper, circular saw, chain saw, reciprocating saw, abrasive wheel grinder and others. The shoulder tool changer allows the Telerobot to pick up a two-armed electric master/slave manipulator made by REMOTEC or the drum lifter.

The Telerobot was installed in 1986. Joysticks are used instead of a standard teach pendant for much faster and easier manual control. Push-button programming and menu-driven selection of programs also simplifies programmed control. This operation has been enhanced and many features have been added by the inclusion of a graphical interface based on the DOE Generic Intelligent System Control (GISC).

GRAPHICAL INTERFACE (SNL, SRTC, LLNL)

Two 3-D robot simulation packages were demonstrated that are both compatible with GISC. One package is Robline, from Cimetrix, which operated the PUMA robot and the IBM robot. The other package is IGRIP, from Deneb, which operated the Telerobot. Both programs ran on Silicon Graphics Inc. workstations. IGRIP included the Low Level Telerobotics Interface (LLTI) that previously was developed by SNL and transferred to Deneb. LLTI allowed the IGRIP simulation to track movements of the robot in real time. In order to track the Telerobot, PaR systems increased the simultaneous communications available with their Real-time Path Modification (RPM) board from 6 axes to 8 axes.

With both simulation programs, programming of the robots was accomplished directly from menus on the computer screens. Both simulation programs also allowed previewing of each robot program in the simulation. IGRIP provides automatic conversion of the program into the robot controller specific language, downloading of the program and execution along with real-time movement tracking. The Robline system includes the robot controller, so it uses the same program to drive both the simulation and the controller. Control of the hardware, i.e. conveyors, is accomplished through a series of software drivers that interface with the equipment controllers.

MODEL-BASED COLLISION AVOIDANCE (SNL, SRTC, LLNL)

Both simulation packages included collision and near miss detection. The advantages of using this feature to anticipate collisions between the robot and known objects (equipment and material) in the workcell were demonstrated. By preventing these unintended collisions, both in teleoperation and in programmed operation, safety risks, damage, cost and subsequent downtime can be minimized. In teleoperation, if an impending collision with a known object is detected by the simulation, control will be automatically taken away from the operator, the robot will be moved away from the object, and control returned to the operator. During simulation, impending and actual collisions are indicated to the operator by dramatic changes in object and robot colors. Paths with collisions are not allowed to be downloaded from the simulation. Collision-free paths are found and displayed on the simulation for review by the operator.

DRUM LIFTER (INEL)

Tens of thousands of drums of waste will have to be transported in waste treatment facilities. Manual handling would be a safety risk, especially with the large number of drums that will be processed over the life of a facility. There are many options for remote drum transport. However, if a gantry robot similar to the Telerobot is available, it can quickly and reliably move drums in a precise path and precisely locate them in machines that require top loading, such as the drum and liner opener. The drum lifter has been tested with a 55 gallon drum that weighed over a thousand pounds and performed well even with deformed drums. The drum lifter includes an Applied Robotics tool changer that is compatible with the tool changer on the shoulder of the Telerobot. It has sensors that measure relative force and displacement of the lifting straps. These sensors are monitored and used for control during operation. In the demonstration the drum lifter lifted a drum of simulated waste from the drum conveyor and placed it in the drum opener. After the drum was cut, it removed the top of the drum. It then was placed over the exposed 0.090 inch thick liner as it was cut to prevent the liner from falling off after cutting. After the liner was cut, the drum lifter removed the top of the liner. The lifter can also remove the full drum from the drum opener and place it in a drum dumper, or remove the empty drum after it is emptied at the drum opener.

DRUM AND LINER OPENER (SRTC)

Tens of thousands of drums of mixed waste will have to be opened in mixed waste treatment facilities. Many of these drums and their fasteners will be corroded and deteriorated so that removal of the lids would be difficult. Manual opening of the containers would risk injury from exertion, power tools and sharp edges. Remote container opening would reduce risk of injury, reduce secondary waste from personal protective clothing and increase throughput. The drum and liner opening equipment was developed to remotely open drums and liners. It is similar in concept to a design by Merrick & Company for a proposed Waste Characterization Facility (WCF) for INEL. Initial testing of the SRTC equipment has identified tools and techniques that will open drums and liners. After the demonstration, other types of tools and techniques will be tested to optimize the process. The results will be available to aid in the design of actual equipment for the WCF and other mixed waste facilities. The equipment is composed of a powered, rotating chuck that can grip the bottom section of 30, 55 and 83 gallon drums and overpacks. Tools and supports are deployed from opposing masts and can be remotely manipulated up and down on the mast and in and out. In the demonstration a set of idler wheels was brought in contact with one side of the drum and an unpowered, sharp-edged disk was slowly brought in contact with the opposite side of the drum. As the drum was rotated the disk slowly moved into the drum wall until the drum wall was completely cut, much like a huge tubing cutter. After the top of the drum was removed by the drum lifter, a second tool, a knife blade, moved up to contact the exposed 0.090 inch thick polyethylene liner and cut the liner. The drum lifter then removed the top of the liner to expose the contents. The contents could be removed directly from the drum or the contents could be dumped out. Both alternatives were demonstrated.

WASTE ITEM REMOVAL, CHARACTERIZATION, SORT AND TREATMENT (LLNL, SNL, ORNL)

The heterogeneous solid waste items were removed directly from the drum, as well as dumped from a drum and removed from the resulting pile of waste. The waste items were placed in trays and conveyed through characterization and sorting systems. One type of waste, simulated lead bricks, was treated by scarifying, surveyed and palletized. This technology is discussed in the paper "Advanced Robotics Technology Applied to Mixed Waste Characterization, Sorting and Treatment" in session TA7 at this conference.

AUTOMATED WORKCELL MODELING (SNL, SRTC)

Graphical programming, collision avoidance, path planning and program preview are all based on graphical models of the robots, equipment and material in the environment. Accurate models are required to accomplish this. Material, such as containers (drums, boxes, and bins), will be moving in, through, and out of workcells on a continuous basis. Large waste items such as gloveboxes and vessels will be moved into the workcell and size reduced. In order to maintain the accuracy of the model, an automatic system to update the workcell will be required. SNL has a Cooperative Research And Development Agreement (CRADA) with Mechanical Technologies, Inc. (MTI) on a structured light modeling system. MTI, with assistance from SNL, provided a structured light system that demonstrated automated updating of a portion of the Telerobot workcell model. The structured light system covered an area of approximately 20 feet by 20 feet in the workcell. A metal box was placed in the workcell but not entered into the model. The structured light system used four identical stations at each corner of the area to model the metal box. Each station had two precise stages with very accurate feedback that act as pan and tilt mechanisms. These stages manipulated a camera, laser line generator (laser and lens) and a laser pointer. The laser pointer was used only for initial calibration of the system. One station passed the laser line across the workcell, while the camera on another station tracked the line. By repeating this four times, with each station eventually panning a laser line, the shape and location of the box was calculated. This information was then automatically entered into the graphical simulation system as a model of the box. The model was accurate to $\pm$ 1 inch in this application.

AUTOMATIC STANDOFF CONTROL (SRTC)

In waste facilities there will be some large metal objects, such as gloveboxes and vessels, that must be size reduced before they can be put into the final form or placed into a shredder, compactor, other size reduction devices or process equipment. Plasma arc cutting is the most popular method for remote cutting of metal. It is a very aggressive process and its control is not very demanding. However, if the geometry of the object to be cut is not well known, it is difficult to control remote plasma arc cutting. In waste facilities we will be challenged by a large number of metal objects that will vary widely in size and shape and will not be well documented. Experience with remote plasma arc cutting of these undefined objects has shown that it is difficult to maintain the arc and keep the torch from hitting the surface.

Industry typically uses torch voltage to monitor and control standoff distance. This technique works well, if the type of material and material thickness are known and uniform. This will not be the case in waste facilities. The model of the box produced by the workcell structured light system is accurate enough to allow the operator to graphically program the start and stop point for the torch, but is not accurate enough and is not updated often enough to control the standoff distance of the torch. Sensor-based control needs to take over from model-based control. A Selcom laser distance measuring sensor added to the torch end effector to measure the standoff distance was demonstrated previously. The laser is unaffected by the plasma arc or the type or thickness of material. The output from this sensor was used to perturb the robot trajectory, using GISC. At this demonstration a new, low-cost Selcom laser was used to control the standoff. This laser costs less than $5,000, compared to the previous laser that cost over $17,000. Cutting has been improved by Clemson University by having the laser measure three points on the surface to be cut to automatically position the torch perpendicular to the surface. Also, the data obtained by the laser is now stored in the computer with its position in space. This allows the torch tip to be manipulated to avoid contact with sloped surfaces or the leading or trailing edge of changes in slope. This control system is also applicable to different types of cutting and decontamination tools that require control of the standoff distance.

SWING-FREE CRANE CONTROL (SNL, ORNL)

A table-top model, built by Sandia National Laboratory, demonstrated swing-free crane control and a video showed this technology implemented on a full sized gantry crane at the Oak Ridge National Laboratory. This technology is discussed in the paper "Implementation of Damped Oscillation Motion Control on an AC Induction Motor-Driven Crane" in session TA7 at this conference.

STORED WASTE AUTONOMOUS MOBILE INSPECTOR (SRTC)

The Stored Waste Autonomous Mobile Inspector (SWAMI) was demonstrated. This system is based on a mobile robot that navigates down the aisles in warehouses with stored waste drums. It performs a radiation survey of the floor in the aisle, reads the drum number from a bar code label on each drum, captures an image of each drum and stores it with the drum number, location, time and date. This technology is discussed in the paper "An Autonomous Mobile Robot to Perform Waste Drum Inspections" in session TA7 at this conference.

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