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MOBILE TELEOPERATOR RESEARCH AT SAVANNAH RIVER LABORATORY

by

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ABSTRACT

A Robotics Technology Group was organized at Savannah River Laboratory to employ modern automation and robotics for applications at the Savannah River site. Several industrial robots have been installed in plant processes. Other robotics systems are under development in the laboratories, including mobile teleoperators for general remote tasks and emergency response operations. This paper discusses present work on a low-cost wheeled mobile vehicle, a modular light duty manipulator arm, a large gantry telerobot system, and a high technology six-legged walking robot with a teleoperated arm.

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INTRODUCTION

The Robotics Technology Group was organized at the Savannah River Laboratory in August 1982. The objectives were to employ modern industrial robots, to develop unique robotic and automation systems in new processes, and to enhance present process operations for the Savannah River site, Savannah River Plant (SRP) and Laboratory (SRL). The incentives for this activity are to improve safety, reduce personnel radiation exposure, improve product quality, improve productivity, and reduce operation costs. Robotic systems have been installed to fill chemical dilution vials in the laboratory, to remove radioactive waste materials from a production facility, to lubricate a large extrusion press, and to enhance operations in a separations process. Two other industrial robot systems are scheduled for installation in a fuel assembly manufacturing area during this year. Other systems are under development in the robotics laboratories include mobile teleoperator systems for general remote tasks and emergency response operations.

We have participated in two Department of Energy Robotics Seminars (sponsored by IMOG, CAD/CAM Subgroup) at Rocky Flats Plant and Pinellas Plant and a JOWOG Robotics and Automation Seminar at Rocky Flats Plant. A Savannah River Site Activity Report was presented at each seminar. We have also presented papers at American Nuclear Society conferences and other robotic conferences (References 1-4). Recognizing the need for strong safety considerations in the design and implementation of all automated systems, we have published an in-house document on robotics safety (Reference 5).

TELEOPERATORS DEVELOPMENT

Pedsco Mobile Vehicle

Many emergency response operations can be performed with a simple teleoperated mobile vehicle and a manipulator arm. We identified such a vehicle, manufactured by Pedsco Canada Limited, and have employed these units for several site applications. We are presently enhancing this vehicle to increase its versatility.

The Pedsco RMI (Remote Mobile Investigation) vehicle is a six-wheeled unit equipped with a controllable arm and hand (Figure 1). A closed-circuit TV system and 200 foot long umbilical cable permits remote control with a joystick and switches from a portable control station. It is approximately 40" long, 26" wide, and 28" high, is battery powered, and can operate at speeds up to 3 miles per hour. The boom structured arm has two degrees of motion. The hand is a simple claw with binary operation; however, it has a "soft touch" closure mode for handling more fragile items. The arm and hand can lift up to 70 pounds, but it can

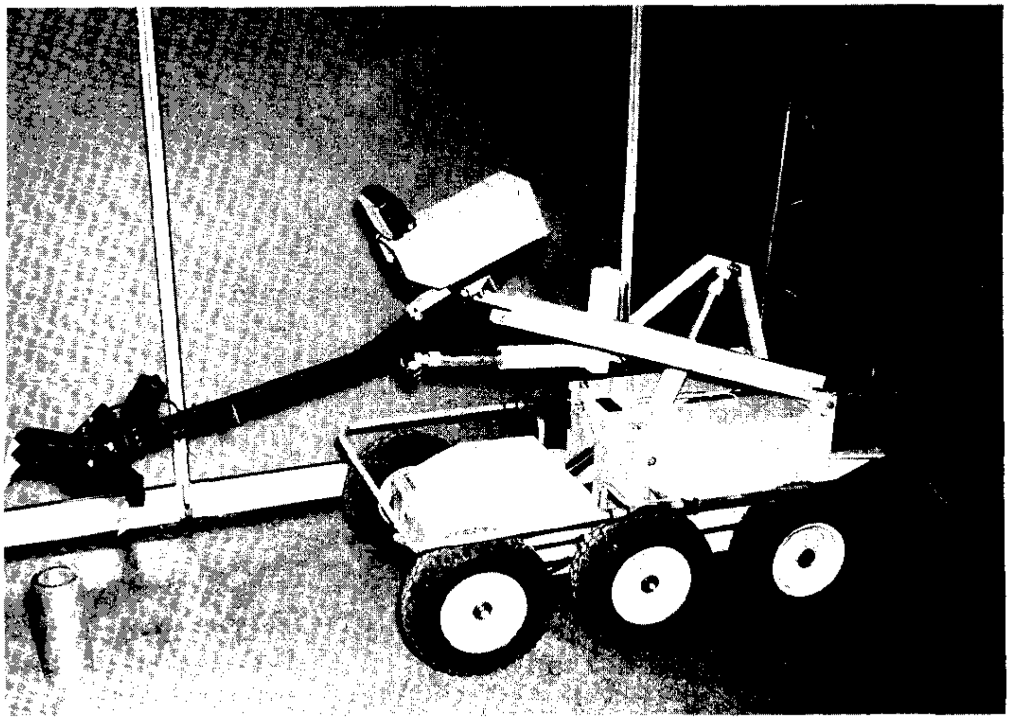

Figure 1. PEDSCO Mobile Vehicle

easily drag objects over 100 pounds. Total vehicle weight is 230 pounds.

The RMI vehicle was developed in 1976 by Pedsco for the Royal Canadian Mounted Police and is used primarily for police and military applications for bomb disposal and hostage situations. In late 1982 a modified Pedsco RMI was employed by Ontario Hydro at their Bruce NGS-A reactor for an emergency cleanup operation in a highly radioactive nuclear environment. The reported success of this operation called our attention to the potential use of this vehicle.

We have successfully used this vehicle at Savannah River for radiation monitoring and mapping on the top of an outdoor waste storage tank and for an emergency operation involving a suspected explosive package that was discovered in the administration building mail room. Its capabilities are presently being explored for several decontamination and cleanup applications in process areas. We have successfully tested the Pedsco vehicle in a reactor process room in which we found the retrieved simulated reactor fuel assembly components. We have modified one radio-controlled unit with a microwave TV system, have waterproofed it, and will test it in a reactor process room with the water spray system operating. We have designed an improved arm and control system to enhance the manipulator capabilities of the vehicle. In the near future we will have a relatively low-cost mobile vehicle suited for a variety of nuclear service applications including surveillance, monitoring and equipment handling.

Modular Light Duty Manipulator

A teleoperated manipulator arm is being developed by Teleoperator Systems, Inc., Troy, NY to perform general remote operations tasks (Figure 2). An in-house development program will upgrade the system to telerobotic operation. The design objective for this arm is to produce a low cost, modular arm to perform manual and programmed tasks. The arm has a 52-in reach capability and a lifting capacity of 50 pounds. The manipulator, including its base, will fit through a 30-inch opening. The joint motions will be powered by DC motors enabling its employment on mobile vehicles.

The arm consists of seven modules which are easily detachable and replaceable. A design criteria states that these modules be inexpensive, typically less than $5 thousand each except for the base module. No module except the base will weigh more than 25 pounds. All joints will operate with slip clutches that can be arm and control system to enhance the manipulator capabilities of the vehicle. In the near future we will have a relatively low-cost mobile vehicle suited for a variety of nuclear service applications including surveillance, monitoring and equipment handling.

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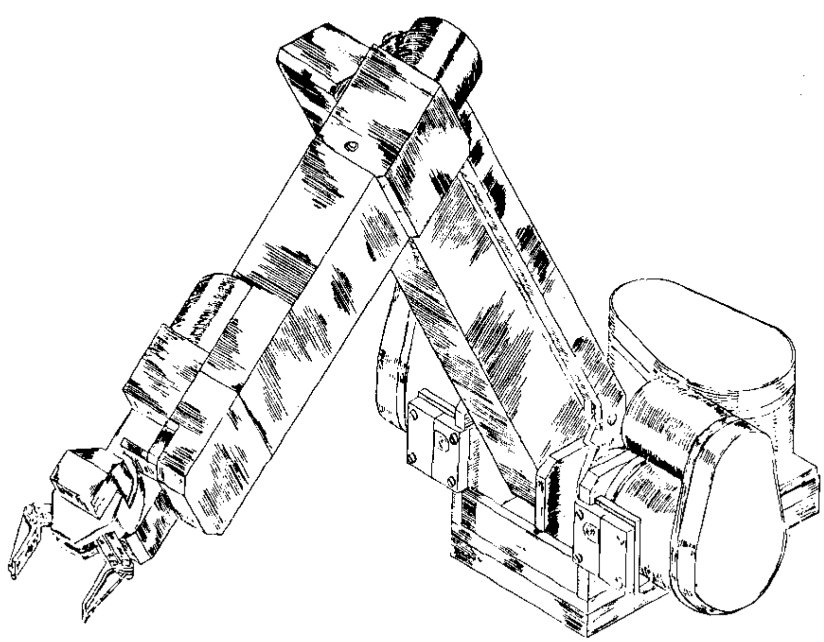

Figure 2. TSI Modular Arm

TELEROBOT DEVELOPMENT

Large Gantry Telerobot Facility

Telerobotics technology combines the "man in the loop" teleoperated systems and programmable robot systems. Many applications require both operations, the robot to perform the routine programmable tasks and the teleoperator to perform unique real-time tasks. A substantial engineering development is required in hardware, firmware, software, and human factors to effectively integrate robotic and teleoperator operations.

At Savannah River a telerobot system will be employed in a new facility to decontaminate and dismantle obsolete nuclear equipment (gloveboxes, etc.). A five-axis manipulator integrated with a three-axis gantry robot system will serve a 70' X 20' X 20' work area (Figure 3). The telerobot system, being manufactured by GCA Corporation, St. Paul, MN to SRL specifications, will handle up to 300 pounds at its end-effector. Operators will control the manipulators with joysticks, function switches, and a computer terminal. Programmed robotic operations will include the tasks of changing manipulator hand tools for specific operations and of performing routine maintenance operations. System controls will coordinate motions for the nine system axes to move end effectors in straight line trajectories. Cutting and drilling operations will require this. Human factors engineering is a prime consideration in the overall design and development. The telerobot will communicate process information to a process computer network.

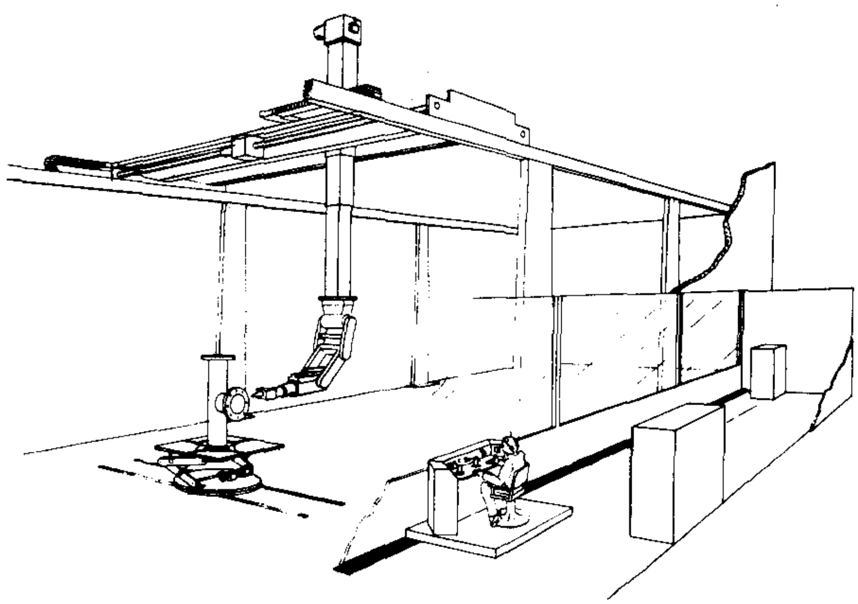

Figure 3. GCA Telerobot System

This robot is scheduled for September delivery to SRL. Development work, evaluation, and demonstration will be performed in the robotics laboratory prior to installation in a full scale prototype facility in another area.

Odex Walking Telerobot

The six-wheeled, unintelligent, teleoperated mobile vehicle is applicable for simple tasks. However, even an enhanced version of that vehicle is quite limited in versatility. The state-of-the-art in mobile vehicles is the more intelligent, six-legged walking machine. A commercial, research-oriented company, Odetics, Inc. of Anaheim, California developed and demonstrated a prototype model of this type, the Odex-I robot, in March 1983 (Figure 4). Advantages of walking vehicles, as opposed to the more common wheeled and tracked types, are the capabilities to assume a stable foothold to improve traction, to minimize lurching, and to step over obstacles while maintaining a stable payload platform. The Odex walking machine can operate in a variety of stances and modes. It has built-in firmware that

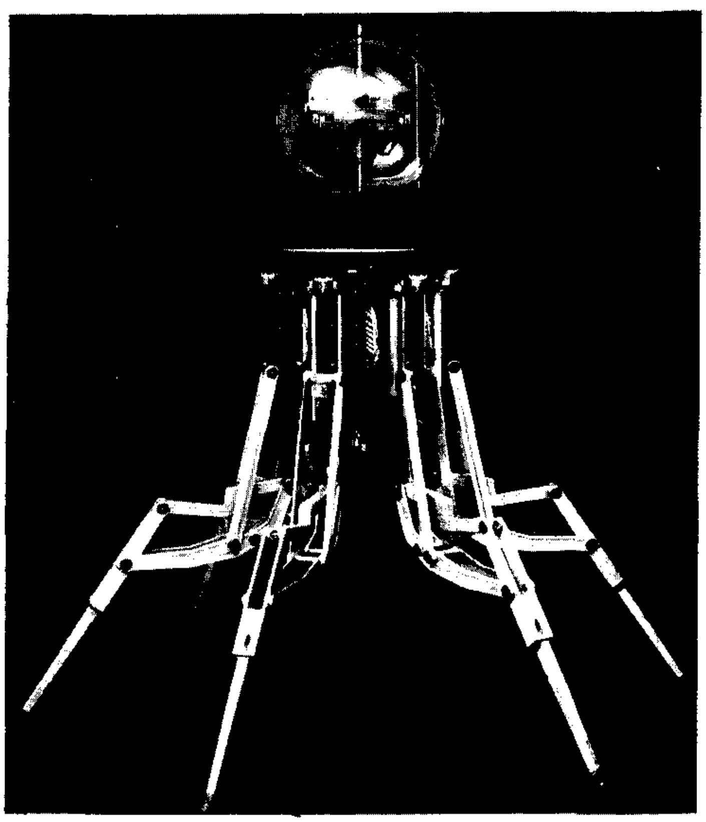

Figure 4. ODEX-1 Prototype

includes the walking, stance, and reflexive intelligence algorithms that minimize the required control operations from a human operator. It can be classed as a mobile telerobot.

We have a contract with Odetics to develop, fabricate, demonstrate and deliver a telerobot, ROBIN (Robotic Insect), to the Savannah River Laboratory in January 1986. It is not being built to withstand a hostile radioactive environment but will be used in a laboratory environment to develop and demonstrate techniques, procedures, and applications for mobile robots at the Savannah River site. Applications include emergency response operations, routine maintenance, radiation surveillance, decontamination and removal tasks. It will also be used in a research and development program for expert robot systems.

ROBIN's walking mechanism will be an improved version of the original ODEX-I prototype, incorporating better control algorithms and aesthetics (Figure 5). Some of the unique differences are a teleoperated manipulator arm, a fiber optic umbilical cable with an automatic take-up reel, and a TV/lighting system. The

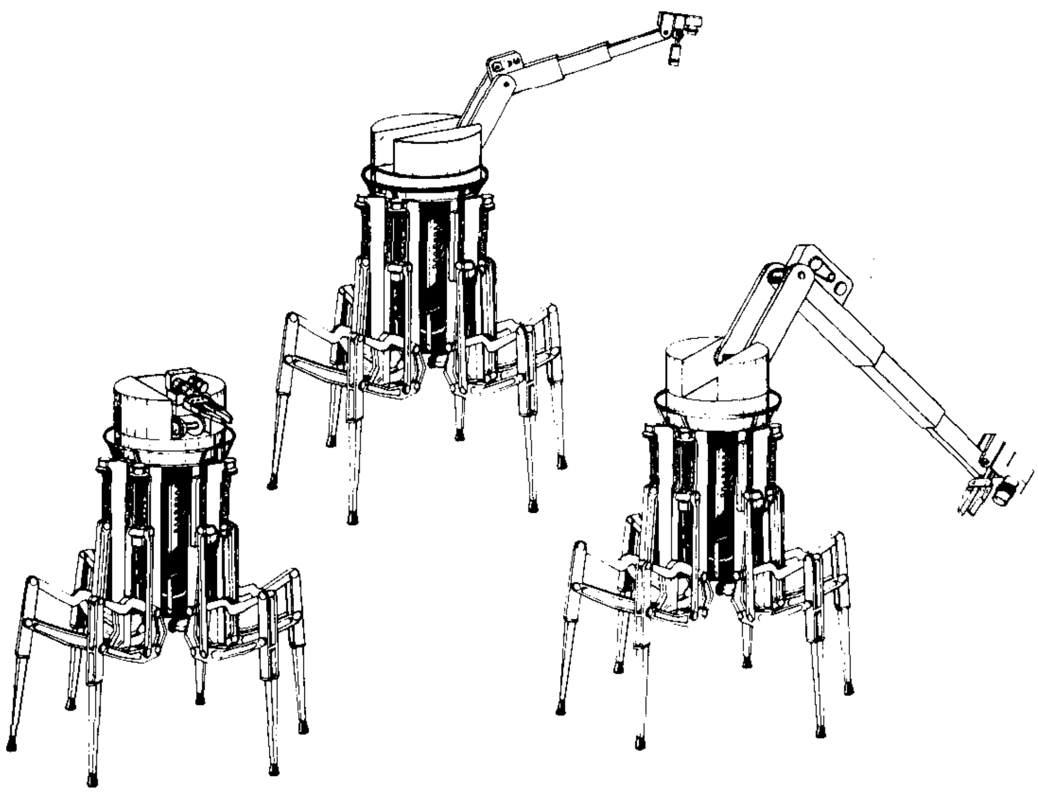

Figure 5. Conceptual Drawing of ROBIN

telescoping arm, that normally resides within a turret at the top of the robot, will handle up to 50 pounds in a work envelope that extends from 7 feet above the robot to the floor over full circumference of the vehicle. Six degrees of freedom and a programmable force limited binary action for the gripper are available for operation. Three TV cameras, two on the turret and one at the end of the arm, may be selected in pairs for viewing from the control console monitors. The 3/8-inch, 250-foot umbilical cable system will have programmable tension in its servo controlled reel system.

The computer on-board the robot controls all motions, stances, reflexive actions (to step over obstacles), and maintains stability once desired operations have initiated from the human operator at the control console or from a control computer. Overload conditions and safety alarms are automatically sent to the controlling device. A data acquisition system integrated with the robot computer can be connected and interrogated to monitor various analog and digital process conditions. Analog and digital outputs are available to control special tools and external processes.

All control functions (inputs and outputs) are available at the control console unit for teleoperated human control or for external computer control through a standard serial communications channel. The control console contains three joysticks for walking, cameras, and manipulator/gripper control, a key pad for programming special modes and limit values, and switches for several common operations. Two TV monitors are used for cameras and status information.

OTHER RESEARCH PROJECTS

Expert Robotic Systems

Our program plans include the development of expert robot/telerobot systems for site applications, using knowledge bases and artificial intelligence techniques. A solution to many general process and emergency operations problems in nuclear plants and other industrial plants is the effective employment of intelligent robots. Intelligent robots are in their infancy and are not an off-the-shelf item available to industry. Research programs are well underway at major universities and research centers throughout the world and many experimental intelligent prototype machines are being developed at those institutions. Robots with sensory capability (vision, tactile, etc.) are often referred to as intelligent. However, having sight, hearing, voice, and a sense of feel does not make a human an intelligent person nor does it make a machine an intelligent robot. Cognitive reasoning ability and knowledge must be present.

An expert system is one that incorporates knowledge-based artificial intelligence dedicated to very specific and limited tasks. The first truly intelligent robot systems in industry will appear as expert robot systems, not as a generic robot with enough intelligence to perform any job in a plant. Extensive experimental and development work will be required to program the system with the knowledge base and instructions necessary to expertly perform a given task. A desirable system would be a hierarchical system that contains a large intelligence data base made up of expert modules (Figure 6). That system would be capable of recognizing a process problem, taking direct action through a standard process control network, then making the decision whether or not to call on the expert robot. A network of generic mobile robots, telerobots, or modular manipulator arms would be on standby at work stations located at strategic places in the process. Each work station would contain special tools and special equipment that the robot may need to perform many different jobs in its area. When called on to work, the robot would be instantly trained from the knowledge base to perform expertly in the task.

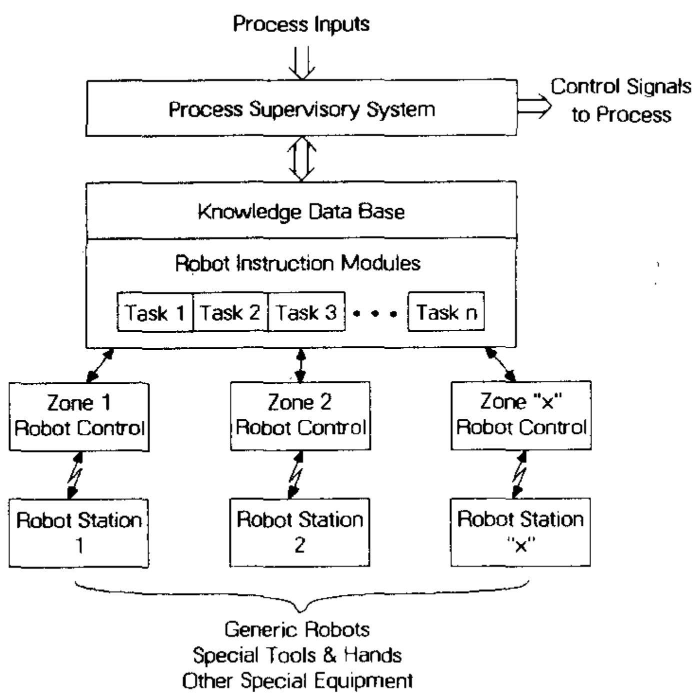

Figure 6. Network of Expert Robots

Vision and Other Sensory Systems

We have set up a laboratory to develop product inspection techniques and systems for both real-time and batch applications. Automated expert inspection systems will improve product quality and productivity for many processes. Our laboratory contains an Automatix AV-4 Computer Vision System with the capacity for 16 cameras and 32 input/output control signals. It is a completely self-contained unit, enabling it to operate as an autonomous inspection station, a sensory system for a robot, or a process control sensor. Special peripheral laboratory equipment includes a low-power (1 mw) Helium-Neon laser, a laser scanner for use in 3-D inspection, several computer controlled positioning tables, and various cameras, lenses, and light sources.

Commercially available, six-axis force sensors are being evaluated and integrated into several of our robotic systems.

CONCLUSIONS

The Department of Energy and DuPont management at Savannah River have recognized the need for robots, telerobots, and teleoperators for emergency response and many routine operations at the site. We have organized an in-house research and development activity and much progress has been made in developing techniques and systems and in applying them to practical applications. In the mobile robotics field we are developing low-cost wheeled vehicles and the most sophisticated walking machine presently available in the world. Future plans call for more involvement in expert systems incorporating artificial intelligence. We plan to maintain an engineering group with expertise in state-of-the-art robotics technology.

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