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Remote Manipulators in Industry and Space

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ABSTRACT

Many challenging scientific, engineering, and manufacturing tasks in both industry and space can be performed most effectively and efficiently by means of remote-controlled robotic systems. We will examine a variety of manipulators in use around the world today. These computer/operator instructed devices are built to operate in hazardous environments and/or to rapidly perform precise, material handling, repetitive functions reliably for long periods of time.

INTRODUCTION

By definition, as recently adopted internationally, "a robot is a reprogrammable multifunctional manipulator designed to move material, parts, tools, or specialized devices, through variable programmed motions for the performance of a variety of tasks." The Robot Institute of America and Robotics International of the Society of Manufacturing Engineers are now gathering the strength needed to interface with the strong Robotics Institutes of Japan, Germany, Italy, Sweden, France, and the U.K. The presentation materials used with this paper illustrate machines and equipment used in all these countries plus Canada, Switzerland, Norway, and Russia.

ROBOTICS IN INDUSTRY

Most of us think of automated assembly lines with motorized parts, conveyor belts, stamping machines, numerically controlled machine tools, etc. as we visualize modern day industry. These items, however, are only basic building blocks comprising a portion of the automation picture today. Sophisticated, hierarchal computer-controlled robots with multiple manipulators, interchangeable end-effectors and sensor subsystems can now perform the positioning, inspection, measurement, and other functions formerly requiring human workers. Electro-optic, electromechanical, electro-acoustic, electromagnetic, and electrochemical sensors provide a range of sight, tactile (or touch), hearing, smelling (gas analysis), and tasting (liquid or compound analysis). In addition, radiation sensing, radioactive tracing, ultrasonic measurement, infrared pattern recognition, and other capabilities beyond human perception. The sensors provide signals which are received by a microcomputer (or larger computer). Signal processing and analysis can then lead to man-taught decision making processes to implement various useful functions. Several systems and applications will not be illustrated.

In a factory environment or any fixed mounting configuration, a manipulator arm has a well-defined reach and working volume as shown in Fig. I. One should note that this anthropomorphic arm has shoulder roll and elevation joints, an elbow joint, and wrist roll, pitch and yaw joints. The end effector here is a mechanical gripper much like a hand. Figure 2 shows an actual remote mobile manipulator system dubbed the "Spider". Its two television cameras allow the remote operator to see and control what the robot is approaching and handling. A trailing umbilicus allows two-way signal transmission. Some mobile systems use rf, laser, or fiber optic communications links. This and the robot shown in Fig. 3 are designed for use in hazardous situations or environments. The large steam generators (heat exchangers) associated with pressurized water nuclear power generating stations become radioactive from the circulating primary coolant. They must be decontaminated and serviced periodically. The insertable arm illustrated can perform many of the functions listed in Table I. A few of the benefits are noted in Table II. A representative listing of

United States robot vision and/or optical inspection system developers appears in Table III.

ROBOTICS IN SPACE

Of particular interest to the aerospace community is the Remote Manipulator System (RMS), which has been built to handle payloads on the space shuttle. Figures 4 and 5 provide considerable detail about the arm subsystems and operational features. Successful functional testing was conducted during the second Columbia flight in November 1981. It is anticipated that future missions will utilize remote manipulator spacecraft systems similar to the one sketched in Fig. 6. Multiple manipulator arms and legs will attach themselves to a satellite orbiting on station and then perform required maintenance checks, equipment (module) changeouts, and other service functions. This type of remote control has unique problems due to signal delays (delayed real time) from the earth-based operator console link to orbital range and return. Thus careful sequential pre-programming of routine operational functions will be done as much as possible.

CONCLUSION

There are many interesting and worthwhile challenges to be met in designing and building precision servo drive manipulators for various applications in industry and aerospace. Serious efforts are being undertaken by many countries around the world. Significant advances in applying space-age technology in robotics and automation have already demonstrated increased productivity and economic dividends.

ACKNOWLEDGEMENTS

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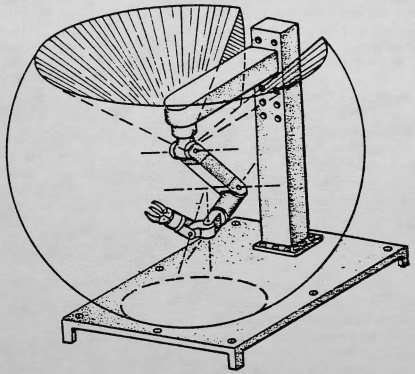

Figure 1. Manipulator Arm Mounting and Work Volume

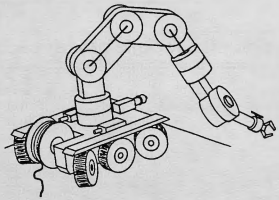

Figure 2. Mobile Remote Manipulator System

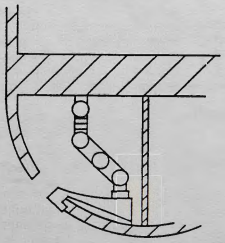

Figure 3. Servicing a Nuclear Power Steam Generator

TABLE I

potential robotic arm applications

- Plant Security
  - Door Interlock Verification
  - Fire Control
- Plant Surveillance
  - TV Monitor
  - Vibration (contact and non-contact)
  - Gage reading
  - Temperature
  - Humidity
  - Microphone
  - Radiation
- Remote Health Physics
  - Air Sampling
  - Rad Owl (Remote reading type)
  - Geiger Counter
  - Teletector
- Spent Fuel Pit
  - Rack Inspection
  - Liner Repair
  - Spent Fuel Inspection
  - Rack Bolting for Replacement of Racks
  - Transfer System Repairs
- Pipe and Pump Casing Inspection
  - Visual Inspection
  - Non-Destructive Testing
  - Internal Inspection
- Welding and Machining
  - Weld
  - Braze
  - Grind
  - Wire Brush
  - Drill
- Material Handling
  - Filter Change
  - Filter Disposal
  - Radwaste Handling
  - Debris Retrieval
  - Acids and Corrosives Removal
- Reactor Vessel
  - Visual Inspection
  - Non-Destructive Testing
  - Debris Retrieval
  - Baffle Inspection
  - Machining as Required
  - Thermocouple Repairs
  - Guide Tube Repairs
  - Flux Thimble Inspection
  - Stud Hole Cleaning
- Steam Generator
  - Decontamination
  - Mechanical Plugging
  - Eddy Current
  - Sleeving
  - Welding/Grinding/Drilling
  - Clad Repair
  - Divider Plate Weld Repair
- Decontamination
  - Cavity Cleaning
  - Platform Cleanup
  - Walkway Cleanup
  - Spillage Cleanup
  - Hazardous Chemical Cleanup
  - Tool Cleanup
  - Reactor Vessel Studs

Table II

benefits of a remotely operated service arm

- REDUCE RADIATION EXPOSURE
- REDUCE EXPENSIVE DOWNTIME
- IMPROVE MAINTENANCE PRODUCTIVITY
- IMPROVE PLANT SAFETY

TABLE III

U.S. ROBOT VISION/OPTICAL INSPECTION SYSTEMS

ACADEMIC/INSTITUTIONAL DEVELOPERS

MIT: A.I., M.E., DRAPER LABS
STANDORD RESEARCH INSTITUTE
CARNIGIE-MELLON INSTITUTE
UNIV. OF FLORIDA
UNIV. OF RHODE ISLAND
UNIV. OF MARYLAND
UNIV. OF MICHIGAN: ERIM
UNIV. OF ILLINOIS
UNIV. OF SOUTHERN CALIFORNIA
JET PROPULSION LABORATORY
CALSPAN
CASE-WESTERN RESERVE UNIV.
GEORGIA TECH. UNIV.
DARTHMOUTH

INDUSTRIAL DEVELOPERS

AUTOMATIX, INC.
AUTO PLACE, INC.
BENDIX CORP.
COMPUTER DESIGN & APPLICATIONS
DEFT LABS, INC.
DIFFRACTO, INC.
EMR SCHLUMBERGER
FORD MOTOR
GENERAL ELECTRIC
GENERAL MOTORS CORP.
HAM INDUSTRIES
JONES & LAMSON
IMTECH, INC.
INSPECTION TECHNOLOGY, INC.
LOCKHEED - CALIFORNIA CO.
MACHINE INTELLIGENCE CORP.
MEASUREMENT TECHNOLOGY, INC.
OBJECT RECOGNITION SYSTEMS, INC.
OCTEK
OPTICAL GAGING PRODUCTS
RECOGNITION SYSTEMS, INC.
PROCESS EQUIPMENT CO.
QUANTEX, INC.
RETICON CORP.
SPATIAL DATA CORP.
STOCKER & YALE, INC.
TECHMET CO.
TEXTRON, INC.
SOLID PHOTOGRAPHY, INC.
UNIMATION, INC.
VIDEO AUTOMATION SYSTEMS, INC.
VIDEOMETRIX, INC.
VIEW ENGINEERING
XEROX CORP.

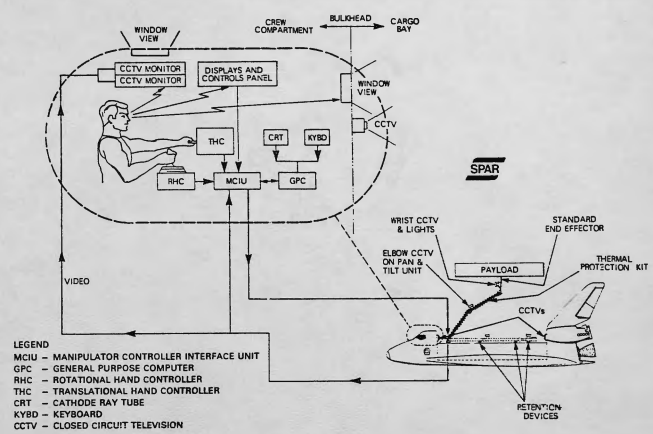

FIGURE 4 REMOTE MANIPULATOR SYSTEM

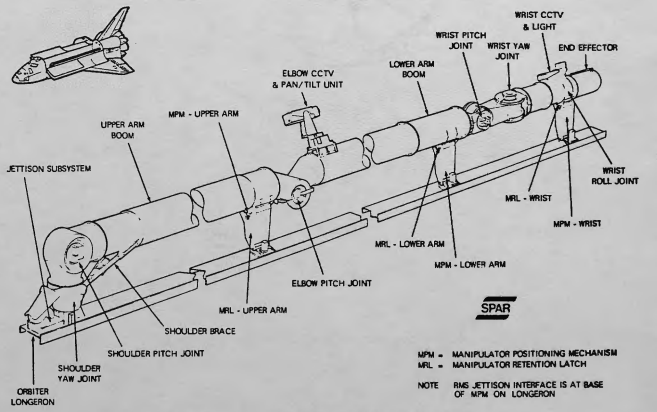

FIGURE 5 MECHANICAL ARM ASSEMBLY

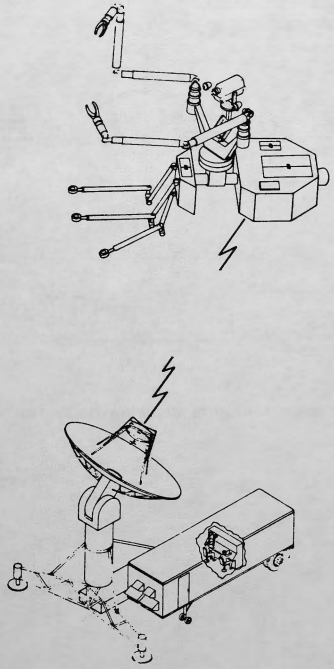

Figure 6. Remote Manipulator Spacecraft Systems