Teleoperation R&D activities in Korean Nuclear Waste Program

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This paper presents some results of teleoperation R&D activities for radioactive work. Heavy power manipulator feature is integrated with vision system implementation of advanced type and tool adaptation to hand gripper. Some associated research activities of interests to the teleoperation and future directions are also presented.

I. INTRODUCTION

Nuclear industry has been one of the leaders in the application of teleoperation technology for radioactive environment work(1). With sizable nuclear power program in place, Korea now stands among world ranking nuclear industry nations. Nuclear waste management, in subsequent to the nuclear power generation, is becoming a serious concern in Korea as well as other nuclear nations.

The recently established National Radioactive Waste Management Project includes an R&D program to promote remote technologies to be used for improving safety and efficiency of radioactive waste handling work in hostile environments. Not much attention has been paid, if any, to this topic in the past KAERI R&D activities. The present program intends systematic approaches to improve the performance and reliability of teleoperation for radioactive waste handling operations.

This paper describes major activities of the teleoperation R&D program that has been initiated since a couple of years at the Remote Technology Department.

II. REMOTE OPERATION TESTS

The approach taken in the initial phase of the remote handling research activities was higher priority to practical applications. Real scale test systems were selected, therfore, in the equipment installation among the wide spectrum of available options.

Aside from master-slave type mechanical manipulator(CRL Model F) which was installed for only test purpose, electro-mechanical type power manipulator(HWM Model A1065) is the main body with which major test activities are to be berformed for developmental uses. Other auxiliary systems, like vision and tooling, associated with the teleoperation performance improvements, are selected and installed as required.

1. Power Manipulator System

A commercial, heavy-duty equipment(HWM Model A1065) was selected mainly for maintenance tests with real scale equipments in radioactive environments. This system was supposed to be the "main body" that would also support associated tests of "peripheral" equipments such as vision hook-ups and end effector tool add-ons to improve the system (FIGURE 1)

Summary of the power manipulator general specifications is as shown in TABLE 1. Contrary to the higher handling capacity, dexterity is not good due to lack of force-feedback.

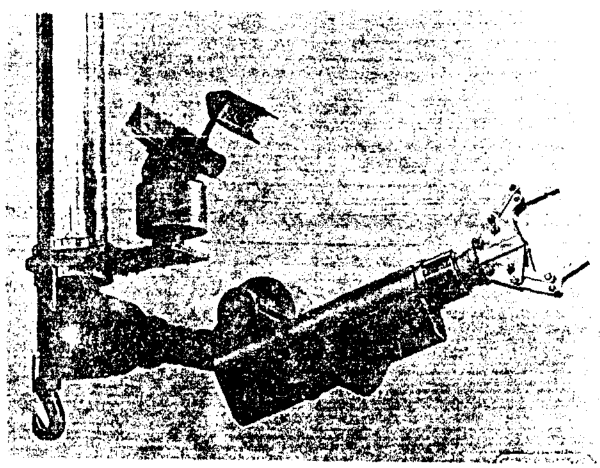

FIGURE 1. Power Manipulator

COMPONENT	D.O.F	CAPACITY	SPEED	OP. RANGE
Telescope	Translation	7000 N(Lift)	3.8 m/min	240 cm
	Rotation	0 - 600 N	3 rpm	Continuous
Shoulder	Rotation	1000 N	3 rpm	Continuous
Upper Arm	Rotation	1000 N	6 rpm	270 deg.
Lower Arm	Rotation	1000 N	6 rpm	270 deg.
Hand	Translation	2000 N	0.6 m/min	12 cm
	Rotation	120 N	4 rpm	Continuous

TABLE 1. Summary of Power Manipulator

2. Vision System

Functional tests of the power manipulator installation, performed at several meters distance from operator console, have revealed some apparent visual problems with either through-the -window or with CCTV observation. To improve teleoperational performance, better vision system application appeared indispensable. Stereoscopic vision techniques are well known(but difficult to implement) alternative to come up with the geometrical perception problem. Some novel techniques that are applicable to this problem were believed feasibe through clever integration in the system, especially through digital picture processing. Even though there are wealth of litterature informations on machine vision application research in manufacturing application most of them are problem specific or too sophiscated that direct application to the present teleoperation anviroment are found difficult. The examination does indicate, however, some possible merits of trying advanced vision systems to complement certain features of teleoperation.

Dimensional measurements(such as range finding, sizing of objects to be handled or around the handling space) were the approach intended in the experiment. Range finding making use of laser beam usually take either one of two principles: time of flight count or geometrical triangulation measurement. From litterature survey, an experimental application of triangulation method using laser beam spot position measurement by picture processing was identified (2). A variety of different application in teleoperation use was supposed to exist.

The approach taken in our simple vision experiment is to exploit the laser beam spot projection property together with the picture process system to measure distance and object size or possibly shape. Spot projected from known beam source to the object scene is captured by the camera to be sent to image processor which calculate the spot size that will permit the distance from the beam source(i.e. manipulator) and sizes of nearby objects by comparison. Measurement improvement is achieved by splitting the beam to get two spots.

Overall configuration of our system is represented schematically in FIGURE 2. The laser beam source and the camera are mounted on a remote controlled pan/tilt device on attachment plate fixed to the lower end of power manipulator telescopic tubes(3 stages). The position of the vision assembly is controllable, therefore, with the vertical/rotational motion of telescopic tubes at the frame of manipulator transporter.

The camera is 440x400 dot CCD type with remote zoom/exposure control. It is easily adaptated for mounting on pan/tilt device of which motion is controlled remotely. Image from the camera is sent to the control room where camera scene is monitored. Image processing system is connected to the CCTV monitor. Larger view is obtained with picture projector. The image processing system consists of a picture processing module(PIAS Model KIT-500) and computer(IBM Model PS/2-50). The picture processor has 512x512 pixel array and 256 gray level. It has four input channels each of which speed is 1/30 sec. Eight frames are stored in the memory during processing. A lot of picture processing functions are available on the system, on menu-driven bases. The picture processing takes the route of usual steps: picture sampling, binary value calculation, contrast reversion, edge filtering and final computation for requested results.

As the control of automatic positioning of the manipulator frame and the camera was not possible, manual setting of geometrical reference was done for the intended test. Suitable setting for measurement was easily made. For calibration, over dozens of measurements using the image processor were made to enhance precision. Results showing less than 1% numerical error bound were obtained in the flat surface case at least. Together with the CCTV monitor, the projection spot guide should serve for remote handling.

There are a lot of things desired, from this preliminary exploration, to complemt the system toward a teleoperation practice, perhaps with different techniques. The test has demonstrated possibilities of advanced vision technology application but limitations as well. Speed control is still a problem of the vision processing for real-time action.

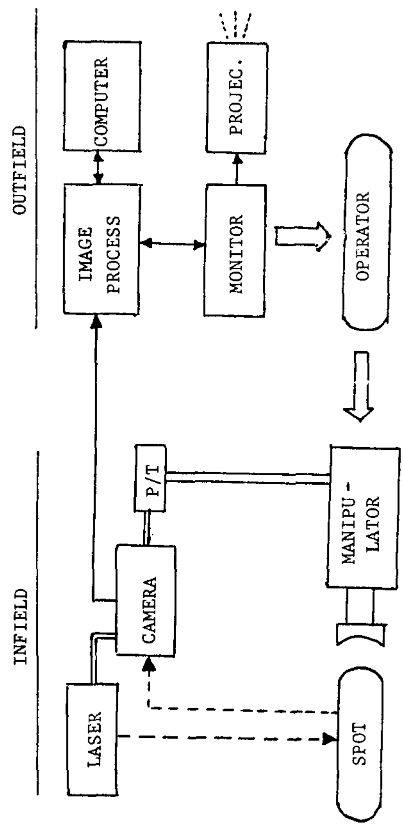

FIGURE 2. Vision System Configuration

3. Tool Operation

As the final element of manipulative action, end effector tool operation is critical to successful achievement of remote handling, especially of remote maintenance task.

Main focus in tool operation have been directed to tool handling with the power manipulator hand for some typical tasks. In this area, usual practices are custom made or specially designed tools to fit in tasks in question. Impact wrech operations on bolting/debolting are typical of such task. One of such practices reports the difficulty of tool engineering in use for radioactive installation(3). It is suggested that commercially available standard tools be used, as far as possible, for efficient and cost-effective maintenance work.

Use of ordinary hand tools is looked for in our approach. In a demonstrative effort to fasten and release the bolt, electrically driven 1/2″ hand wrench was purchased in the city market place. It has enough power for the test operation and light enough weight to handle directly with the power manipulator hand. Holding the tool is obviously not suitable, however, with the manipulator hand gripper. In order to test the feasibility of using the gripper for tool operation with simplest possible effort, a gagging adapter was made of rubber that is solid enough to hold the tool grip with manipulator hand. The adaptor is as shown in FIGURE 3.

The test has shown adequate operation of hand wrench by power manipulator by adding simply designed adapter.

III. ASSOCIATED RESEARCH ACTIVITIES

Some activities associated with the teleoperation technology also been implemented in view of advanced research. They include tactile sensor application and enchancement of motor control system.

1. Tactile Sensor

Tactile sensing is one of useful elements as perception device to provide the teleoperation system with more intelligence. Even if no instance of applying it in the radioactive teleoperation was found in the litterature, an experimental test of such possibility was considered valuable for further research(4).

The device that was selected for the test has 10x16 photo transistor array structure (Lord Model LTS 210) in 1.8x1.8 cm^2 contact surface. Instrumentation system of the device is as schematised in FIGURE 4.

Force measurement range of the device (up to several Kg) is too restrictive to test the device directly with other than small research robot. Tests were made for plug-in operation of electrical connector using a small robot available at the laboratory. When the robot gripper has probably grasped the object (plug body) in wrong position relative to the desired direction, the deviation is perceived by the sensor array to the computer display. Correction calculation is made by the computer and correction control is realized to the robot motion. To improve precision, sensing error correction algorithm is integrated in the pattern calculation process. Similar application of force recognition for ogher objects were tested with satisfactory results. Tactile sensing will be applicable to tool gripping also.

The demonstration tests have successfully shown the possibility of using tactile sensor as an aid to more intelligent teleoperation. Direct application of the technique would require , however, much engineering details in specific application problems.

2. Motor Control Research

An effort to improve motoric performance of remote handling equipment is under initiation in the research program. Among many possibilities open to this direction, better control system application to AC motor to improve performance is the main focus in the research direction.

The bulk of manipulator motors for articulative motions have conventionally been of DC types. Main reason behind this is easier control. Recent progress in control system of AC motors, thanks mainly to cheaper and performant microprocessor usage indicates the promising introduction of AC motors for advantageous industrial

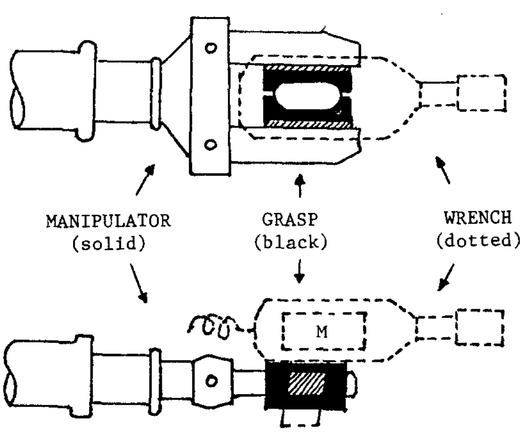

FIGURE 3. Impact Wrench Grasp

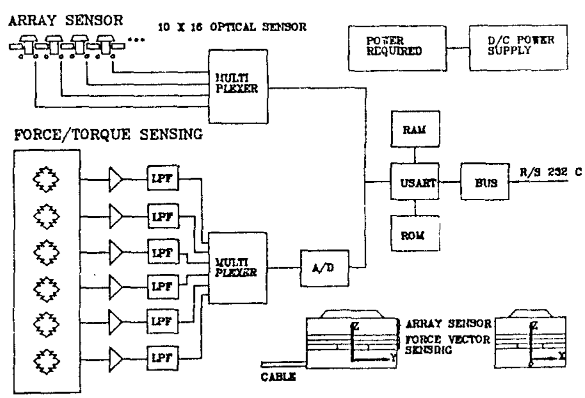

FIGURE 4. Tactile Sensor System.

application(5). This feature of AC motor application should contribute also to performace improvement of our manipulator operation.

To size up the development feasibility, a simulation study of control system was done and expected results are obtained. Encouraged by the analysis results, a plan for systematic test, using advanced inverter in the system, has been established for short time to come. Should the test show promising result, the system will be engineered for prototype application.

IV. FUTURE PLAN

From the initial efforts of remote handling R&D, several major directions of future plans have been derived.

. Servo control of manipulator which is indispensable for flexible teleoperation

. Powerful sensory system (especially 3-D vision) for better recognition of teleoperation environments.

. Wireless signal transmission to dispense with messy cables.

. Speedup of computational tasks for real time response.

V. CONCLUSION

Teleoperation is an essential element of radioactive engineering. Korean Nuclear Waste Management Project includes an R&D program to promote remote technology for radioactive waste handling in view of the performance and safety enhancement.

Power manipulator is still the widely used remote equipment in radioactive environment. Limitations of the power manipulator operation can be partially surmounted by better sensory instrumentation. Advanced vision system test in respect to the manipulator has demonstrated the possibility of improved dimensional perception by the operator. Ordinary hand tool grasp with the power manipulator hand was also demonstrated. Some associated R&D have been done as part of the program.

Future directions of the R&D program have been surfaced out from the test. They includes servosystem application, 3-D vision, wireless communication and high-speed real time computing.

REFERENCES

1. J.S. Lee, J.S. Yoon, '88 KAAC, Seoul, Oct. 21-22, 1988
2. D.M. Connah, C.A.Fisherbourne, Proc. 2nd Int. Conf. Robot Vision and Sensory Control, Nov. 2-4, 1982, Stuttgart
3. J.J. Kalk, Proc. of 34th Conf. Remote Systems Technology, 1986
4. J.S. Yoon, J.S. Lee, '88 KAAC, Seoul, Oct. 21-22, 1988
5. K.B. Bose "Microcomputer Control of Power Electronics and Drives" IEEE Press (1987)