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CONSOLIDATED FUEL-REPROCESSING PROGRAM

MASTER

DEVELOPMENT OF A STANDARD METHODOLOGY FOR OPTIMIZING REMOTE VISUAL DISPLAY FOR NUCLEAR-MAINTENANCE TASKS

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INTRODUCTION

The aim of the present study is to develop a methodology for optimizing remote viewing systems for a fuel recycle facility (HEF) being designed at Oak Ridge National Laboratory (ORNL). An important feature of this design involves the Remotex concept: advanced servo-controlled master/slave manipulators, with remote television viewing, will totally replace direct human contact with the radioactive environment. Therefore, the design of optimal viewing conditions is a critical component of the overall man/machine system.

Previous research with undersea[1] and space-related[2] remote viewing systems suggests that optimized closed-circuit TV systems are task-specific. Therefore, research is being performed at ORNL to design systems specific to fuel recycle tasks.

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METHODOLOGY

Specification of Generic Remote Tasks

An analysis of HEF design requirements produced five generic small volume dextrous tasks[3]. They involve transportation of end effector and remote tools, positioning, assembling, and dissembling functions. The tasks have been demonstrated at Los Alamos National Laboratory to be capable of being performed remotely using dextrous manipulators and closed-circuit television.

Simulator

A remote handling simulator has been constructed in the 7601 area of ORNL. An operator chair is placed in a lighted cubicle facing a TV monitor. The distance between the monitor and the chair is specified at four times the monitor height. A pair of master/slave M-8 manipulators are situated so that the master arms can be controlled while an operator is seated in the chair. The slave arms and task area, which are brightly lighted at 100-ft-lamberts, are separated from the operator by curtains and are visible only on the monitor. Tasks are performed on a worktable or adjacent walls. Television cameras are placed at prespecified locations in the slave area. Direct audio feedback is possible in that sound from the slave area can easily be heard by an operator in the master area. An automatic electric timer is started by initial movement of the task procedure and stopped by completion of the task. On task completion a green light appears on a board to the left of the monitor.

Task Visual Cue Requirements

Analysis suggests that tasks require differing visual information depending on the planes in which they are performed and on the specific remote tools, modules, and motions involved. Generally tasks are analyzed as to which X, Y, or Z plane depth cues are needed. More specific requirements are then stated in terms of acuity, juxtaposition, shadow, tool, and task and end effector positioning.

Design of Remote Display System

Placement of the TV camera in the slave area is specified in relation to task and end effector so that the necessary visual cues demanded by each task are provided. In some cases the optimal camera location in providing the visual cues necessary to the task may be disorienting to the operator; that is, the display deviates markedly from the eye's line of sight (directed straight ahead at the monitor, between the master arms). In these cases, a compromise may be reached by placing a camera in a position that provides fewer visual cues but is also less disorienting to the operator. Although camera position is a major emphasis, comparisons can also be made, using this simulator, between black and white, high-resolution and standard-resolution, and color systems.

Subjects

Subjects have been chosen from the experienced manipulator technician population at ORNL. All are male and none have previously worked with remote viewing systems. Measures are planned of possible task-related characteristics: height, weight, right- or left-handedness, work history, TV habits, sports activities, and mechanical interests. The subjects also undergo a thorough vision screening for acuity, phorias, depth, and color vision.

Experiment

The experimental design allows each subject to perform each task a stated number of times under each experimental condition. Those camera conditions that are statistically significantly related to performance enhancement can then be determined, as can any relationship between biographical information and performance. Learning control can be accomplished by various strategies:

1. Using only highly experienced manipulator operators to help minimize learning during the experiment;
2. Randomizing viewing conditions between subjects; and
3. Collecting baseline data throughout the experiment to provide a measure of any learning during the testing, which can then be accounted for in the final data reduction.

Subject Observations

Interviews with subjects should concern the following:

1. Speed vs. Accuracy. Experienced manipulator operators usually perform careful, precise tasks in a hot cell. Speed is of less importance than accuracy. Subjects should, therefore, be interviewed concerning any disadvantage they feel in having to work fast.
2. Display cues. Subjects should be asked the extent to which they are aware of using various display cues such as shadow, orientation to large scene planes, juxtaposition, and auditory feedback.
3. Fatigue. Subjects may have differing reactions to fatigue - some giving up, others continuing to perform.
4. Equipment variability. Subjects are more aware of manipulator and task aging and misalignment than the experimenter.
5. Motor memory. Some subjects may perform tasks using motor memory (i.e., memory of specific movements) rather than visual cues, as primary performance inputs.

RESULTS

The utility of this method has been demonstrated in that preliminary characterization of optimal closed-circuit TV systems has been specified for generic fuel recycle tasks. Generally, camera positions that do not deviate markedly from the line of sight in the sagittal plane, or that compensate for such deviation by providing spatial information about various surface planes (e.g., as with an offset view) are superior to positions that do deviate markedly from the line of sight (e.g., 90° above horizontal in the sagittal plane). The increased fine visual information on surface properties, boundaries, edges and shading, as provided by high resolution systems, has been shown to be important in tasks requiring precise alignments and positioning of end effectors and remote tools. Operator comments on the usefulness of sound information when a task is visually obscured (e.g., a "click" signaling that two task elements have been properly aligned) provide useful input to the placement of remote microphones in future systems. Operator comments on the use of shadow provide similar useful input to the placement of remote lighting.

SUMMARY

A methodology has been developed for optimizing remote visual displays for nuclear maintenance tasks. The usefulness of this approach has been demonstrated by preliminary specification of optimal closed circuit TV systems for such tasks.

REFERENCES

1. Smith, D. C., Cole, R. D., Merritt, J. O., and Pepper, R. L. *Remote Operator Performance Comparing Mono and Stereo TV Displays: The Learning and Task Factors.* Technical Report NOSC TR 380, Naval Ocean Systems Center, San Diego, Calif.

2. Freedman, L. A., Crooks, W. H., and Goans, P. P. *TV Requirements for Manipulation in space.* Mechanism and Machine Theory, 1977, 425-438.

3. Acid Fractionator Module Maintenance Task Procedures for Servomanipulator Application, Nuclear Systems Associates, N79-018AR11, Fullerton, Calif. (October 1979).