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THE DEVELOPMENT OF A SIX DEGREE-OF-CONSTRAINT ROBOT PERFORMANCE EVALUATION TEST

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ABSTRACT

A remote manipulator performance evaluation test was developed jointly by Stanford Research Institute and NASA Ames Research Center to test certain tool mating configurations not possible with the standard peg-in-hole type of test. The test attempted to evaluate robot manipulator (the Ames Arm) performance over a full range of six degrees of freedom of motion between a tool and its intended receptacle. The test consists primarily of four different tool geometries and three different receptacle geometries which provide for a progressive reduction in the degrees of freedom of motion, and a progressive increase in the degrees of constraint (DOC) over motion, between the tool and the receptacle. The manipulation times of actual tools (wrenches, screwdrivers) and couplings would be predicted by the times for the test tool most like it geometrically (with appropriate time allowance for the actual mating clearance). In addition, the influence of four different transmission delays was tested. The results indicate that tool manipulation time can vary by a factor of about four depending on the degrees of constraint over final tool positioning. The effect of transmission time delay is independent of the degrees of constraint and increased manipulation times for all DOC's by as much as an order of magnitude for a 3-second delay.

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ROBOT PERFORMANCE EVALUATION TEST

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A remote manipulator performance evaluation test was developed jointly by Stanford Research Institute (Hill, 1976) and NASA Ames Research Center to test certain tool mating configurations not possible with the standard peg-in-hole type of test.

The test attempted to evaluate robot manipulator performance over a full range of six degrees of freedom of motion between a tool and its intended receptacle. The test consists primarily of four different tool geometries and three different receptacle geometries which, in the combinations illustrated in Figure 1, provide for a progressive reduction in the degrees of freedom of motion, and a progressive increase in the degrees of constraint (DOC) over motion, between the tool and the receptacle. The manipulation times of actual tools (wrenches, screwdrivers) and couplings would be predicted by the times for the test tool most like it geometrically (with appropriate time allowance for the actual mating clearance).

The test was then run using the "Ames Arm" -- a standardized teleoperator manipulator which utilizes remote viewing through a stereo TV link. The tools were moved approximately eight inches from a "START"

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electrical contact to be positioned and inserted into one of the three shaped openings as appropriate. Separate times were recorded for the time from START to the first contact with the opening (TRANSPORT) and from first contact to a one inch insertion (POSITION and INSERT) into the opening. Four subjects performed five trials of each of the six degree-of-constraint tests, for each of the four transmission delays arranged in a latin square design. The resulting data are the mean performance times averaged over all trials of all subjects for each degree of constraint for each transmission delay.

The mean times for the complete motion (TRANSPORT + POSITION + INSERT) are shown in Figures 2 and 3. Figure 2 shows the effect of signal transmission delay on manipulation time for each of the six degrees of constraint, and Figure 3 shows the effect of various degrees of constraint on manipulation time for each of the four levels of transmission delays.

The results indicate that tool manipulation time can vary by a factor of about four depending on the degrees of constraint over final tool positioning. Therefore, this is an important characteristic to consider in evaluating remote manipulation performance.

Interestingly enough, the effect of transmission time delay is independent of the degrees of constraint. A 1/3-second delay results in manipulation times roughly twice as long as no delay, a 1-second delay produces manipulation times about four times as long as no delay, and a 3-second delay causes an order of magnitude change in manipulation times compared with no delay. Studies are continuing to develop a predictive display to offset the pervasive effect of the time delay on manipulation times and accuracies.

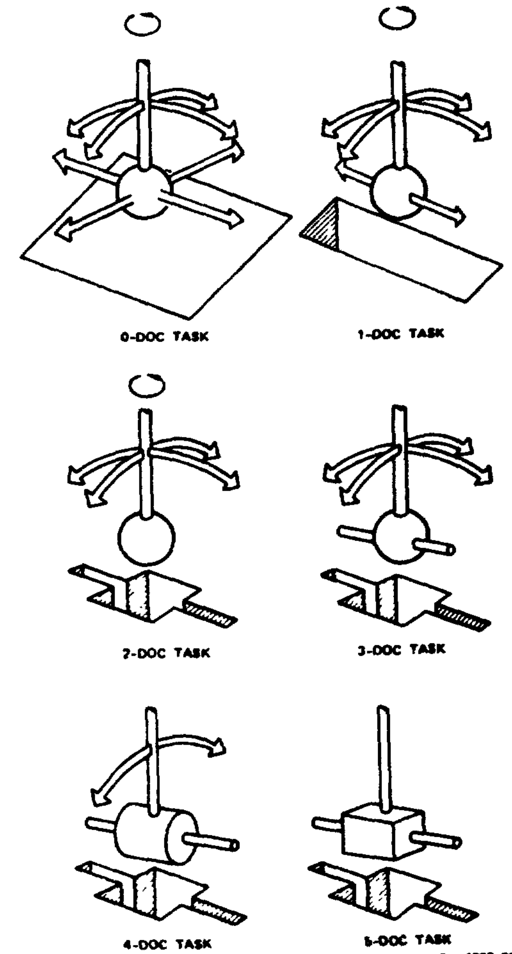

FIGURE 1: SIX TASKS FITTING TOOLS INTO RECEPTACLES

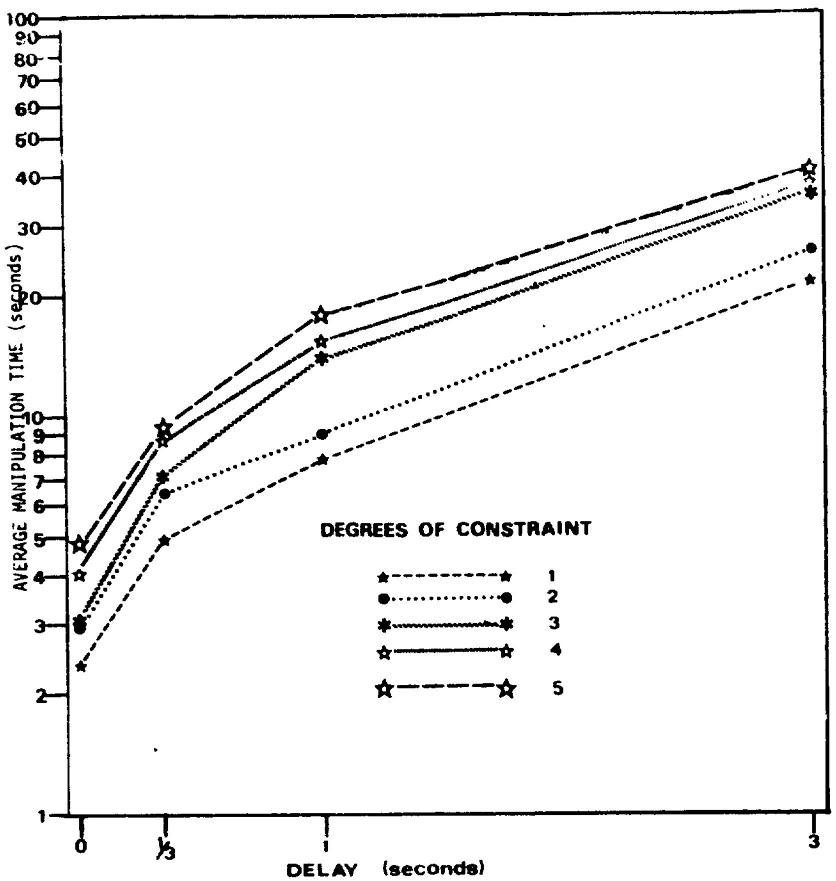

FIGURE 2: Remote Teleoperator Manipulation Time.
The average manipulation time for all 5 subjects as a function of the transmission delay is shown for each of the degrees of constraint over positioning the tool in the workplace receptacle. Manipulation time includes transport to the workplace, positioning, and inserting the tool in the receptacle.

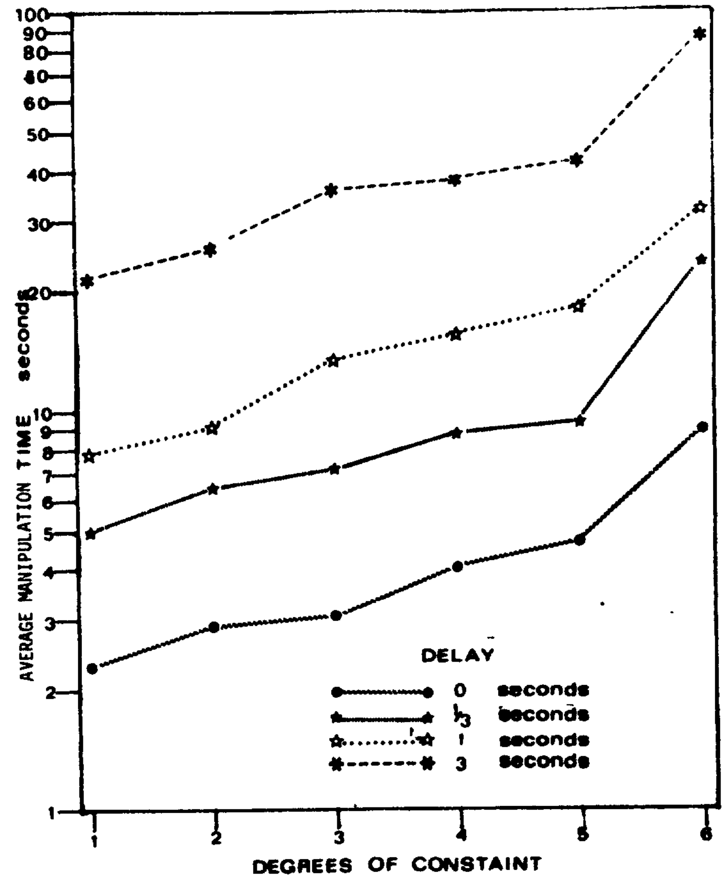

FIGURE 3: Remote Teleoperator Manipulation Time.
The average manipulation time for all 5 subjects as a function of the degrees of constraint over the final tool positioning is shown for each of the transmission delays. Manipulation time includes transport to the workplace, positioning, and inserting the tool in the receptacle.

REFERENCE

Hill, J. W., "Study to Design and Develop Remote Manipulator Systems" Annual Report 1, Contract NAS2-8652, SRI, Menlo Park, CA, July, 1976.