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STUDY OF DESIGN AND CONTROL OF REMOTE MANIPULATORS PART I

SUMMARY AND CONCLUSIONS

Daniel E. Whitney

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Engineering Projects Laboratory
Department of Mechanical Engineering
Massachusetts Institute of Technology

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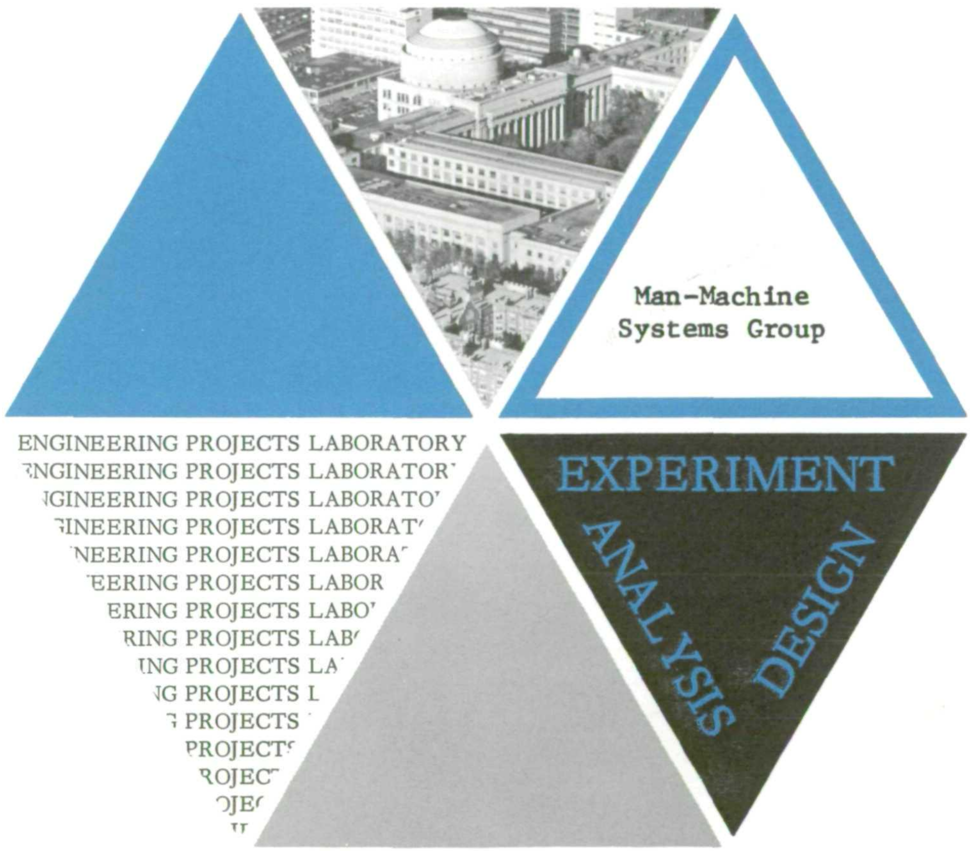

Final Report on NASA Contract NAS8-28055

Study of Design and Control of Remote Manipulators

Part I

Summary and Conclusions

by

Daniel E. Whitney
Associate Professor of Mechanical Engineering
Co-Principle Investigator

Prepared by Mechanical Engineering Department
Massachusetts Institute of Technology
Cambridge, Massachusetts 02139

For George C. Marshall Space Flight Center, NASA
Marshall Space Flight Center, Alabama 35812

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Summary and Conclusions

This is the final report on NASA Contract NAS8-28055, Study of Design and Control of Remote Manipulators. The long range objectives of this study are to extend theoretical understanding of the following kinds of design and control problems:

1. Static and Passive Dynamic Considerations in Manipulator Design

The mechanical design of a manipulator involves many considerations which affect its performance. An arm's weight, speed and power consumption are important variables. Design choices which affect these variables are choice of materials, type and location of actuators, kinematic arrangement, overall size and range of loads. The original goal of this part of the research was to determine the basic tradeoffs with respect to these variables. This in turn required formulation of a mathematical model of a manipulator. The formulation of this model has turned out to be the major effort. It is now complete and allows the following kinds of calculations to be made:

a) a manipulator of arbitrary size, shape, kinematic arrangement and materials can be specified

b) its stiffness can be calculated at the endpoint or between any pair of points in the linkage

c) stiffness attributes of joints can be included

d) lumped masses may be specified, to represent links, joints, actuators and loads

e) small motion vibration frequencies can be calculated.

This kind of information is valuable in determining load capacity, passive vibrations, overall weight and so on. Note that any manipulator will exhibit passive vibrations. The extent to which these are bothersome depends on desired speed of endpoint motion or endpoint accuracy.

A detailed report of this work is included as Part II of this report, bound separately.

2. Active Control by Man or Man-Computer Combination

The information gained in the above studies applies to passive (non-powered) arm motions. Here, however, we are concerned with long distance powered motions. A major problem is to generate efficient joint angle histories which take the arm from one point to another. If efficiency is measured in realistic terms like consumed energy, then a complex optimal control problem would in general have to be solved prior to each move. To eliminate this costly effort, an approximate method has been devised in which a relatively small number of typical arm motions is optimized. A table of these results can be used, with a simple interpolation formula, to find almost optimal joint histories for any other motion. Only a small amount of computation is required, and this can easily be accomplished by an on-board computer. Energy savings of 25% (compared with making no attempt to optimize) are typical.

A detailed report of these results was submitted with the third quarterly report on this contract in September 1972, under the title "Optimal Trajectory Generation for Mechanical Arms," by Johannes A. Iemenschot, and is considered to be Part III of this report.

Other problems of concern include active suppression of vibrations, generation of vibration-free nominal trajectories, design of the control station, and so on. Of these, the last is dealt with below while the others will be the subject of continuing study in the second year of this work.

3. Integration of Sensors, Sensor Control and Displays

This large topic was addressed only with respect to television viewing, where major issues are how best to provide visual presence to the distant operator with minimal expenditure of weight and energy. Alternatives include multiple television cameras, pseudo 3-D and other effects. The method by which the cameras or the monitors are maneuvered also is influential. The work performed this year indicates that some simple expedients, such as providing a second camera attached to the arm itself or making sure that reorientations of the camera are matched by reorientations of the monitor, can improve the speed of test manipulation tasks.

A detailed report of this work is included as Part IV of this report, bound separately.

Thomas B. Sheridan — Co-Principle Investigators — Daniel E. Whitney

Thomas B. Sheridan — Daniel E. Whitney