The MIT/Marine Industry Collegium
Opportunity Brief #29

Directions for MIT Research in Unmanned Underwater Work Systems

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SEA
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A Project of
The Sea Grant College Program
Massachusetts Institute of Technology
MITSG 82-4

The MIT/Marine Industry Collegium

DIRECTIONS FOR MIT RESEARCH IN UNMANNED UNDERWATER WORK SYSTEMS

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Revised Edition

July 15, 1982

Marine Industry Advisory Services
MIT Sea Grant College Program
Cambridge, Massachusetts 02139

Index No. NA 81AA-D-00069/A/M-2

PREFACE

This Opportunity Brief and the accompanying Workshop (held on March 5, 1982) were presented as part of the MIT/Marine Industry Collegium Program, which is supported by the NOAA Office of Sea Grant, by MIT and by the more than 90 corporations and government agencies who are members of the Collegium. The underlying studies were carried out under the leadership of Professor Thomas Sheridan and members of the Man-Machine Systems Laboratory in the Mechanical Engineering Department at MIT. The author is responsible for the synopsis presented herein.

Through Opportunity Briefs, Workshops, Symposia, and other interactions the Collegium provides a means for technology transfer among academia, industry and government for mutual profit. For more information, contact the Marine Industry Advisory Services, MIT Sea Grant, at (617)253-4434.

Norman Doelling

July 15, 1982

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1. An Invitation to Collaborative Research

While the needs for working beneath the sea increase, there has been no increase in federal and private funds available for research to improve capabilities for working underwater. At the same time, advances in telemetry, in digital control, in transducers for providing feed back, in supervisory control, in automatic control, and in microcomputers all tend to expand the range of interesting and relevant problems that deserve to be addressed. Given the rich range of opportunities and limited funds, those involved in research and applications should communicate more frequently and freely to avoid solving problems already solved by others, to avoid duplication of research efforts, and to achieve a better concensus on priorities for attacking the many potentially fruitful areas of research.

It is with this intention that the present workshop and this opportunity brief were presented. Industry participants benefit from an exposure to our research plans and the ideas drawn from a diversity of departments, disciplines, and laboratories at MIT. We benefit from an increased familiarity with the interest, needs and capabilities of the members' companies and government agencies.

This Brief describes only research being sponsored in whole or in part by MIT Sea Grant. The workshop addressed present and anticipated research in the Department of Mechanical Engineering, the Department of Ocean Engineering, and in the Artificial Intelligence Laboratory.

2. Current Research in Unmanned Underwater Vehicle Systems at MIT

The research programs in this area at MIT have been described in Opportunity Briefs 18 and 23. (MIT Sea Grant report #80-5 and #81-4). As noted in those reports, research at MIT is primarily supported by the Office of Naval Research and by the MIT Sea Grant College Program. These research programs work in close conjuncton with allied research programs at the Naval Oceans Systems Center (NOSC) in San Diego, California. The research programs at NOSC are supported by NOSC Independent Exploratory Development Funds, and the Research and Development Office for OSC Oil and Gas Operation of U.S. Geological Survey, and the Office of Naval Research. For the development of supervisory controlled manipulator systems, almost identical, compatible computer systems exist at both MIT Man-Machine Laboratory and at NOSC so that programs developed at one institution can be used at the other. Periodic visits by MIT research personnel to NOSC provide the necessary technology interchange activities. With these arrangements it is possible for MIT's laboratory research to be applied and tested at NOSC.

We have been working also with the ALVIN group at Woods Hole Oceanographic Institute to study easier, more energy efficient ways of piloting ALVIN safely.

2.1 Vehicle Simulation

Significant progress was made in this area during FY82. A rather sophisticated simulator is now available for use. Any one of a number of undersea vehicle types may be piloted in real-time by a human controller who can observe a computer-generated display of the ocean bottom. Vehicle hull dynamics, thruster capability, control systems, and sonar and other sensors are modeled and all can easily be modified. A number of control system evaluations have been done to show the effects of number and scanning rate of bottom sensors, strategy of thruster actuation (e.g. bang-bang continuously on, on-off with deadzone, continuous control with and without deadzone) on bottom-following accuracy and energy use. A full report on this simulator will be available shortly. H. Kazerooni has been the lead person in this effort.

Vaaler has been working directly with the ALVIN group at Woods Hole Oceanographic Institute designing an automatic bottom-following system for the ALVIN vehicle. At present, bottom-following is a frequent need, and it is done manually but extremely slowly and at great energy cost. The available autopilot is not sufficiently sophisticated. Vaaler is directly using the results from Kazerooni's simulation studies, and doing his design in view of sensor capabilities, expectation about bottom profiles and space and power requirements.

We expect to use our simulator not only to complete current control system design work for the Woods Hole ALVIN but also to evaluate controllability of other vehicle configurations, trade-offs with energy saving (critical where batteries are used for thruster power) etc.

2.2 Manipulator Systems

J. Raju has continued his work to demonstrate improved control techniques for force-reflecting and computer-controlled remote manipulation. He has some laboratory prototype equipment built and should be ready with an evaluation report in several months. During FY83 Raju should have a working demonstration of his improved digitally driven, force-reflecting manipulator servo-system using brushless D.C. motors. This is a basic technology improvement for electrical drive systems, which are relatively new in the undersea application because of their previous limitations on power.

Both C. Winey and D. Fyler completed Masters Theses (primarily under ONR support but partially supported by Sea Grant) which involved computer-graphic display aids to the operator of a remote work vehicle. Winey's contribution was to develop a dynamic "picture" of the manipulator arm which changes in direct correspondence to the operator or computer's control of it. This not only permits real-time, operator-in-the-loop simulation of arms (which would be extremely costly to build in hardware prototype), but also allows the operator to view the arm at any arbitrary orientation. Fyler used Winey's arm to develop a probing technique to discover and display shapes that cannot be viewed with remote TV, as in very turbid water.

2.3 Relative Motion of Manipulator Relative to Work Object

Following from the work of K. Tani, described in last year's proposal/progress report, H. Hirabayashi has completed a demonstration system using a "measurement arm", a passive and light-weight six-degree-of freedom arm the distal end of which can be attached to an object moving relative to the manipulator base, which has sensors but not motors. Movements of the joints of the measurement arm can be transformed by computer to tell the active manipulator's control system how the object is moving in six degrees of freedom. The manipulator can then automatically compensate for this relative motion.

2.4 Touch Sensing for Underwater Manipulators

One of the most vexacious problems in underwater manipulators is to provide the operator with some kind of tactile feedback information. In an underwater environment, electrical systems are particularly prone to damage and short-circuit. Last year, work was begun under a Sea Grant "seed project" to review the literature of touch sensing, to detemine the most promising approaches for underwater applications, to study and derive principles on which to design touch sensors, and to investigate ways in which information from these transducers should be processed and displayed in order to be meaningful to human operators.

An undergraduate thesis involved construction of a primitive fiber optic touch transducer. A master's thesis was begun by J. Schneiter who built a fiber optic transducer with a 10 x 50 resolution, which is sufficient to uncover some of the problems in light valving relative to a deformed surface. Meanwhile he has also begun work on the display problem, i.e. display both to a computer and a human operator. Some special computer boards have been purchased from Data Cube Corp. These allow reading pixel by pixel at high speed from video camera into a computer for further processing. Specification of these boards took several months, and now that they are available, efforts to develop a proper software interface has been developed which allows the information from the transducer to be displayed on a CRT or to be processed by the computer.

In all, progress is satisfactory, and we anticipate significant contributions toward the ability to do high-resolution, high-speed touch (pressure) gradient sensing under remote control at the end of an undersea manipulator or similar device. In principal, the technique could be used for dynamic differential deformation measurement on a larger scale as well.

REFERENCES

1) Cicciarelli, A., Fiber Optic Touch Sensor Devices for Telemanipulators, MIT SB Thesis, June 1981.

2) Deghuee, B., Operator Adjustable Frame-Rate, Resolution and Gray Scale Tradeoff in Fixed-Bandwidth Remote Manipulator Control, MIT SM Thesis, Sept. 1980.

3) Fyler, D., Computer Graphic Representation of Remote Environment Using Position Tactile Sensors, MIT SM Thesis August 1981.

4) Harmon, L. D., Touch-Sensing Technology, A Survey and Assessment, Informal Report, Case Western Reserve University.

5) Hirabayashi, H., Supervisory Manipulation for Assembling Mechanical Parts while Compensating for Relative Motion, MIT SM Thesis, June 1981.

6) Kazerooni, H., Real-Time Simulation of Underwater Work Vehicles, MIT Man-Machine Lab Report, in Progress.

7) Ranadive, V., Video Resolution, Frame-Rate and Grayscale Tradeoffs Under Limited Bandwidth for Undersea Teleoperation MIT SM Thesis, Sept. 1979.

8) Raju, J., MIT ScD Thesis in progress.

9) Schneiter, J., MIT SM Thesis, in preparation.

10) Tani, K., Supervisory Control of Remote Manipulation with Compensation for Moving Target, MIT Man-Machine Lab Report, July 1980.

11) Vaaler, E., MIT SM Thesis in progress.

12) Winey, C., Computer Simulated Visual and Tactile Feedback as an Aid to Manipulator and Vehicle Control, MIT SM Thesis, May 1981.