INTERNATIONAL COOPERATION IN ADVANCED ROBOTICS AT THE MECHANICAL ENGINEERING LABORATORY

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ABSTRACT

Existing international cooperation programs in advanced robotics at the Mechanical Enginnering Laboratory (MEL) such as Measurement, Analysis and Synthesis of Human Movement, Design and Control of Anthropomorphic Manipulator, and Real-time Robot Simulator are first described, and the future cooperation plan is shown based on the research activities at MEL. The topics of the future plan for international cooperation include such items as Intelligent Control of Robots (e.g. visual navigation of autonomous mobile robot), Rehabilitative Robotics, Tele-robotics, Simulation Technology in Robotics, and Bio-robotics.

1. INTRODUCTION

The current state of the robot can be realized as the mixture of three generations of robots, which greatly influence and interact with each other. The first generation, the playback robot with internal sensors, has already reached the stage of prevalence. The second generation, the adaptive robot with external sensors, has entered the stage of practical use. Reseach and development has begun of the third generation, the robot that will have communication functions.

At the Mechanical Engineering Laboratory (MEL) reseach and development are conducted toward the third generation (knowlege based) robotics and the next generation (intelligence based) robotics. In this paper activities on advanced robotics at MEL are outlined with special emphasis on international cooperation programs.

2. CURRENT STATUS OF THE INTERNATIONAL COOPERATION

2.1. International Collaborative Project on "Advanced Robotics" -International Advanced Robotics Programme (IARP) -

"Advanced Robotics" International Collaborative Research Project, which was originated from Versailles Economic Summit in June 1982 and is steered by the Joint Coordinating Forum (JCF), is the most formal international cooperation in advanced robotics at MEL. Japanese Large-scale Project "Advanced Robot Technology: ART JUPITER" (FY 1983-1990) is the domestic conterpart of the international project [1].

"One of the priorities for a healthy development of our society is to liberate human labor from harsh, demanding or dangerous working conditions or environments so as to provide a safe and pleasant environment in which people can work for worthy tasks [2]."

The "Advanced Robotics" International Collaborative Project aims at reserch and development of the technologies which enable "advanced robot systems that can dispense with human work for difficult activities in the aforementioned conditions or environments[2]." These technologies include (1) system architecture, (2) intelligence, (3) sensors, (4) man-machine systems, (5) mainpulation, (6) locomotion and (7) actuators.

At MEL research and development of the above technologies, especially, legged locomotion, bilateral manipulation, autonomous navigation, tele-existence and system evaluation technologies, are being conducted.

Progress has been achieved, not by exchanging agreements or the equivalent among paticipating countries, but by accumulating performance records based on the "Framework for Discussion [2]" agreed on at the first JCF at Tokyo in September 1983. Beyond the initial impetus of the Economic Summit Initiative, the cooperation is being continued as the "International Advanced Robotics Programme (IARP)".

To date cooperation has been effectively performed by means of information exchange, workshops, study missions and the preparation of joint site study.

2.2. Measurement, Analysis and Synthesis of Human Movement

Human movement provides excellent model for the control of mechanical systems. By establishing both real time measurement technology of human free movement and estimation technology of the physiological based musculoskeltal models, control scheme of human movement is analyzed. According to the analysis, new control method is sought for the cybernetic movement of the mechanical system. Design and control of anthropomorphic manipulator and real-time robot simulator are being studied as a part of this project.

This is between MEL and the Massachusetts Institute of Technology (MIT). This project is under consideration as a project based on the Agreeement between the Government of Japan and the Government of the United States of America on Cooperation in Research and Development in Science and Technology.

Tentative cooperation period is from April, 1987 throughMarch, 1992. This project can be expanded as a part of the Human Frontier Science Program.

2.3. Robot Mechanisms

The objective of the collaboration is to establish new design technology of robot mechanisms. Activity includes research programs concerning the development of dexterous joint mechanisms and finger mechanisms, and kinematic and dynamic analysis of robot motion.

This project is under consideration as a project based on the Agreement between the Government of Japan and the Government of Italy on Cooperation in Research and Development in Science and Technology.

2.4. Other Activities

Informal international cooperation activities are being conducted and/or being under consideration. These activities include the following countries and organizations but not at all exclusive.

Australia (The Austrailian Academy of Technological Sciences, The Austrailian Robot Association); France (CEA, INSERM, INRIA, LAAS, etc.); Mexico (The National University of Mexico); Norway (Helsinki University of Technology); United Kigdom (Oxford University, Cranfield Institute of Technology, NEL, etc.); United States of America (MIT, Stanford University, UCLA, CMU, University of Utah, etc.).

3. THEMES FOR THE FUTURE INTERNATIONAL COOPERATION

3.1. Legged Locomotion

Mechanism and control for legged locomotion robots have been studied, and several test hardwares have been designed and made [3]. Fig.1 shows a hexapod walking machine with decoupled freedom using an appropriate straight-line mechanism.

Dynamic technique to control legged machine that balnces itself as it walks or runs is one of the main foci of our current research.

3.2. Visual Navigation

Autonomous navigation using the area map and preregistered natural landmarks has been established through the extensive study on the Guide Dog Robot dubbed MELDOG [4,5,6]. Fig.2 shows general view of the guidance by MELDOG MARK IV. It travels from a starting point to a destination finding its route and avoiding moving and stationary obstacles on the way.

Visual navigation using two color TV cameras is now under study. For the first step, knowledge about the environment is given a priori to the robot.

3.3. Tele-robotics

There exist lots of working environment that are difficult for people or inaccessible to them. These include disaster environment, high temperature, radiation, high pressure, clean rooms, and remote places.

Man-intelligent-machine systems approach is one of the most promising ones when we use robots in the aforementioned cases. At MEL we are developing technology that can give people the sensation of being in a place other than where they are. The name "Tele-existence" is given to describe the concept and/or goal being achieved.

In the tele-existence system, the operator's body movement and force condition are measured in real time, and the internal conditions of the operator are estimated. These conditions are transmitted to the robot and directly control the motion-control circuit of the intelligent robot.

The robot controls its artificial eyes, neck, hands and legs, faithfully reproducing man's motions. At this time, all information from the artificial sense organs of the robot is transmitted to the corresponding sense organs of man by a high-fidelity display system with sensation of presence.

For example, if the operator looks in some direction intentionally, the robot also turns its face to the same direction and displays the image corresponding to the view the man would see if he were in the robot's location. When the operator brings his arm before his eyes, the robot's arm also will take the same position in its visual field. Therefore, knowing the relation of his arm to the object and the surrounding space, the operator can proceed with his work, relying only on normal, basic skills rather than on control-system specific ones.

The sense that a robot has when it touches an object is presented to the operator's hand as a stimulus to the skin, and the operator accordingly can perform his work having the sense that he touched it himself. Therefore, the skill with which the operator controls the robot and completes the task can be increased to a level equal to that of a man working inside the robot and ideally, to that of a man performing the work directly.

At MEL basic researches for the realization of Tele-existence have b
een conducted [7,8]. Fig. 3 shows general views of the experimental hardware system built.

The crucial subjects for reserch and development of Tele-existence include the following:

(1) Measurement or estimation of the motion and conditions of a human operator.
(2) Mechanism and control of an anthropomorphic robot.
(3) External information detection by artificial sense organs.
(4) Display of information with sensation of presence.
(5) Master assisting knowledge base.
(6) Augumentation of human ability.
(7) Supervisory control technology.

3.4. Other Themes

Efforts have been made toward the realization of the next generation robotics. The following themes can also be considered as the themes for the future international cooperation.

(1)Simulation Technology in Robotics (e.g., Real-time Solid Model Robot Simulator)

(2) Bio-robotics (e.g., Study on the Mechanism of Hand-eye Coordination, Design and Control of Anthropomorphic Mechanisms)

(3) Rehabilitative robotics (Guide Dog Robot MELDOG, Patient-care Robot MELKONG, Three-dimensional Wheelchair)

(4) Impedance Control

(5) Tactile Sensor

4. CONCLUSION

Current status and future prospects of international cooperation in advanced robotics at the Mechanical Engineering Laboratory are outlined from the standpoint of next generation robotics. Locomotion,

manipulation, sensor, intelligence, man-machine systems, and system architecture are typical research and development themes for the third generation robot.

The Japanese Government is launching the Venice Economic Summit based International Project of the Human Frontier Science Program (HFSP). Investigating the biological functions, and realization and artificial application of these functions are the ultimate purpose of the Program. Thus, understanding of the biological functions becomes quite meaningful.

At MEL human functions of senses and motor control are being investigated. Some of these studies will be adopted as a part of the international project of HFSP, which will be a great leap toward the next generation robotics.

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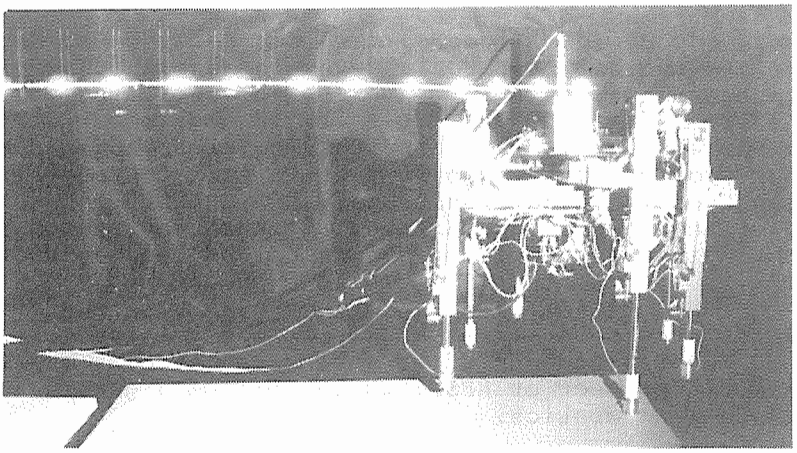

Fig.1 General view of the Experiment with Hexapod Walking Machine MELWALK III.

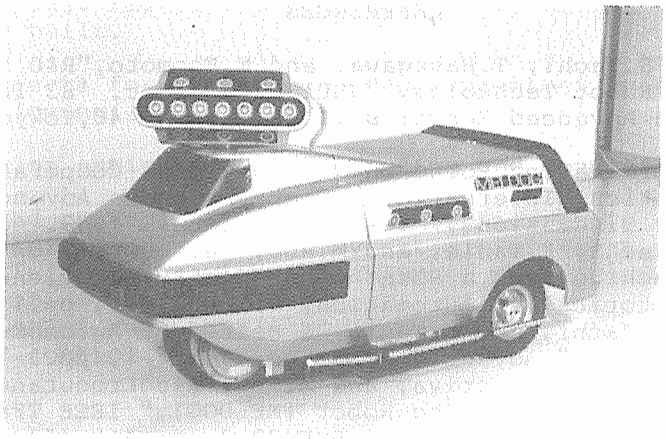

Fig.2 General view of the Guide Dog Robot MELDOG Mark IV.

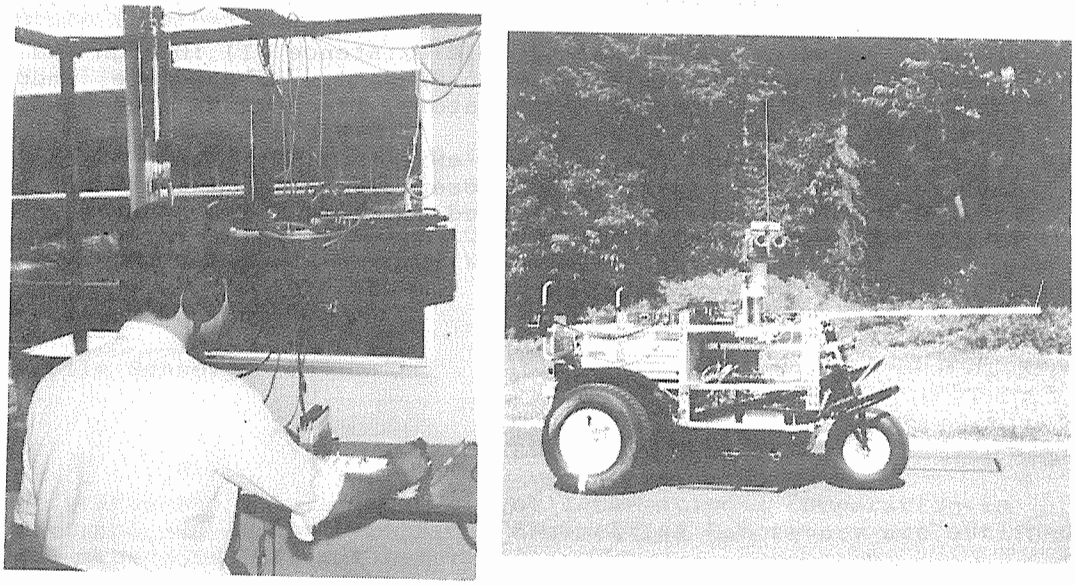

Fig.3 General view of the Experiments with Tele-existence Test Hardware.