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JAPANESE PROGRAMS IN ROBOTICS FIELD

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ABSTRACT: The present state of robotics in Japan is considered from the standpoint of evolution of robots. Also, the Japanese national robot projects are reviewed with special emphasis on the large scale national project of "Advanced Robot Technology" in hazardous environments. This project is considered to be the key link to the third generation of robotics. Since this project is expected to be successfully completed at the end of 1990, plans for the next generation of robotics are now being formulated.

EVOLUTION OF ROBOTS

When we consider the state of the robot in the 1980s and in the beginning of the 1990s, we realize that three generations exist which have greatly influenced and interacted with each other. The first generation, the playback robot with internal sensors, has already reached a state of widespread use and is both technologically and economically practical. The second generation, the adaptive robot with external sensors, has entered a state of technological operability, and is becoming more economically operable. Research and development of the third generation, i.e., supervised autonomous mobile robots, began in the mid-1980s and is now becoming technologically feasible (see Fig. 1).

Though robot applications have mainly been in manufacturing, application in other fields, such as construction, civil engineering and mining, has been investigated. Applications to primary industry such as agriculture, forestry and fisheries, and to tertiary industry such as transportation, distribution, services, atomic energy, and medical treatment and welfare, are under serious consideration. Among these applications, demand have been increasing for robots to undertake critical and hazardous work in very dangerous environments, such as in nuclear, ocean or disaster areas. Work in these areas is now performed by man.

In 1983, the Japanese Ministry of International Trade and Industry (MITI) started a large scale national project focusing on Advanced Robot

Technology. The eight year project is considered to be an important effort for third generation robots, and it comes to the final stage at the end of this year.

Several plans toward the next generation, e.g., space robotics, micro robotics, robots for natural disaster prevention and neurobotics, are being examined right now. From next year, Japan hopes to launch a new program toward the next generation of robotics.

ADVANCED ROBOT TECHNOLOGY IN HAZARDOUS ENVIRONMENTS

The "Advanced Robot Technology" project is an eight year project which started in 1983. It aims at establishing technologies necessary for the development of advanced robot systems capable of carrying out inspection, maintenance, emergency operations and other highly complex tasks in environments that preclude any direct human intervention because of high radiation levels, high water pressures or high temperatures.
Nuclear power plants, undersea operations and fire fighting/prevention are the three major areas of application, and both generic technologies and application specific technologies are being researched and developed.

Figure 2 shows the organization to execute the project. AIST (Agency of Industrial Science and Technology) which belongs to MITI is in charge of planning and coordination of the whole project. The two national laboratories, i.e., MEL (Mechanical Engineering Laboratory) and ETL (Electrotechnical Laboratory) are engaged in generic technologies, while the application specific technologies are being developed at ARTRA (Advanced Robot Technology Research Association), an association of private companies.

Generic technologies being studied at MEL and ETL are as follows:

(1) Legged Locomotion
(2) Dexterous Manipulation
(3) Vision
(4) Autonomous Control
(5) Tele-Existence
(6) Advanced Teleoperation
(7) Simulation

The application oriented research items being conducted at ARTRA are as follows:

A. Nuclear Power Plant Robot

i) Total system for the experimental robot
ii) Optical wireless communication system
iii) Movement (a: Quadruped motion system, b: Actuator, c: Locomotion-on-wall)
iv) Manipulation (a:Manipulator, b: Actuator, c: Tactile sensor)
v) Vision (a:Binocular vision, b:3D vision system using motion stereo and spherical mapping)

B. Undersea Robot

i) Total system for the experimental robot
ii) Movement (a: Motion control, b: Variable vector propellers, Fiber optic gyroscope, d: Attachment legs)
iii) Manipulation (a: Manipulation system, b: Seawater hydraulic actuators)
iv) Vision (a: Acoustic imaging

system, b: Three dimensional position detecting system, c: 3d location measurement)

C. Fire Fighting/Prevention Robot

i) Movement (Six leg/wheel hybrid locomotives)
ii) Manipulation
iii) Middle range laser vision
iv) Short range ultrasonic vision

The aggregate R&D capital investment will amount to approximately ¥ 15 billion (see Fig. 3).

The project approaches the final stage at the end of this year. In the fy. 1988, interim evaluation was conducted, and most of the basic research for the robots in the three fields (nuclear power plant, undersea and fire fighting) had been finished. In addition, detail design and fabrication of the experimental robots, which will be used in the feasibility study, had been started.

In October, 1989 and in June, 1990, ETL and MEL demonstrated generic technologies of the third generation of robotics, respectively.
An experimental nuclear power plant robot and an experimental undersea robot for feasibility studies are now under construction by ARTRA. They will undergo testing and the feasibility of the technology will be demonstrated in the middle of December in 1990.

INTERNATIONAL ADVANCED ROBOTICS PROGRAM (IARP)

At the Versailles Economic Summit in June 1982, it was agreed that further international scientific and technological cooperation would be required for the revitalization and growth of the world economy. In support of this, the "advanced robotics" project was initiated together with 17 other projects. Progress reports on these projects were made at subsequent Economic Summits, and a final report at the summit level was submitted at the Tokyo Economic Summit in May 1986.

In keeping with the original intent of the Economic Summit, the continued pursuit of the "Advanced Robotics" project as the "International Advanced Robot Program" was unanimously approved by all countries attending the 5th Joint Coordinating Forum (JCF) held in Hawaii in April, 1986.

The objective of the program is to encourage development of advanced robotic systems that can perform the work of humans in harsh dangerous environments, and contribute to the revitalization and growth of the world economy.

The activities include holding JCF and workshops, exchange of study missions and researchers, and implementation of joint site studies.

Member countries are Austria, Canada, EC, France, Germany, Italy, Japan, United Kingdom and United States.
Japan serves as Secretariat.

The area of international cooperation consists of both application fields and elementary technologies. The former includes nuclear power, underwater operations, fire fighting and rescue operations, agriculture, mining and tunnelling, civil engineering and construction, domestic services, space and medical and health care. The latter includes intelligence, sensors, man-machine systems, manipulation and locomotion.

INTELLIGENT MANUFACTURING SYSTEM (IMS)

Changes in today's social environment are giving rise to a number of problems that could threaten the foundation of the manufacturing industry in the advanced industrialized nations. One of these is an outright shortage of skilled workers and technicians. Adding to this, workers are aging and becoming better-educated, and many are leaving the manufacturing industry for jobs in the tertiary sector because of its more attractive working conditions.

In view of this situation, it is urgent to make manufacturing industry a more attractive field to ensure its healthy development in the world economy.

Japan decided to take initiative in developing new technologies and sharing the results with other countries, and has proposed the establishment of a joint international research program for developing a manufacturing system aimed at the 21st century for global use.

In the project's initial year, beginning April, 1990, an international Committee, which is made up of leading researchers and experts in the field of production technologies from Japan, North America and Europe, will be formed to discuss the details of the project and how best to carry out the program's goals.

The Japanese government has also agreed to participate, and a budget of approximately 110 million yen has been set aside by MITI to cover expenses for the international Committee meetings.

The total budget for ten years is expected to be ¥ 150 billion from Japan, the U. S. and Europe.

HUMAN FRONTIER SCIENCE PROGRAM (HFSP)

This international program was proposed at the Venice Economic Summit by Japan. It is aimed at promoting, through international cooperation, basic research on biological functions, i.e., the elucidation of brain functions and molecular functions.

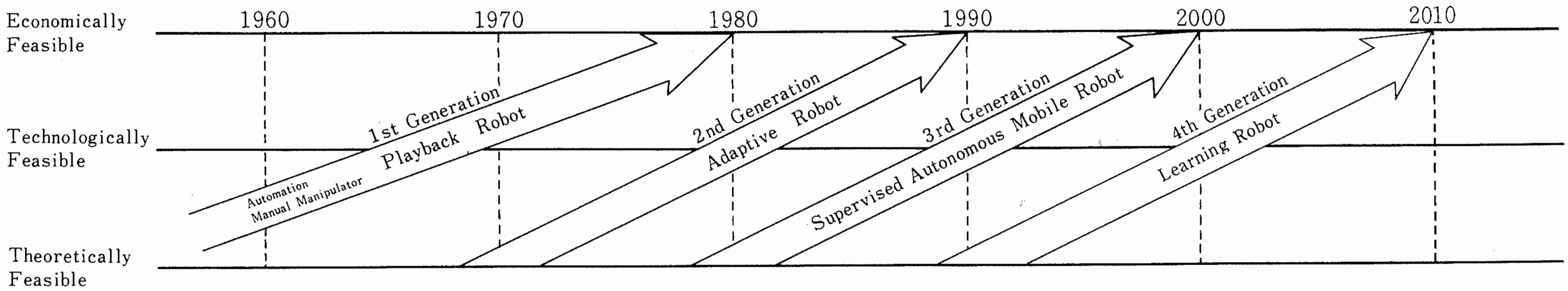
The former research includes perception and cognition, movement and behavior, memory and learning, and language and thinking. Although this program does not have any application in mind, the results can be used for the basis of the next generation of robotics.

TOWARD THE NEXT GENERATION OF ROBOTICS

The large scale national project toward the third generation of robotics, i.e., "Advanced Robot Technology" program, will end in December, 1990. Because it is quite certain that the generalized technologies for the robots in hazardous environments will be established by then, it is high time to step further.

We are now planning several robotics programs for the next generation, which include space robotics, micro robotics, robotics for natural disaster reduction, and neurobotics.

We hope to launch a new program toward the next generation of robotics from next year.



		1st Generation	2nd Generation	3rd Generation	4th Generation
Brain Fnnction	Intelligence	a priori [inborn] (play back)	adaptation, accomodation	inference, problem solving	a posteriori [acquired] learning knowledge base
	Knowledge	data	date base	knowledge base	neural network
Sensor Function	Internal Information	exist	exist	exist	exist
	External Information	none or point	1–D, 2–D (structured environment)	3–D (structured natural environment)	3–D (unstructured environment)
	Communication	unilateral (teaching, tape)	interactive (robot language)	bilateral (supervisory control, tele-existence)	autonomous bilateral (natural language, communication between robots)
Effector Function		position control (static) 1–D (guide cable)	position control (dynamic) 2–D (plane guided)	force control (dynamic) 2–D (uneven autonomous) ;3D (stairs free space)	coordinated control (dynamic) 3–D
Application Fields		Secondary Industry (Manufacturing Industry) [Material Handling Painting Spot Welding]	Secondary Industry (Manufacturing Industry) [Arc Welding Assembly]	Secondary Industry (Non-Manufacturing Industry) Primary Industry Tertiary Industry [Inspection Maintenance]	Secondary Industry (Non-Manufacturing Industry) Primary Industry Tertiary Industry
Technological Characteristics		Internal Sensor + Servo Technology	External Sensor + Microprocessor Technology	Knowledge Processing + Man-Machine Interface Technology	Learning + Simulation with Artificial Reality

Fig. 1 Generations of robots and their features

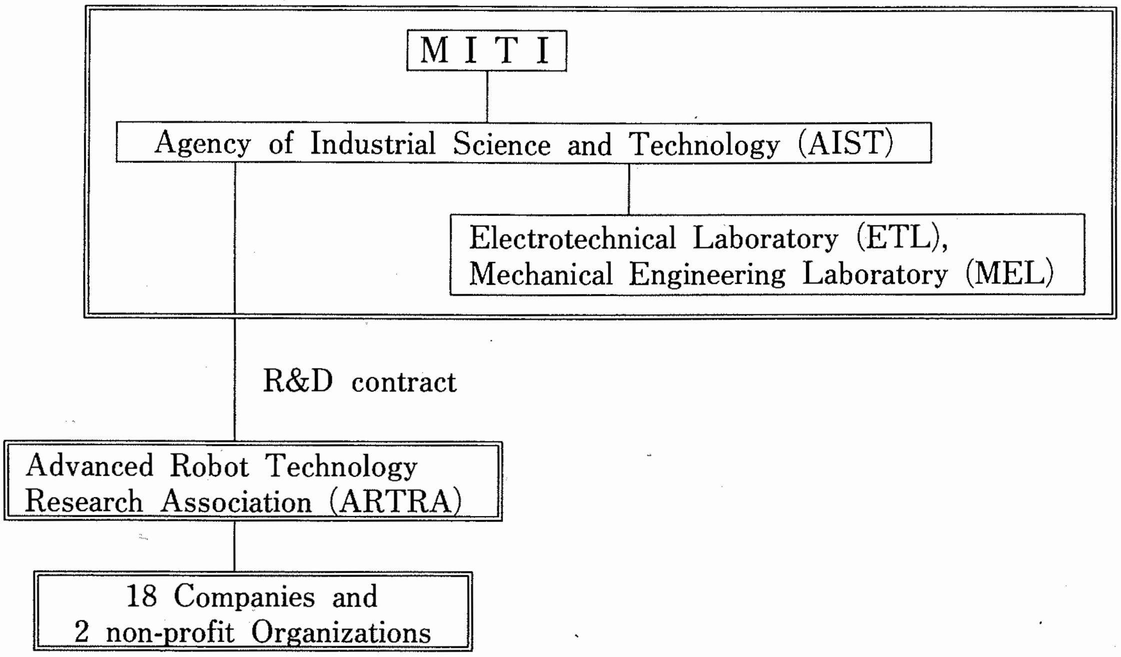
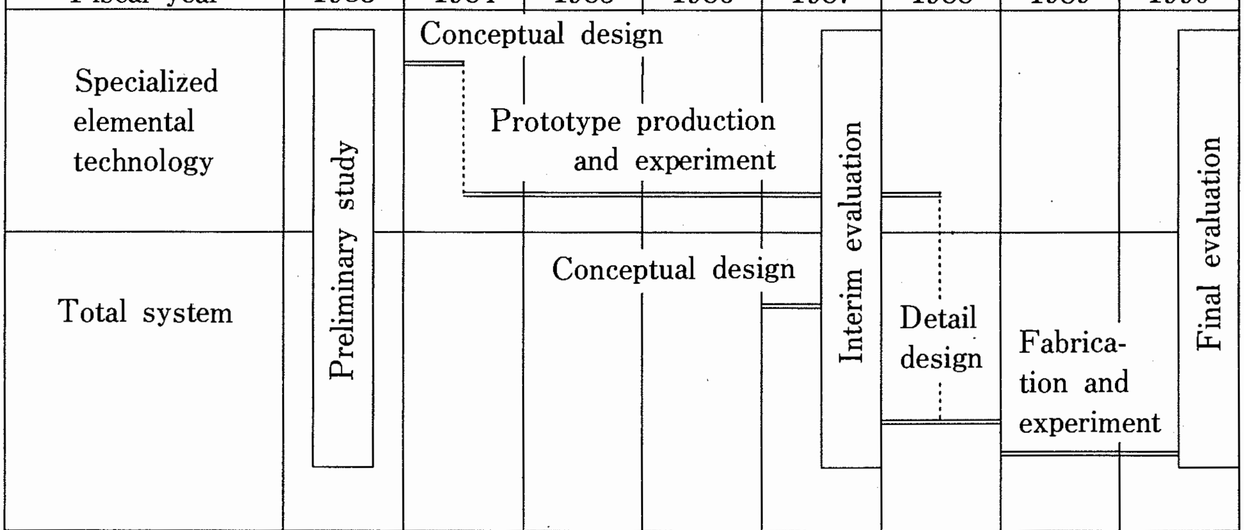


Fig. 2 Organization of "Advanced Robot Technology"project

(Unit : million yen)



Fiscal year	1983	1984	1985	1986	1987	1988	1989	1990
Fundamental tech.	40	319	406	368	351	291	269	217
Nuclear robot	0	465	814	1,000	1,131	1,182	1,200	1,090
Undersea robot	0	0	512	732	648	756	906	792
Fire fighting robot	0	0	165	304	295	251	300	380
Total budget	40	784	1,896	2,405	2,425	2,479	2,675	2,483

Fig. 3 Schedure and budget of the program