Robots—Flexible & Intelligent Manufacturing Systems

By Nozawa Ryoichiro

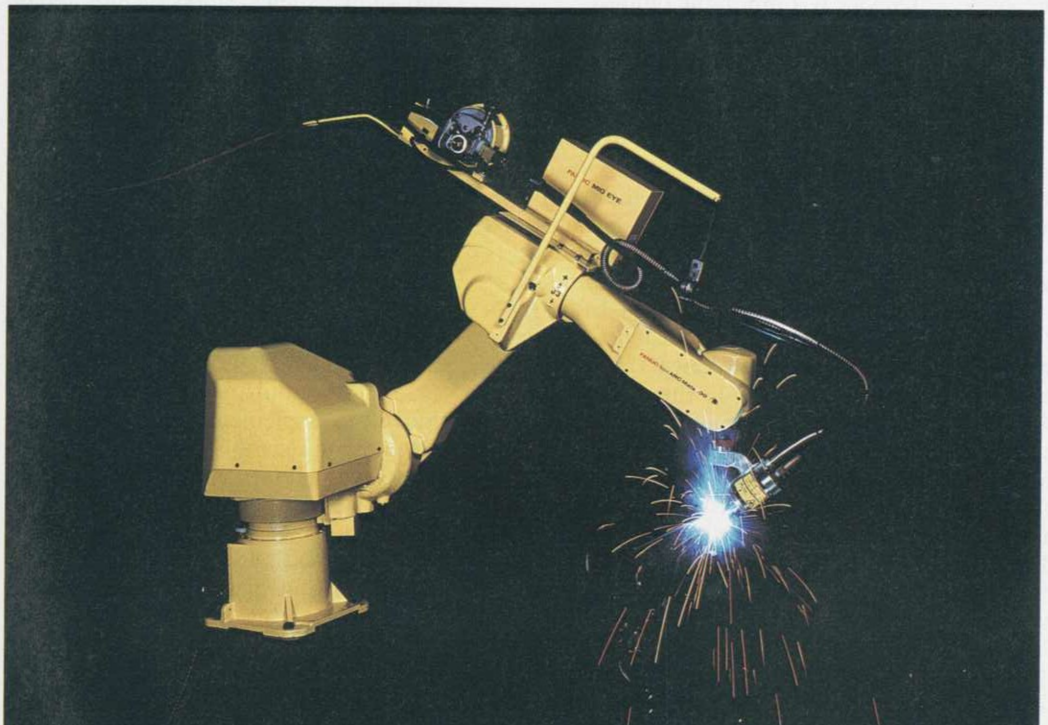
With the flight of young workers from the so-called "3K" (*kiken, kitanai, kitsui*—dangerous, dirty, difficult) jobs, a shortage in the skilled workforce, and a larger than average percentage of the population over the age of 60, Japanese industry is confronted with inescapable labor problems. Robotics is not merely a technician's dream, but a technology that provides solutions to the labor shortage and environmental problems, and it is thought that the demand for robots will continue to grow.

Beginning with the rapid acceptance of robots in the automation of automobile production lines in the early 1980s, this technological advancement swept across a wide spectrum of other manufacturing sectors. This development has not only sought a supply of robots, but the production of robot systems that utilize hands and fixtures, along with visual, force and other sensory equipment.

Robot systems must have the ability to adapt to external surroundings as well as to perform processing tasks. For example, one type of robot system has visual sensors which measure the rough location of a car body on a manufacturing line with high precision, accurately tracing the body's seal lines and then emitting an appropriate amount of sealant from a nozzle at a speed that matches the robot's operating speed. A high quality automatic arc welding robot system (shown in the photo on this page) has a laser sensor attached to the torch that tracks the seams and makes automatic adjustments. In both of these systems, robots equipped with visual sensors are able to execute sophisticated tasks in conformity with their exterior surroundings, while carrying out high quality processing.

Robots with programmed intelligence are being built and they can accomplish tasks on par with skilled workers, enabling robots to be applied to a broad variety of sectors. With high performance robot controllers, made possible by rapid advances in electronics technology, robots will be able to control their mechanical tasks with high speed and precision. Mechanical arm mathematical models are contained in digital servo-loops and the precise control technology that estimates, measures and suppresses mechanical arm vibration is already being applied.

Vibration suppression control has led to great improvements by electronically boosting the rigidity of mechanical arms, giving robots a precise loci of movements, and reducing cycle time through efficient movements. Electronic rigidity improvements also reduces mechanical arm weights and along with enhanced operation capacity plays a major role in cutting costs. This is the fruit of electro-mechanical technology, a high-level fusion of electronic and mechanical technologies.



Arc welding robot with laser seam tracking sensor

A new technological trend involves the use of "multi-robots"—a single robot controller operating two mechanical arms, working together like human arms, which are able to handle tasks dexterously. The industry's future goal is the introduction of robots that truly possess the working capacity of skilled workers, an advance made possible by the further integration of high-level electro-mechanical technology, intelligent sensors and artificial intelligence (AI).

Utilization of robots on a national and corporate level is also expanding in the midst of worldwide globalization. Companies that have internationalized also possess development, manufacturing, sales and service locations overseas and, as they effectively utilize capable personnel and financial resources, they are proceeding with horizontal labor divisions in their operational allocations. Cosmopolitan production expansion will develop robot systems in accordance with international market needs and in today's smaller world it is hoped that international cooperation can be strengthened so that robots can contribute to all of humanity. This also fits in with the goals of the Intelligent Manufacturing System (IMS) Program which I will discuss later.

IMS Program Test Cases

1. **Clean manufacturing in the process industry**
   Designed to offer fundamental solutions for environmental problems in the chemical, petrochemical, paper and pulp and other process industries
2. **Global concurrent engineering**
   Create an overview designed to deal with development, design, and performance verification and each manufacturing process both simultaneously and in parallel
3. **Globeman 21: Enterprise integration for global manufacturing in the 21st century**
   Creates models of production environments for each stage from design through manufacturing and the implementation of hypothetical models
4. **Holonic manufacturing systems**
   Attempts to develop autonomous manufacturing modules. "Holon" is defined as an intellectual, autonomous cooperation medium
5. **Rapid product development**
   Reduce the time required for product development while holding development costs down
6. **Gnosis: Knowledge systematization for design and manufacturing**
   Systematize the manufacturing and design knowledge and know-how that veterans possess and create a database that can be accessed by anyone

Flexible manufacturing systems

Manufacturers are confronted with a challenging environment: the maturation of domestic markets, diversification in customer needs, and increasingly ephemeral product life cycles. In order to survive inter-company competition with the high yen and trade friction in export markets, companies are trying to cut costs, shift to high value added products and reduce delivery time. So a high level of flexible manufacturing systems (FMS) have been introduced to boost production capacity. Machinery plants in particular are confronted with a series of problems, so demands for improved productivity are increasing.

In the FMS shown in the photo on page 13, machine tool units are consolidated to enable the production of similar groups of manufactured articles, combining automatic transport, storage and cleaning in a FMS that consolidates production control. This system makes possible 72 hours or more of unmanned operations over weekends or holidays and remarkably boosts productivity. Robots, for example, are actively employed in deburring and cleaning holes, making it possible to qualitatively reduce the work force. Workers are also able to accomplish a higher level of work and this shift to intelligent operations has improved productivity.

Japan has introduced the highest number of flexible manufacturing systems. However, those in existence are only able to cope with aspects for which they have been programmed, limiting the use of automation and unmanned operations. The practical application of knowledge engineering and AI requires the introduction of intelligent manufacturing systems (IMS) that could change the face of FMS in the future.

Intelligent manufacturing systems

The IMS Program, a project that seeks to harmonize humans, machines and their environment in the future factories of the 21st century, has attracted close attention. Its basic parameters were presented at the 1989 Ministry of International Trade and Industry's Factory Automation Vision Conference chaired by Yoshikawa Hiroyuki. The following April, the International Robotics and Factory Automation Center was established within the IMS Promotion Center. Since its inception, the IMS Program has emphasized collaborative international research, and responses from Europe and the U.S. laid the groundwork for the first tripartite meeting between the EC, Japan and the U.S. held in Brussels in May 1990. There an agreement was reached to establish IMS as an inter-governmental, cooperative program.

Subsequently, in December 1991 a secretariat-level meeting was held in Switzerland to implement a feasibility study that would be promoted by six parties—five European Free Trade Association (EFTA) countries, Canada, and Australia joining the EC, Japan and the United States. Fundamental agreement upon the terms of reference was also reached, the organization of each member's international committee was decided upon, and in February 1992 the first international steering committee (ISC) was convened in Toronto. The intellectual property rights guideline modalities, and technical guidelines for the feasibility study were decided upon at the second ISC meeting and participants in international test cases were sought. Eleven projects were proposed and in January 1993 the international steering committee selected six and moved to implement them. The Kyoto Declaration regarding fundamental IMS ideals was adopted at the fourth international steering committee meeting in Kyoto in April 1993.

At the sixth ISC meeting held in Hawaii in January 1994 the results of the two-year feasibility studies were evaluated and it was agreed to formally move to a full-scale, 10-year IMS Program. It was also decided that a review would be undertaken in the seventh year.

Flexible manufacturing system

IMS Program's Objectives

A. To enable greater sophistication in manufacturing operations;
B. To improve the global environment;
C. To improve the efficiency with which renewable and non-renewable resources are used;
D. To create new products and conditions which significantly improve the quality of life for users;
E. To improve the quality of the manufacturing environment;
F. To develop a recognized and respected discipline of manufacturing which will encourage the transfer of knowledge to future generations;
G. To respond effectively to the globalization of manufacturing;
H. To enlarge and open markets around the world; and
I. Advancement of manufacturing professionalism worldwide by providing global recognition and establishing an educational discipline for manufacturing.

On a global scale

International cooperative IMS research is based upon the guiding principle that "the contributions from joint research and the benefits derived should be equitable and balanced." This means that participating partners can profit from the results of other partners' research, but at the same time everyone is obliged to make equal contributions.

The full-scale program will commence with six partners. Research will be conducted in three regional locations and after assembling corporate, university, and public research organization partners and setting up an international consortium, research and development will be divided up among the regions. R&D funds will be allocated to each region, and the consortium partners will be able to use newly derived R&D results and intellectual property rights free of charge (with some exceptions). Further, the IMS administrative organization will be executed by the international steering committee, inter-regional secretariats, and regional secretariats.

Separate from these international activities, preliminary research to advance IMS is being conducted in Japan where the organization to promote the IMS Program is already in place. The IMS Program is a systematic trial without precedent that will attempt to effectively utilize personnel, physical and monetary resources on a global scale through collective international ownership of research results and intellectual property rights pertaining to manufacturing technology. As noted above, moves toward full-scale research can now be said to be underway.

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