# AI Technology in CIM

Shigeharu Kawai
Jun'ichi Kuroe
Kenzo Sugai

## 1. Introduction

As consumer needs have diversified, CIM has been introduced into manufacturing industries. As a result, automation of facilities represented by FMS has advanced further and more information has been integrated through the use of computers than ever before.

In the future, CIM will be required to materialize an intelligent manufacturing system through the efficient utilization of acquired data for diverse purposes. To achieve this goal, it is expected that AI technology will be applied to CIM.

In response to demands to widening the scope of automation in manufacturing systems, Fuji Electric has introduced AI technology intended to enhance the efficiency of rule-based processing by allowing easy processing by the field operator. In order to expand this effect over the entire range of CIM, AI technology is now being applied to manufacturing control systems to realize intelligent manufacturing control systems. This paper introduces the present state of AI technology in CIM, the concept of AI-based intelligent manufacturing control systems, and application examples of actual system.

## 2. Fuji Electric's Approach to AI Technology in CIM

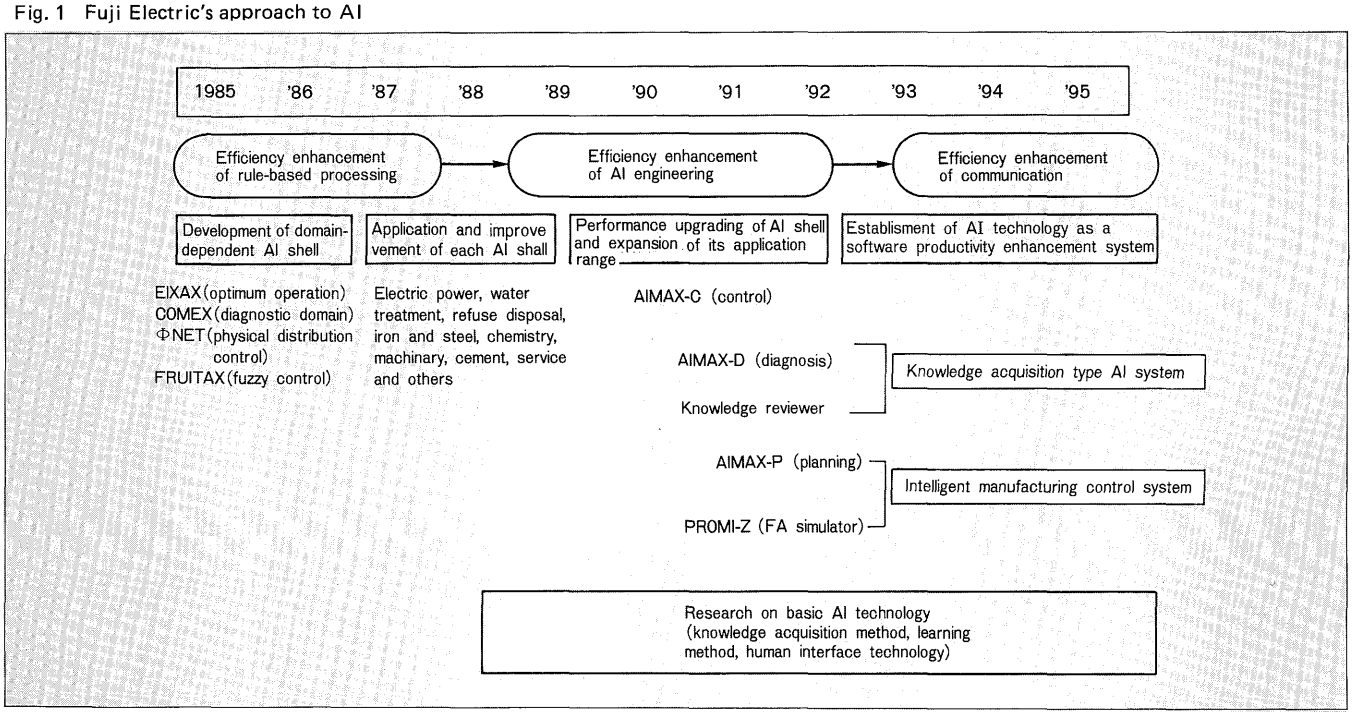
Fuji Electric's approach to AI technology in CIM is shown in **Fig. 1**.

### 2.1 Development of domain-dependent AI tool

The AI boom arose circa 1985 and a number of general purpose AI tools have been announced. Fuji Electric has judged that a bottom-up approach from the field would be effective for incorporating AI technology into system configuration technology, and has developed the following domain shells which can represent field know-how in an easy to understand way.

(1) EIXAX oriented for optimum operation
(2) FRUITAX oriented for fuzzy control
(3) COMEX oriented for diagnosis

Fig. 1 Fuji Electric's approach to AI



(4) ΦNET oriented for physical distribution control

By utilizing these AI shells, Fuji Electric has developed expert systems for iron/steel, cement, automobile, water treatment, chemistry, petroleum, foodstuff and other industries, while accumulating AI application technology know-how.

From experience in AI applications, Fuji Electric has come to recognize that speed of inference, ease of knowledge acquisition/arrangement and readiness of system configuration are key factors. The AIMAX series developed by Fuji Electric is a new AI tool with improvements to these key factors. The AIMAX series employs a knowledge representation system compatible with the aforementioned AI tools, in which the tools are translated into a FORTRAN program and then executed. Fuji Electric has developed three domain-dependent AI tools enumerated below.

(1) AIMAX-C oriented for control
(2) AIMAX-D oriented for diagnosis
(3) AIMAX-P oriented for planning

The AIMAX series, with its newly added function "knowledge reviewer", achieves a high efficiency in engineering tasks such as the preliminary arrangement of user' know-how, and verification and adjustment of the knowledge base.

## 3. Advance to Intelligent Manufacturing Control System

To upgrade the intellectual level of manufacturing systems, not only is there a need to expand the area of automation in manufacturing, but also man-machine interfacing and communication must be facilitated. In order to achieve this, it is essential to develop a knowledge acquisition type AI system which acquires and arranges field expert knowledge and to develop an intelligent manufacturing control system which operates in linkage with object-oriented modeling and data base technology, to express the knowledge in common terms, and OR technology for theoretical optimization as shown in **Fig. 2**.

### 3.1 Linkage with object-oriented technology

To make AI technology user-friendly and standardize knowledge, the concept of object orientation is introduced into the system detailed below. A manufacturing control system based on global information is realized through linkage with AIMAX-P.

(1) Production system modeling and simulation

Production system components and product functions are defined as objects which include data and methods. The objects are combined to model the production system. PROMI-Z, a precursor of this concept, has been developed as a tool that supports production simulation and scheduling.

(2) Production system database

Through introduction of an object-oriented data base into the manufacturing control system, the data base is designed so as to be flexible enough to allow easy reference by people from the different divisions of design, production engineering, production control and manufactutring, and to respond to changes in equipment and product promptly.

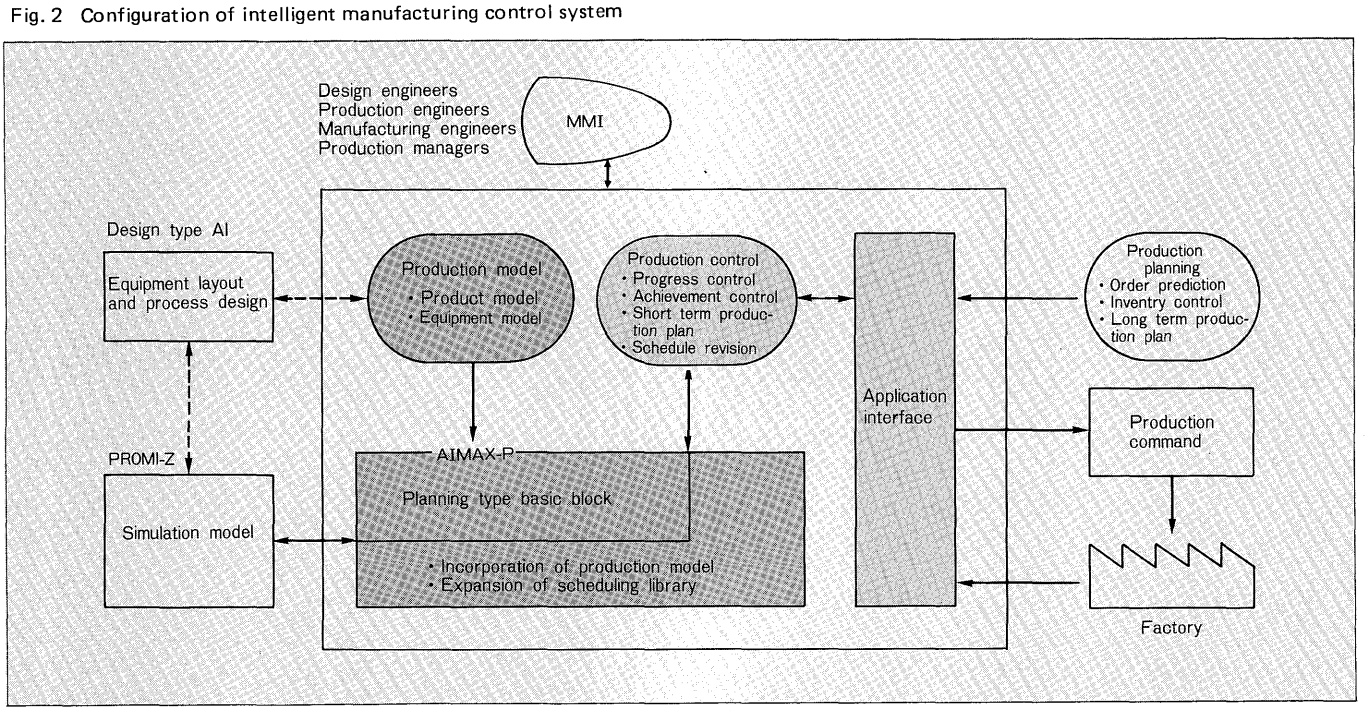
(3) Man-machine interface (MMI)

A human interface, which inputs knowledge via icons and evaluates a production system visually through use of animation, has been developed to make AI more accessible by field engineers.

### 3.2 Scheduling expert system linked with OR technology

In production scheduling, optimization techniques

Fig. 2 Configuration of intelligent manufacturing control system



such as mathematical programming have been attempted, but practical application has been difficult because of the many restrictions imposed. New methods such as SA and GA have been applied in a limited area. These algorithms are effective for the partial solution of problems and can best be utilized with the aid of user know-how. AIMAX-P is supported with a library of OR technology. By calling the library as a function in rules, coordinated scheduling of user know-how and OR technology is possible.

## 4. AI Technology in Assembling/Machining Production System

Production in manufacturing industries which engage in the assembly and machining of automobiles, electronic equipment, machine tools, etc. is more diverse in type and fewer in quantity than other industries in the same category. In these industrial fields, it is important to control the part composition data base for an extremely large number of products and to schedule the production to be carried out under strict guidelines as stipulated by JIT. A manufacturing control system for an automobile industry assembling/machining line is introduced in **Fig. 3**.

(1) Production model

(a) Part configuration database (product model)

This data base consists of information about the parts themselves and set information about the part configuration. In the information about each part, the hierarchical structure of the entire part is modeled through the link structure using objects.

(b) Production line configuration data base (equipment model)

Information encompassing different production processes, information about products to be manufactured in each production process and in-process information during operation are represented by use of objects as in the product model.

These data bases allow retreievals which use parts and lines as keys. Data structures are compatible with the operational forms such as in-process work and current arrangement. Furthermore, data can be added, corrected or deleted in response to model changes without revising the program.

(2) Production plan

The quantity of parts to be produced in each process for the production plan of a particular product is calculated by using the production model data base.

(3) Charging order plan

It is desirable to make a charging order plan in each process so that the production ratio will become constant. The plan must satisfy various restrictions such as a limited equipment buffer, minimized worker wait time, avoidance of tools shortage and implementation of machine trouble-shooting. To cope with this, rules constructed from the production engineers' know-how are used together with a constant production ratio algorithm..

This system will have the following merits.

(a) Data bases referred to by production and manufacturing engineers can be unified so that users in both production and manufacturing divisions can retrieve data.

Fig. 3 Configuration of assembling/machining line control system by AIMAX-P

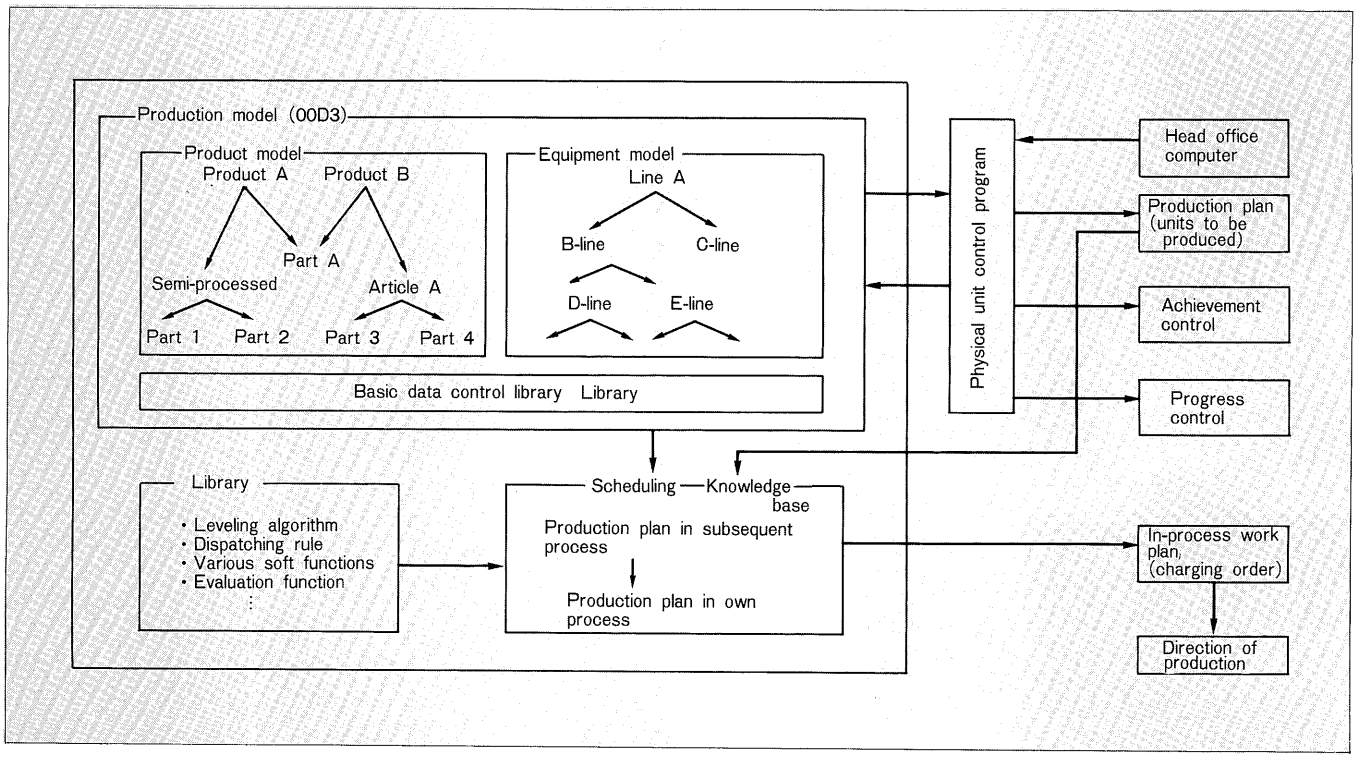
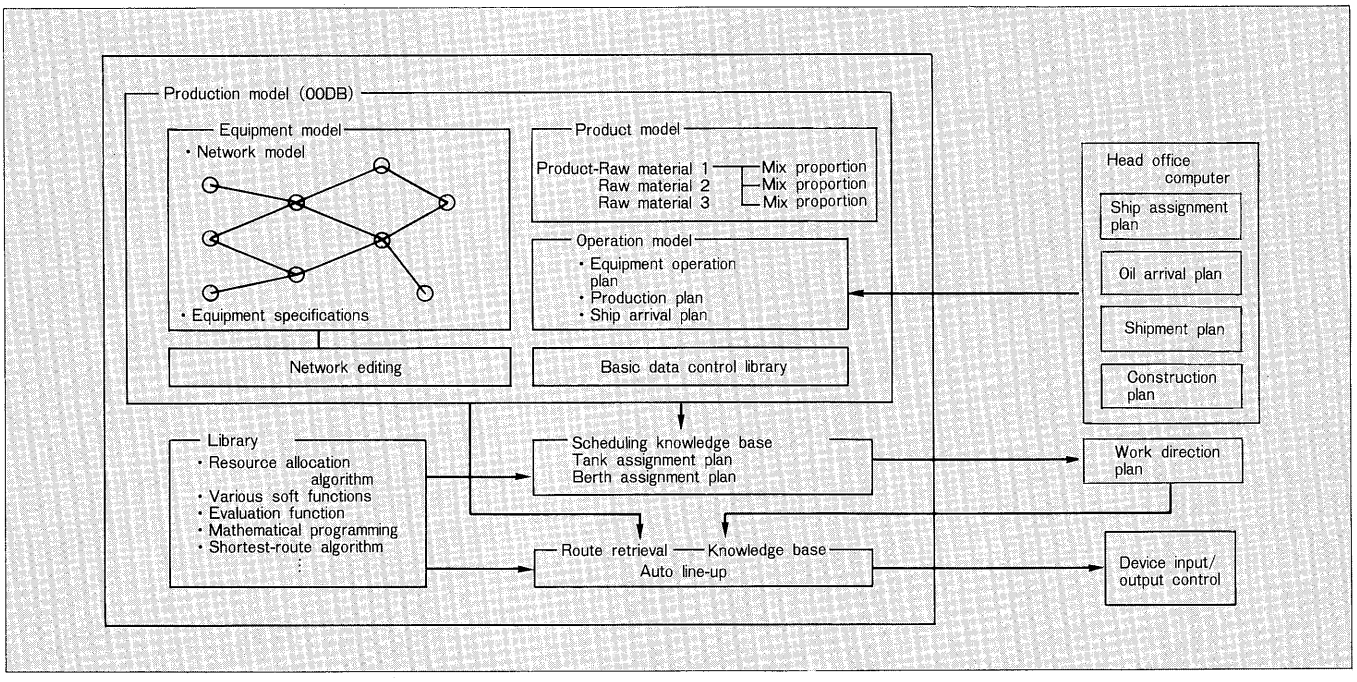


Fig. 4 Configuration of AIMAX-P applied petroleum offsite control system




(b) Product configuration can be altered for a model change in a shorter time period.

(c) A charging order plan based on the constant production ratio algorithm, can be realized to take equipment restrictions into account and ensure a constant production ratio.

## 5. AI Technology in Processes of Piping System

In the processes of chemical, petroleum and other pipeline systems, optimum facility operation is most important for a manufacturing plan based on demand forecasting. To draft a plan of this task, an experienced manufacturing engineer required nearly half a work day. In addition, the facility was frequently changed to meet demand trends. Therefore, a substantial period of time was required for the maintenance of data bases. This section outlines the application of AI technology to a piping system process using the example of a petroleum offsite control system as shown in **Fig. 4**.

(1) Manufacturing model

An offsite facility is represented in a drawing called P & I (Piping and Instrumentation diagram). In facility modeling, the piping system is expressed by a network model based on the P & I drawing. The specifications of each facility, the kind of oil to be processed, etc. are linked to this model. Facility data is represented by the objects of AIMAX-P for each facility element, and can be corrected or changed readily corresponding to a change in the facility. Product information such as job and blending information necessary for the type of oil, etc. is provided.

(2) Scheduling function

A host computer determines necessary oil operation work each day based on ship assignment, off-loading, shipment and construction plans. Oil operation work is scheduled by assigning tank and berth locations to avoid delays at the facility.

(3) Auto line-up function

The auto line-up function selects an oil-operable line for the oil type in the above work schedule and issues a command to the appropriate devices. Multiple candidates for the oil-operable line are determined by using a graph retrieval technique in which the objects are represented as a facility model and the data is converted into a network like expression of nodes and branches. These candidates are checked for whether they can operate necessary devices and for isolation, namely whether a combination of valves can be closed to prevent contamination. From the oil-operable lines which satisfy the above check, the most appropriate one is selected according to the order of priority which varies with operating conditions.

## 6. Afterword

This paper has summarized the Fuji Electric's past approach and future prospects for AI technology in CIM. The need for intelligent manufacturing system configurations is keenly recognized by all companies. In response to this, the intelligent configuration of production systems and the global organization of production engineering information are important keywords in the IMS project for next-generation manufacturing systems, guided by the Japanese Ministry of International Trade and Industry.

Fuji will continue to develop manufacturing systems in which the need responsive AI mentioned above functions in coordination with other related technologies.