TR-523

Outline of the Fifth Generation Computer Systems Project and ICOT Activities

by
T. Kurozumi

November, 1989

ICOT

Mita Kokusai Bldg. 21F
4-28 Mita 1-Chome
Minato-ku Tokyo 108 Japan

(03) 456-3191~5
Telex ICOT J32964

Institute for New Generation Computer Technology

Outline of the Fifth Generation Computer Systems Project and ICOT Activities

Takashi Kurozumi

Deputy Director, Research Center

Institute for New Generation Computer Technology (ICOT)

ABSTRACT

The Fifth Generation Computer Systems Project was launched in 1982 as part of the information-related policy of the Ministry of International Trade and Industry (MITI). Its purpose is to research and develop a new computer technology that will provide the basis for the creation of knowledge information processing systems (KIPS) needed in the 1990s.

ICOT has been entrusted by MITI to promote this national project in cooperation with manufacturers, national and public research organizations, and universities.

The project has been proceeding according to a ten-year plan, which is divided into an initial three-year stage, an intermediate four-year stage and a final three-year stage. This year, 1989, is the first year of the final stage.

This paper shows outline of the planning stage and the ten-year plan of the FGCS project,R&D results,and ICOT activities to promote the spread of R&D results.

1. Basic Framework of Fifth Generation Computers

The R&D programs of this project aim at creating prototypes of fifth generation computer systems. The basic framework of fifth generation computers is described below.

1.1 Concept of Fifth Generation Computers

Conventional computers have been classified into generations according to their constituent hardware elements: vacuum tubes, transistors, IC, LSI and VLSI. But they are all based on the same Von Neumann architecture, which is characterized by sequential processing and stored-program schemes.

In present-day computers, the characteristics of the architecture determines the type of machine language and software based on machine language is procedural. Present-day computers are limited because there is an enormous gap between the way that they work and the way that human beings think, knowledge-based inference.

Computers must follow pre-defined procedures; they cannot do processing that depends on the circumstances.

There are basic needs that future computers must satisfy. They should be intelligent, easy to use and readily available; their software must be productive. Although conventional computers have the architectural limitation explained previously, there are technical seeds such as research into artificial intelligent technology, architecture technology and software engineering technology. These technologies have been developed independently.

The objectives of the Fifth Generation Computer Systems Project are to overcome the technical restrictions of conventional computers and develop innovative computers capable of intelligent information processing. Such machines will be essential in the information-oriented society of the 1990s.

The concept of the fifth generation computer systems stemmed from the idea that meeting future needs would be possible by selecting the existing R&D results that can be used to further development and by combining these results in a completely new framework.

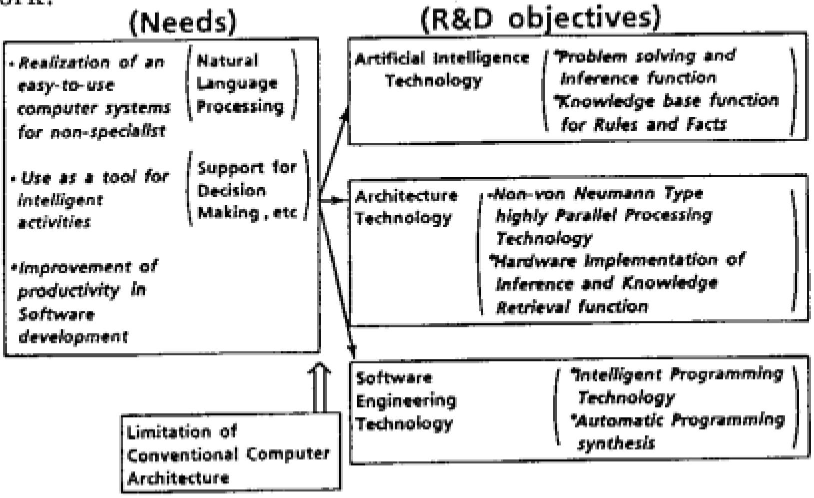

Fig.1 R&D Objectives for 5G Computers to meet needs of the coming "1990 s Information Society"

The new framework can be built by specifying a predicate logic language as a new machine language, by creating a hardware system that performs highly parallel inference processing based on the new language, and by creating a software system that performs a new type of processing, a combination of the basic inference processings provided by the hardware system.

1.2 Basic Structure of Fifth Generation Computer Systems

A fundamental characteristic of intelligent activity is inference that uses every piece of stored knowledge, whether it is conscious or unconscious. Inference based on predicate logic is a procedure to extract unknown information using existing knowledge.

In fifth generation computers, hardware and software are based on a programming method called logic programming in which programs are described in the form of a logic and executed as inference. The predicate logic languages assigned to do this are called the kernel language(KL).

Based on the findings of previous artificial intelligence research, we estimate that fifth generation computers will require an inference speed 1000 times greater than conventional computers. The high-level integration provided by advanced VLSIs enable us to make a reasonably compact and inexpensive computer with more than a thousand processors working in parallel. In this project, we aim at an inference execution speed of 100M LIPS to 1G LIPS, using prototype hardware consisting of one thousand processing elements.

1st - 4th Generation	5th Generation
<Von Neumann Type>	<Non - Von Neumann Type>
· Low-level & Imperative Programming	· Logic Programming
· Numerical Processing	· Inference & Knowledge base Processing
· Sequential Processing	· Parallel Processing

Fig.2 What is the 5G Computer Systems (FGCS)?

In the logic programming framework, a knowledge base for inference will also be represented in a form based on predicate logic. A relational expression in a current relational database can correspond to a predicate logic form as its extended form. For the knowledge base function, we will start working from current relational database techniques, and proceed to processing knowledge data that is represented in a variety of ways in the logic programming framework.

We think that fifth generation computers must have a basic software system with the following basic functions for the knowledge information processing system. The functions needed in the future include an intelligent interaction function and an inference function that uses knowledge bases.

(1) Problem-solving and inference function: A function to perform meta-level inference such as inductive inference, used to control hardware effectively and solve given problems.

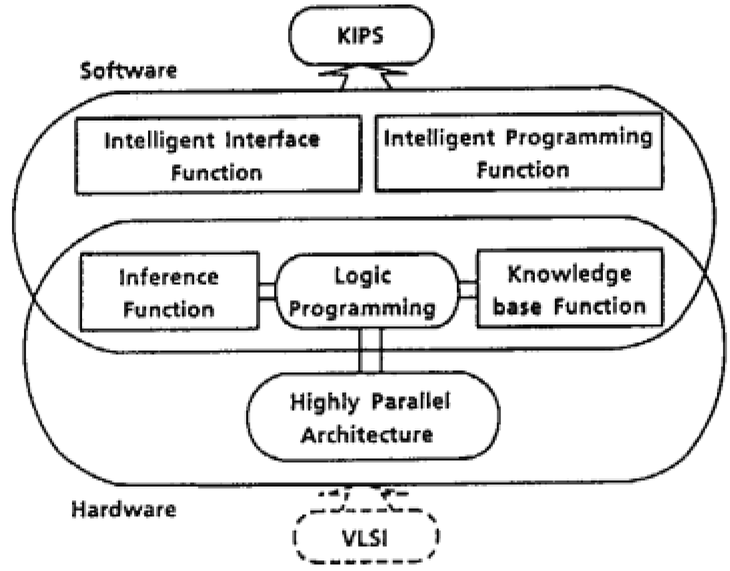

Fig.3 Framework of FGCS

(2) Knowledge base management function: A function to acquire, store and use various types of knowledge needed in the course of inference. It has advanced database management capability, a knowledge acquisition capability that collects knowledge by judging whether it is meaningful, and the ability to retrieve and use knowledge effectively.

(3) Intelligent interface function: A function to make computers easy to use, enabling humans and computers to communicate with each other in a flexible and natural way through natural language.

(4) Intelligent programming function: A function to lighten the user's workload in the processes from writing programs to maintenance. It supports program development, converts given problems to more efficient programs, and verifies the accuracy of the programs.

Our aim is to realize the above four basic functions with fifth generation computers. Although the interface between the basic software system and hardware will be implemented in the kernel language, user languages and other languages will be defined as high-layer languages that have a modularization function and various types of knowledge representation functions.

2. Initiation of the FGCS Project

The history of fifth generation computers began when a survey committee was founded by MITI in 1979. In that year, the survey was undertaken on the prospects of fifth generation computers. In 1980, the survey focused on the goals and subjects of R&D. During these two years, the vision of a fifth generation computer for large-scale knowledge information processing took clear shape.

In 1981, MITI established an R&D plan for fifth generation computer systems, which was presented at an international conference held by MITI in October 1981 (FGCS '81).

2.1 Idea of Fifth Generation Computer Systems

First we would like to explain how the idea of fifth generation computer systems was born.

The Electro-technical Laboratory (ETL) had been leading computer research activities in Japan since the 1950s, including the prototype manufacturing of a second generation computer (MARK III) in July 1956. In the 1970s it began studies on inference mechanism, led by Kazuhiro Fuchi as chief researcher, which included the study of Prolog. Through this research on Prolog as a language having a structure closer to the structure of human thinking, they explored the possibilities of the development of logic programming and the creation of a new type of computer appropriate for inference.

In the meantime, MITI had put in effect a variety of policies aimed at enhancing the ability of research and development in the computer industry in Japan. In the 1970s MITI began to realize that the industry had grown to a level high enough to make such support from the government unnecessary. Amid this situation, MITI's Electronics Policy Division, which was in a position to consider a new policy for the computer industry in the future, brought about a concept in May 1978 that said, "IBM's future system is expected to be a fourth generation computer. We will create the new fifth generation computer that goes one step further."

his concept is based on: 1) a question from user's point of view, "present computers are difficult to use unless the user is professional. Can't we have a new computer that is easier to use?," and 2) an idea from the viewpoint of policy makers, "The design concept of computers has remained the same since Von Neumann. Isn't it possible to create a new non-VonNeumann type of computer? Wouldn't it allow computer development activities for a new market?."

MITI asked for comments from research groups in Japan about whether it was possible to develop a non-VonNeumann type of computer. They knew that the Fuchi's group at ETL had the type of technical idea they needed and were convinced that the concept of a fifth generation computer could be realized.

2.2 Planning Stage for the FGCS Project

It seemed quite tough for this project, which was aiming at "a new, creative, and risky development," to acquire a budget as a government action. MITI thought that organizing a large-scale survey committee, including authorities from the academic society, would give strong support for acquiring a budget if the committee determined that "this type of computer needs to be developed."

In 1979 a committee led by Professor Motooka as chairman, and its sub-committees (Fig. 4), started their activities. This committee (Fifth Generation Computer Research Committee) had its headquarter in JIPDEC (Japan Information Processing Development Center), and it had 35 members, including professionals at universities, national and public institutes, computer manufacturers, and users. The committee had several sub-committees. The Sub-committee for Basic Theory, organized with the ETL group as a center, brought forward the idea of "an innovative computer based on a non-procedural language, and a logic programming language as the language used for the computer."

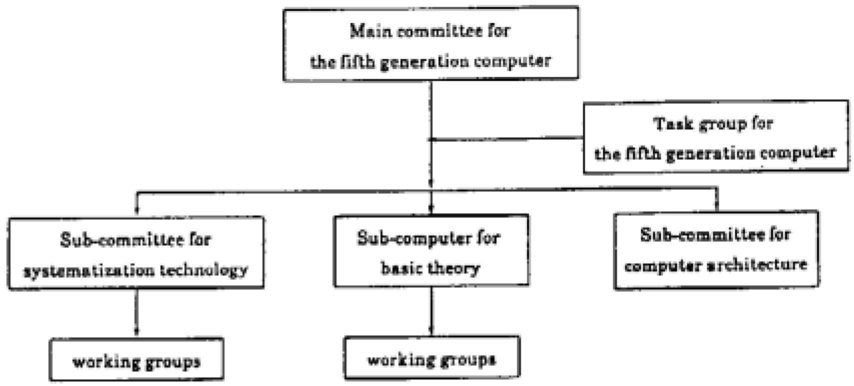

Fig.4 Organization of the Fifth Generation Computer Committee

The Sub-committee for Computer Architecture advocated "improving the computer along the line of the existing technology and then add non-VonNeumann functionalities to it." The committee as a whole produced a report in August 1980 that described opposite ideas, such as "improvers vs. innovators" and "realism vs. idealism."

Meanwhile, in February 1980 at ETL the committee held a lecture to show the possibility of non-VonNeumann type computers and to demonstrate Prolog.

The committee continued its work in 1980, and its membership increased to more than 100. They repeated vigorous investigations and discussions. Working groups were organized under the sub-committees to narrow down technical matters. Discussions at the committee were steadily moving in the direction to support non-VonNeumann type computers. In its second annual report the committee stated its goal by saying. "The fifth generation computer is a knowledge information processing-oriented computer system based on an innovative methodology and techniques, able to deal with advanced functionalities, including problem solving," and it described the concept as a non-VonNeumann type inference machine. The report was translated into English and distributed to computer researchers abroad.

This report, titled "Proposal for the Research and Development of the Fifth Generation Computer," was produced, the members agreed to the concept, and MITI determined to start this project as a government policy action for new information processing. However, another process was still needed to acquire a budget for the project and formally make it a policy action of Japan. The committee continued its work in 1981, members increased to more than 120, and they further examined technical matters. At the same time, they started to prepare for an international conference on the fifth generation computer, which was to be held to discuss the planning of the project and results of their research activities with foreign researchers, and to receive their comments on the project.

In October 1981 the international conference was held. There were more than 300 attendants, including participants from 14 countries outside Japan, and the contents of the project drew much attention. Responding to the enthusiasm of MITI to acquire a budget in fiscal year 1982, the Department of Finance decided to admit the first year budget for the project, on a condition that a budget for the following years would be considered according to the results of the development activities of the project.

The efforts and enthusiasm of a large number of people, including the members of the committee and officers at MITI, and support from many other people, made it possible that this risky project for the research and development of the fifth generation computer, based on innovative ideas, became accepted and started as a national project.

Generally speaking, when many experts take part in a discussion of project planning and compile the results in a report, it cannot be avoided that different types of requirements are included, and that such arguments as "improvement vs. innovation" and "realism vs. idealism" arise. This project has been lucky to have understanding people and promoters, especially on the policy makers' side.

3. Steps in the Development of the 5G Computer

According to the report of the committee, basic configuration of the FGCS was imaged as Fig.5, and concept diagram of R&D was shown as Fig.6.

Because R&D on 5G computers incurs a high level of risk, involving as it does a large number of unknowns, a relatively long period -ten years - has been allotted for the project.

This ten-year period will be divided into three stages : three years for the initial stage, four years for the intermediate stage, and three years for the final stage.

The initial stage of R&D was conducted with emphasis placed on the fundamental technological elements required to build of a 5G system. (1982 ~ 1984)

In the intermediate stage, the algorithms and basic architecture to be used in subsystems that will constitute the foundation of 5G systems will be determined based on the results of the initial stage. Following this, a small - to -medium scale system will be developed using various subsystems as components. (1985 ~ 1988)

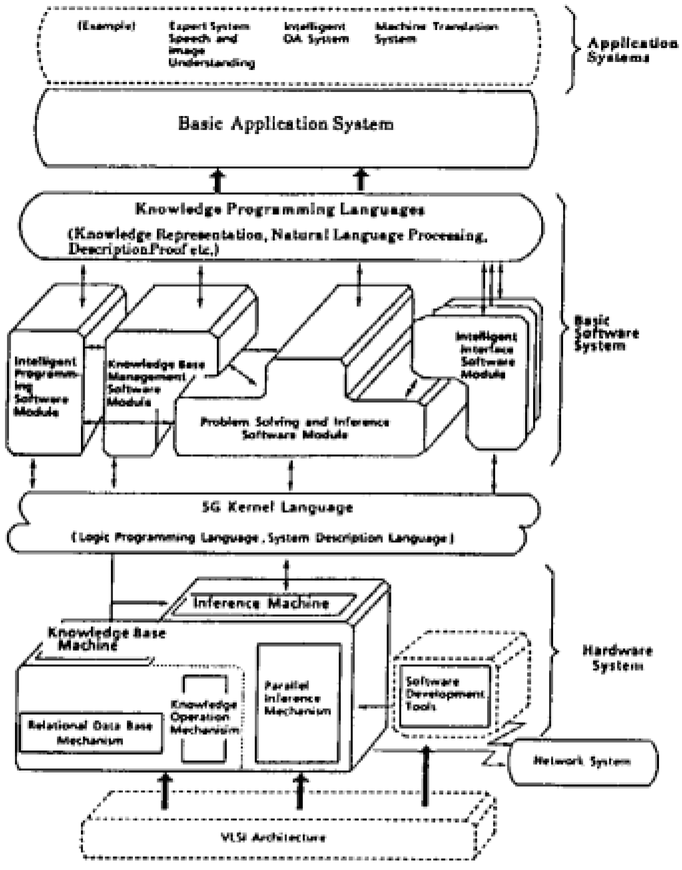

Fig.5 Basic Configuration Image of the Fifth Generation Computer System

The final stage of research and development has as its goal the completion of a prototype 5G system, completely integrating all the results of research performed up to this point. (1989 ~ 1991)

In addition, a primary objective of this project is the inhouse development of R&D tools ; this work will be carried out from the initial through the intermediate project stages. Because the 5G system will be based on revolutionary new programming languages, software development could not be expected to proceed efficiently using conventional computer systems. Existing technology is being employed in the development of these high-performance tools for software development in order to complete in a short time.

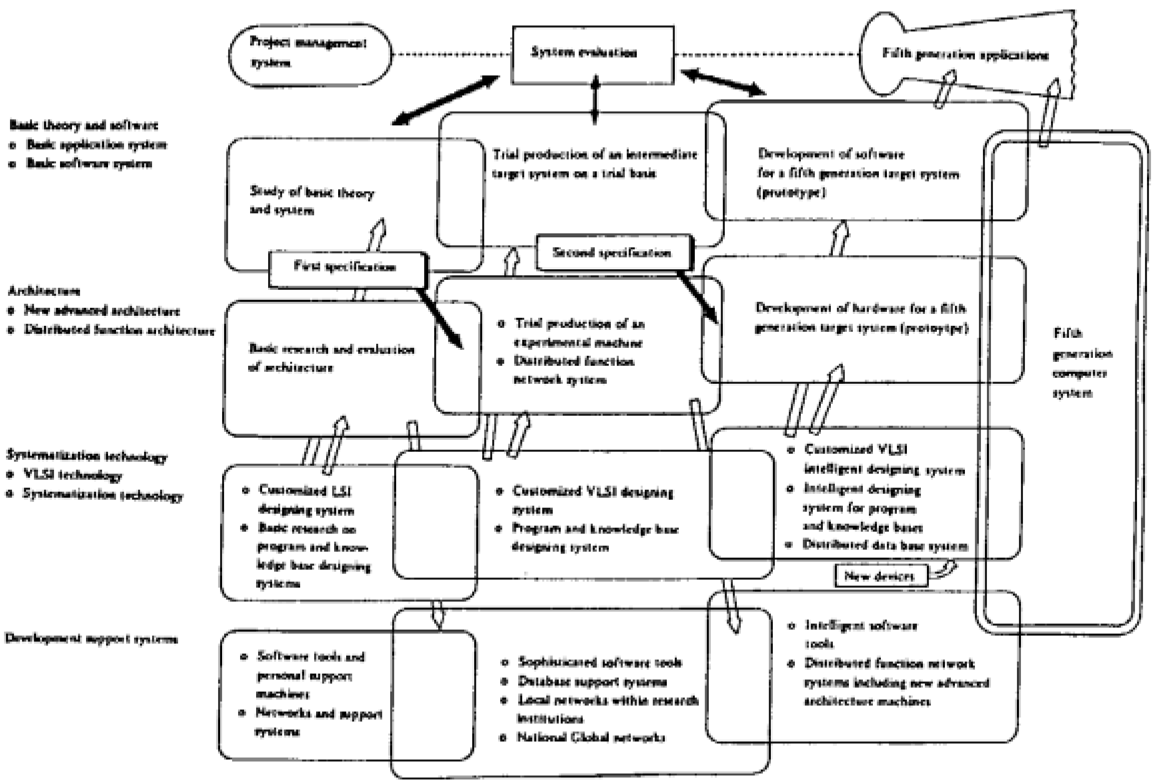

Fig.6 Concept diagram showing how research and development are to progress

4. Organization of the Research and Development of the Fifth Generation Computer Systems Project

In 1982, ICOT (Institute for New Generation Computer Technology) was founded as the central organization for promoting

R&D, and it began R&D work on fifth generation computers, under the auspices of MITI.

The ICOT organization consists of a general affairs office and a research center. In the initial stage, the research center consisted of a research planning department and three laboratories. In the intermediate stage, It has a research planning department and five laboratories. The responsibilities of each laboratory sometimes change occasionally depending on the progress that is made. The laboratories' subjects in 1989 are as follows.

The research staff at ICOT is made up of researchers on loan from the Electro-technical Laboratory, Mechanical Engineering Laboratory, NTT, KDD, computer manufacturers and others.

There were 50 staff at the beginning of the intermediate stage, and their number has increased every year. At the beginning of 1988, there were about 90, and soon there will be about 100.

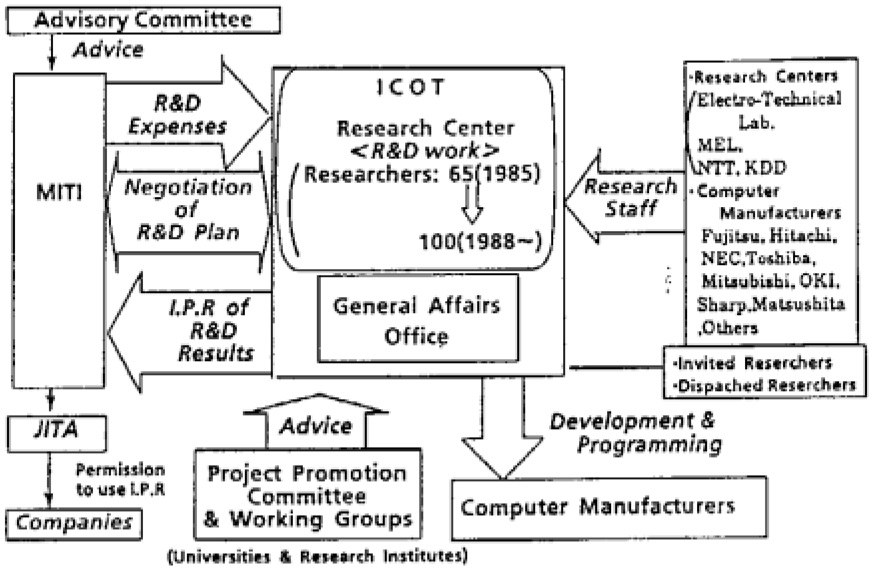

Fig.7 Organization of the FGCS Project

This project has been executed in an R&D organization which formed with the idea that the minds of the first - class researchers in related fields in Japan should be brought together.

(1) MITI has set up an advisory committee to provide overall guidance concerning plan and R&D status of this project. Members are authorities on this area from universities, research institutes and companies.

(2) The researchers at ICOT conduct the core R&D activities, and ICOT entrusts other R&D work that needs experimental manufacturing and development to manufacturers, We are promoting the project as a single structure.

(3) Experts from universities and institute have been participating in the Project Promotion Committee (PPC) and Working Groups (WGs) set up by ICOT. PPC supplies us with general advice about the project. WGs facilitate the exchange of information about each research subject. In 1989, we have 13 WGs that are organized according to the status of the R&D.

We consider it important that ICOT researchers, other researchers in Japan, and scientists abroad stimulate each other, present their results, and exchange information. That is why ICOT is actively promoting the following research meetings and information exchange activities with foreign research institutes.

(1) ICOT researchers make presentations at international conferences. We publish the ICOT technical reports and technical memorandums. We also exchange papers with foreign research institutes.

(2) We welcome researchers from other countries as visitors and our researchers visit research institutes and universities abroad to exchange information.

(3) Every year we invite several renowned researchers form abroad for a short period.

(4) Based on the memorandums with NSF in the United States, INRIA in France, DTI in United Kingdom, we receive researchers from these countries for a long period.

(5) To disseminate the result of the R&D activities, we sponsor symposiums and logic programming conferences every year, as well as this international conference ('81,'84,'88). In addition, we have held a Japan-Sweden-Italy work-shop, a Japan-France AI symposium, and a Japan-U.S.A. AI symposium.

All the R&D expenses for this project are covered by the national budget, and the amount is determined each year according to the government's budgeting system. The budget was 8.3 billion yen for the three-year initial stage and about 21.6 billion yen for the four-year intermediate stage (4.7 billion for '85, 5.5 billion for '86, 5.6 billion for '86, 5.7 billion for '88), and 6.5 billion for '89.

5. Diffusion of the R&D Results

As mentioned in Chapter 4 about international exchange, ICOT has been actively engaged in research and information exchanges with many researchers and institutes that are conducting studies on subjects similar to the research themes of this project. This policy is based on the concept that showing the results of ICOT's research to outside researchers and having free discussions with them is essential to conducting advanced research.

For example, GHC (Guarded Horn Clauses), the kernel of ICOT's parallel logical languages, was created as a result of a study on parallel logical languages through exchanges with researchers doing work on Parlag or Concurrent Prolog.

We believe that ICOT can contribute to knowledge information processing research all over the world by presenting the results of the research conducted at ICOT and exchanging information, including preliminary ideas, with outside researchers. In addition, presentation of the results and free research exchanges will be a major means to promote the diffusion of R&D results and studies on fifth generation computer systems in and outside of the country. The following are our schemes to distribute the R&D results.

(1) Results are issued in the following materials published by ICOT.

a. A quarterly journal, called ICOT Journal, is published to report the activities at ICOT. It is distributed to more than 1100 locations (among them 55 locations in 36 foreign countries).

b. The results of our research are compiled as technical reports (TR) or technical memos (TM) and distributed as required. There have been about 1300 TRs or TMs (among them 460 were written in English) so far.

(2) As for researcher exchanges, more than 200 outside experts participate in the working groups for different research subjects. As for international researcher exchanges, discussions with some 300 to 400 visitors are held per year, foreign researchers are invited for short stays, and we also receive researchers for long-term research programs.

(3) Since the entire cost for the R&D activities of this project is born by the government budget, intellectual property right, including patents for the R&D results, belongs to the government. Intellectual property right is managed by AIST (Agency of Industrial Science and Technology), and any company wishing to use one of them can be granted its patent by paying a fee. PSI (Personal Sequential Inference Machine) and its OS, SIMPOS, have been commercialized by companies licensed by the country. This approach is expected to contribute to the establishment of a basis for the diffusion of fifth generation computer technology.

(4) Software used for research which has not been handled by intellectual property right can be used at outside institutes for research. This scheme, including language specifications, is also one of the new research-promoting schemes for fifth generation computers.

(5) The core research activities of the project are conducted at ICOT. But the test manufacturing of hardware and software, which are highly development-oriented, is entrusted to computer manufacturers. Even those developments assigned to the manufacturers are performed in a special structure, including

ICOT's researchers, because the project is designed to reach its goal as a whole. Through such assignments for development activities and loans of ICOT's researchers, ICOT has been giving incentives to the industry to obtain understanding on fifth generation computer research and prompt them to be actively involved in them.

6. R&D Results of the Initial Stage (1982 to 1984)

R&D in the initial stage was aimed at developing the basic technology required for fifth generation computers. Within the framework of this project, the R&D results concerning knowledge information processing were analyzed and selected results were restructured to achieve the goals of the initial stage.

The specific subjects of R&D included an inference subsystem, knowledge base subsystem, basic software system and pilot models for software development. Goals were specified independently for each subject.

To sum up the results of R&D in the initial stage, we evaluated the basic technology needed to develop fifth generation computers by reviewing and testing various experimental systems. We became convinced that the basic framework described in chapter 1 was not mere hypothesis, but was viable and effective. The major results of each R&D subject are as follows.

(1) Inference subsystem: We experimentally reviewed and evaluated various inference methods, including data flow and reduction, by implementing software simulators and hardware simulators.

(2) Knowledge base subsystem: We reviewed and evaluated the relational database scheme as the basic of the knowledge base function by making an experimental parallel relational database machine (Delta).

(3) Basic software system: We proposed GHC as the parallel logic programming language and verified the effectiveness of the logic programming method by implementing experimental software systems such as an experimental relational database management system (KAISER) and a discourse understanding experimental system (DUALS V.0).

(4) Pilot models for software development: We showed that systems based on logic languages were viable and could be effective by developing sequential inference machines (PSI, CHI), sequential logic programming languages (KLO, ESP), and a sequential inference machine operating and programming system (SIMPOS), although all of them were sequential.

7 R&D Results of the Intermediate Stage (1985 to 1988)

7.1 Inference Subsystem

The multi-PSI system was developed as a basic hardware to conduct full-scale R&D on parallel software. In the multi-PSI system, 64 processor elements are connected in a two-dimensional grid structure using a special connection hardware. Following the development of this hardware, a distributed processing firmware to interpret and execute the kernel language version 1 (KL1) was developed. We started to use them for the test manufacturing of parallel software.

Through the test manufacturing of the multi-PSI system (Fig. 8), we developed a technology to connect some 100 component processors. As the next step, aiming at PIM in the final stage, we started to design some hundreds to a thousand component processors and a method to connect them. At the component processor unit level, we also aimed at gaining an integrity and speed four times those of the multi-PSI. The design of instruction specifications, logic design of the chip, and package designs of the board and frame were completed, and part of the test manufacturing started.

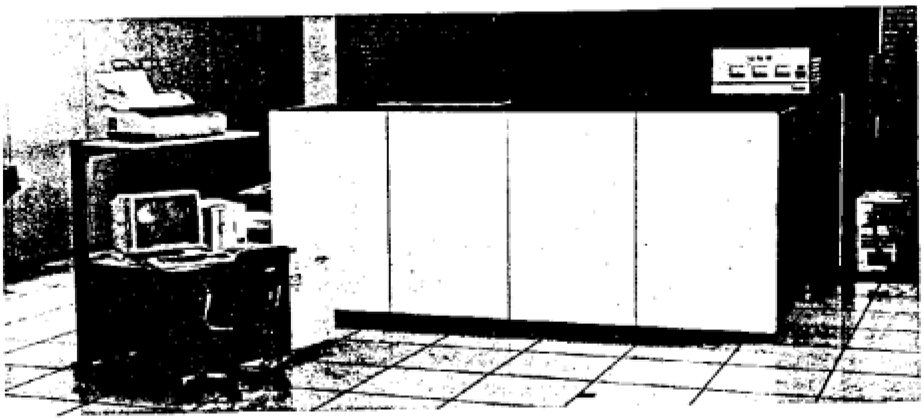

Fig.8 A hardware in which 64 processor elements are connected ... multi-PSI system

7.2 Knowledge Base Subsystem

Aiming at R&D of a method that has a data/knowledge representation method suitable for logic programming language and that effectively executes in parallel expanded relational operations, a test manufacturing experiment of software and hardware was conducted. In the research of a parallel retrieval method for knowledge bases, a parallel knowledge base retrieval mechanism test machine with 8 processor elements for retrieval was created. In addition, research was conducted on inquiry methods and management mechanisms to efficiently manage knowledge bases in a distributed environment by making a variety of test software. Through this research we accumulated major component technologies required during the final stage.

7.3 Basic Software System

(1) Kernel language version 1 (KL1) processing system and parallel inference machine operating system (PIMOS)

Concerning the kernel language version 1 processing system, a distributed processing system according to the machine language specifications has been completed as a firmware for the multi-PSI system. A compiler for the system description language of KL1 (KL1-C) has been also completed.

As for PIMOS, the first versions of PIMOS-S, packaged on the pseudo-parallel processing system of KL1 on PSI-II, and PIMOS-M, packaged on the multi-PSI itself, were completed. We started to use them for the test manufacturing experiment on parallel software.

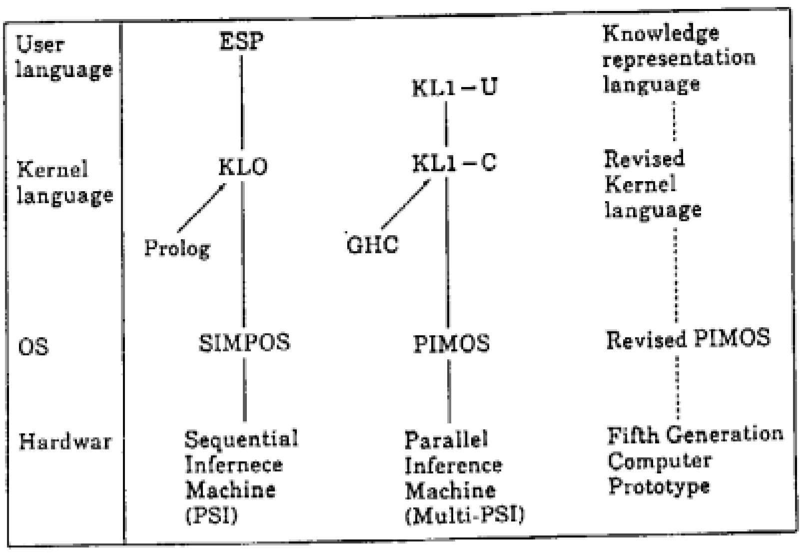

Fig.9 Language System of the Fifth Generation Computer

(2) Knowledge Base Management Basic Software

(Kappa: Knowledge Application Oriented Advanced Database and Knowledge Base Management System)

The basic part of a knowledge base software, performing retrieval and management of large-scale knowledge bases, such as natural language dictionaries and expert systems, was created on PSI/SIMOS. We started to use it for storing natural languae dictionaries. This development made a basis for full-scale research on a method for knowledge description and its management.

(3) Parallel Logical Languages and Parallel Programming Techniques

R&D of parallel languages and programming techniques, forming the core of knowledge programming, was conducted, while the following basic issues were examined.

1) Expansion of the functions of parallel logical languages

·Implementation of the reflection function in GHC

·Development of a processing system for the constrained logic programming language, CAL

2) Development of a conversion method for parallel languages

. Development of a program conversion technique for GHC

. Development of a part calculation technique for Prolog

3) Construction of theoretical models for advanced inference mechanisms, such as induction, analogy, and learning

4) Enhancement of the functions of the proof support system

(4) Natural Language Processing Software

There has been progress in discourse understanding research and the development of common tools for the Japanese processing system.

1) Discourse understanding system

Version three of DUALS(Discourse Understanding Aimed at Logic-based systems), a middle-size discourse understanding experimental system based on the situation semantic theory, was developed.

2) General purpose Japanese processing system

(LTB:Language Tool Box)

An integrated environment to use a language processing system for the analysis, synthesis, and semantic description of the Japanese language, and to use language knowledge bases.

8. Outline of the Research and Development Plan for the Final Stage

The objectives of the R&D in the final stage are to implement prototype hardware that has a parallel architecture and that can perform high-speed inference and knowledge retrieval, and to develop prototype software that can program efficiently in a parallel logic language for knowledge information processing.

To achieve these objectives, we will determine the organization of the project in the final stage according to the state of the R&D at that time, on the basis of that at the end of the intermediate stage. In other words, the R&D in the final stage will be geared to making a prototype system, using the results that have been obtained up until the end of the intermediate stage. Research will also be conducted into the basic technologies that are needed to realize the final objectives and that may be needed in the future.

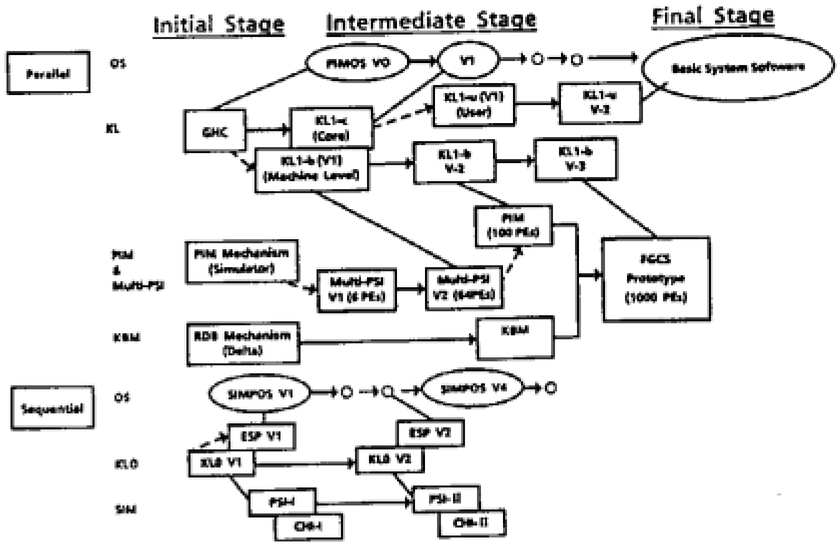

Fig.10 R&d Steps of System Software, Kernel languages & Hardware

The R&D themes in the final stage can be divided into Prototype hardware and basic software system. The prototype basic software system can be further divided into basic software and knowledge programming software.

Prototypes of some substantiative application software systems will be developed to verify the effectiveness of various kinds of basic functions of the fifth generation computer and to clarify the actual application .

8.1 Prototype Hardware System

The objective of the R&D for the fifth generation computer prototype hardware system is to implement a hardware system into which the following two hardware mechanisms will be integrated through a hierarchical structure network. They are dedicated hardwares for realizing high-speed inference function and knowledge base function on a vast amount of knowledge base in parallel hard ware architecture.

This hardware system will be able to execute basic software (parallel OS) and high-speed execution of application software for large-scale knowledge information processing written in parallel logic programming language.

Concretely, the hardware will be implemented by the connection of about 1,000 processing elements to provide the various function. For the hardware performance of inference operation we aim at is 100M to 1G LIPS.

8.2 Prototype Basic Software System

The objectives of the R&D of the fifth generation computer prototype basic software system are to provide the following functions: OS functions for an efficient parallel software execution environment by controlling and managing the hardware system, functions for the description of knowledge forming the core in the development of application softwares in knowledge information processing as programs, functions such as cooperative problem-solving and meta-level inference to support the above activities intelligently, functions to construct, manage and use knowledge bases through the structural formation of described knowledge, and functions for natural language interfaces required essentially for interactive human interfaces.

This configuration consists of the prototype hardware system OS functions, basic software to provide the system programming environment, and knowledge programming software to provide the environment for natural language processing, and the description, management and use of knowledge.

(1) Basic Software

The basic software will handle prototype hardware control and management. It takes as its goal the provision of OS functions, and consists of an inference control module for high-speed parallel inference execution control, and a knowledge base management module for knowledge base operation and management.

The essential functions contain resource management and execution management of the prototype hardware system with an inference function and a knowledge base processing function, efficient execution management of parallel software described in parallel kernel language, and efficient operation management for storing and retrieving large-scale knowledge bases.

(2) Knowledge Programming Software

Knowledge programming software is a group of utility softwares developed using basic software. To develop application softwares for knowledge information processing, we aim to provide a range of knowledge programming functions, a development support system, and a user interface.

Research will be performed into the development of a cooperative problem solving technique to process input problems while avoiding the conflicts and contradictions between knowledge processing softwares developed for different application fields. Research will also be conducted into meta-level inference functions such as common sense decision that approach human intelligence, and into meta-level inference techniques for the learning mechanism.

This software provides the following functions as a step to facilitate the construction of knowledge information processing system: knowledge programming languages, various programming functions, an intelligent programming support function, a knowledge base construction function by the extraction and arrangement of expert knowledge, a function for using knowledge base efficiently according to the application, a function for reconstructing knowledge base, and all the functions required for the construction of an interactive interface that uses natural language to provide a flexible man-machine interface.

This software will consist of the following three modules.

(a) Problem-solving and programming software module

(b) Knowledge construction and utilization software module

(c) Natural language interface software module

9. CONCLUSION

This project is researching new computer hardware and software technologies using parallel architecture based on logic programming language, with the goal of producing a working prototype. We are now using over 300 PSI machines and over 10 multi-PSI (64PE version) which can be divided to smaller scale system as R&D tools for sequential and parallel logic programming.

Technical information generated by this project is being publicly released through technical reports, technical memorandums and other publications, and has been the subject of international exchange. We will continue to such activities in the hope that we can diffuse our knowledge to everyone's benefit.

ACKNOWLEDGEMENTS

This project has been carried out through the efforts of the researchers at ICOT, and with the support of MITI and many others outside ICOT proper. We wish to extend our appreciation to them all for the direct and indirect assistance and cooperation they have provided.

REFERENCE

1. Motooka, et al : Proceedings of International Conference of Fifth Generation Systems, 1981, JIPDEC

2. K. Kawanobe, et al : ICOT research and Development, Proceedings of the International Conference on Fifth Generation Computer Systems 1984, 1984, ICOT

3. T. Kurozumi, et al : Fifth Generation Computer Systems Project, 1987, ICOT, TM-0303

4. T. Kurozumi, et al : ICOT Research and Development, Proceedings of the International Conference on Fifth Generation Computer Systems 1988, 1988, ICOT