Believing that von Neumann computers are now an endangered species, the Japanese have started to develop a knowledge-information processing system for the 1990's.

Japan's Fifth-Generation Computer Systems

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Until now, the Japanese computer industry has aimed at catching up with the US, especially IBM, in computer technology. The result is that three Japanese companies (Fujitsu, Hitachi, and NEC) now claim to offer equivalent computers that are faster than IBM's. In fact, the Japanese computer industry is presently setting its sights on surpassing the rest of the world,[1a] and it sees as its opportunity the growing "technology gulf" between the traditional sequential, control-flow computer and intended application areas such as distributed computing, office automation, and artificial intelligence. All of this is creating the belief that the next generation of computers will have a different theoretical foundation from traditional computers.

With these views in mind the Japanese government in 1979 started a two-year preliminary investigation of this future generation of computers. In April 1982 it embarked on the actual project, which must be the most challenging and extensive computer project undertaken to date. The aim is to develop by 1990 a prototype so-called fifth-generation computer system—a knowledge-information processing system and processor.[1b] The plans for this project have been documented in a series of lengthy reports,[1-3] the main aspects of which are described in this article. These fifth-generation computer systems are intended to represent a unification of four currently separate areas of research, namely knowledge-based expert systems, very-high-level programming languages, decentralized computing, and VLSI technology.

Knowledge-based expert systems[4] are predicted by the Japanese to be *the* application area for the 1990's. These computing systems embody modules of organized knowledge which support sophisticated problem-solving and inference functions for the purpose of rendering to the users intelligent advice on one or other specialized topics. The knowledge bases (each concerning a specific area of human expertise) are analogous to sophisticated versions of current operating-system utilities and their files. Examples include medical diagnosis and mineral exploration.[5] In addition, these systems are intended to support human-oriented input/output capabilities through the use of voice, images, or graphics. Expert systems, however, can require large amounts of computer power for their support.

Very-high-level programming languages provide improved programming methodologies by specifying *what* is to be performed rather than traditionally *how* to perform the programs. The best-developed classes of very-high-level languages are functional languages[6] such as Pure Lisp and predicate logic languages[7] such as Prolog.[8] Functional and logic languages are well-suited to programming knowledge-based expert systems.

Decentralized or parallel computing comprises the fusion of communications and information processing[9] into networks of computers that cooperate on a task. It encompasses both mainframe computers that are geographically distributed as well as miniature microcomputers within a single board or even a single chip. To cooperate, these computers are likely to have a common programming language and will conform to a common (decentralized) system architecture such as data flow or reduction. For instance, in data flow[10] the availability of input data triggers the execution of the task or operation to be performed on them. Both data flow and reduction architectures are suited to being programmed using functional and logic languages.

VLSI technology exploits very-large-scale integration using high-level CAD systems incorporating methods of architecture description, and the new quick-turnaround chip fabrication facilities.[11] This yields high-performance general-purpose and special-purpose computers at a

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modest cost and with greater functionality than conventional machines. With decentralized computing techniques, these computers can be used as building blocks and configured into a powerful computer system supporting a specialist application.

The planned fifth-generation computer systems may be looked upon as forming a new computer family in which members provide powerful facilities for problem-solving and inference, knowledge-base management, and intelligent input/output. Interfaces are to exist at both the software and hardware levels, allowing software modules and hardware computers to be configured for a specific application or set of applications. The resulting systems will be analogous to Lego building blocks, with each block performing some function and a configuration of blocks functioning as a specialized computer system. In turn, these computer systems will form building blocks for even larger systems. High-speed local networks will connect the hardware blocks of a single system, while global networks will link together computer systems for various social organizations. The whole may be viewed as an information processing equivalent to the telephone network.

This article, based on the opinions expressed in the reports,[1-3] previews the Japanese project by presenting an image of a fifth-generation computer system, by outlining the various subsidiary research projects involved, and by discussing the likely impacts and effects of this research.

Background

For the last 30 years, the principles of computer-system design have remained largely static, being based on the sequential control-flow computer. This so-called von Neumann computer contains

- a single computer that incorporates a processor, communications, and memory,
- a linear organization of fixed-size memory cells,
- a one-level address space of memory cells,
- a low-level machine language (instructions perform simple operations on simple operands),
- a sequential, centralized control of computation, and
- a primitive input/output capability.

This computer, initially designed for scientific computations with limited input/output requirements, has been consistently developed for such high-speed processing of numerical calculations. In addition, the high cost of hardware has effectively minimized the number of functions carried out by hardware and gradually increased dependence upon software. The Japanese believe this has contributed significantly to the situation called the "software crisis." In their view:

- Today's computers are not equipped with the necessary functions, including input/output, to process nonnumerical data such as sentences, symbols, speech, graphics, and images.
- Conventional computers seem unable to satisfy the performance demands of applications such as artificial intelligence.
- Improvements in the system design of computers to increase performance have thus far proven fruitless.
- Decentralized computing is expensive and difficult to implement due to the lack of a system architecture to which all component computers conform.
- Beyond memory, it is unclear how to exploit VLSI technology in multimicrocomputer design.

In the 1990's, when fifth-generation computers are expected to be in use, information-processing systems will be key tools in all areas of business, scientific, and social activity. Examples [1a] of office-automation utilities which these computers are to contain include

- systems capable of processing languages such as English and Japanese in a natural way,
- irregular or nonfixed job processing systems capable of freely handling nonnumerical data such as documents, graphics, images, and speech,
- consultation and expert systems having inference and learning mechanisms of their own and capable of storing knowledge and providing adequate information as desired, and
- various data bases for providing high-level information necessary for decision-making, and man-machine interfaces supported by artificial intelligence technology for making and supporting decisions.

Thus, according to Moto-oka,[1a] "Fifth-generation computer systems will be knowledge-information processing systems based on innovative theories and technologies that can offer the advanced functions expected to be required in the 1990's, overcoming the technical limitations inherent in conventional computers."

Fifth-generation computers

Fifth-generation computer systems are to form a computer family linked by a common programming language, even though specific systems are intended to serve specialized applications with one or more of their basic functions enhanced. At a macroscopic level, fifth-generation computer systems are to be linked to each other like telephones in a telephone network. At a microscopic level, each node in this information-processing network is to be a computer system consisting of specialist computers connected by local networks. The combined software and hardware of a fifth-generation computer system is to provide three basic functions: the intelligent interface, knowledge-base management, and problem-solving and inference functions.

The intelligent interface function[1c] is to support conversations with a computer and is therefore described as being analogous to traditional input/output channels and devices. Such conversations are to be in the form of speech, graphics, natural languages, etc.—possibilities aimed at enabling the exchange of information in a form natural to humans.

In traditional terms, the knowledge-base management function[1d] is characterized as being equivalent to an integration of main memory, virtual memory facilities, and a file system. This function is to be capable of retrieving within several seconds a knowledge base required for inference. A main data base system supporting this is expected to have a capacity of 100G to 1000G bytes.

The problem-solving and inference function[1e] can be regarded as equivalent to the central processing unit of a traditional computer. Its maximum performance target is 100M- to 1G-logical inferences per second—that is, inference operations of syllogism per second.[1a] One LIPS is stated to be equivalent to approximately 100-1000 instructions per second on a conventional computer.

These three basic functions are to be combined into a single general-purpose computer system configured to meet performance requirements in a variety of applied fields. Such a general-purpose computer system is shown in Figure 1, which also illustrates the way its components interact to support the three basic functions.

Applications. As previously mentioned, the principal application area for computer systems in the 1990's is predicted[1a] to be that of knowledge-based expert systems. Examples of such applications are "intelligent" computer-aided engineering and design systems, computer-assisted instruction, office automation, and robotics. These are viewed as opening up entirely new fields for computer applications as well as adding to those of traditional business data processing.

Fifth-generation computer systems are to utilize "knowledge" bases as the foundation of processing, beginning with inputs from the human system such as speech, natural languages, pictures, or images, and extending to comprehension of these inputs, synthesis and execution of programs around them, and generation of responses. These bases are to include knowledge of languages, images, and problem domains, as well as knowledge about the mechanisms and data expressions of the machine system.

All application systems[1a] are to be composed of interactive, processing, and management subsystems

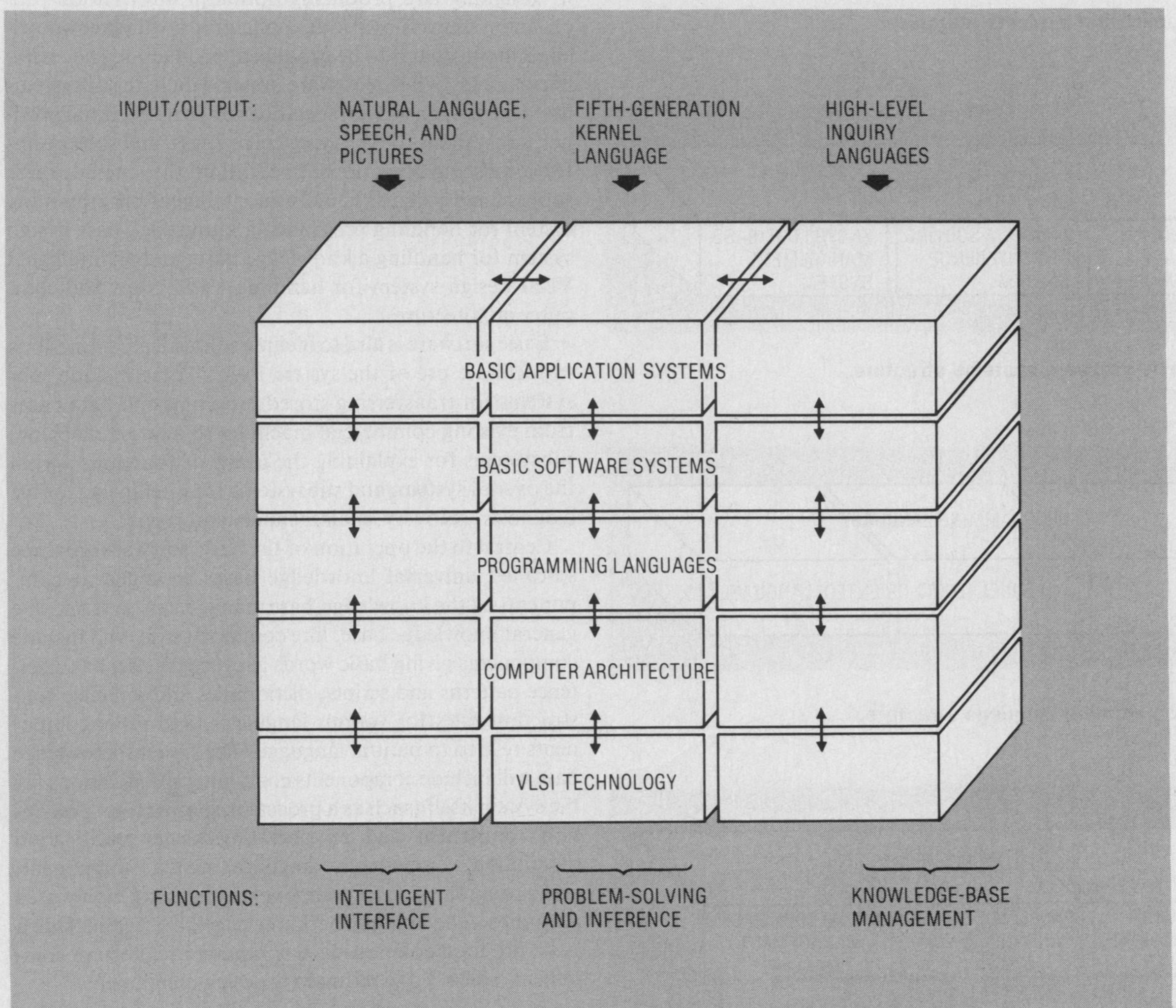

Figure 1. A fifth-generation computer system.

(Figure 2), although these three subsystems will differ proportionally from application to application.

The interactive system is to utilize the knowledge inherent in languages or pictures to analyze a structure (construction) and convert it into an internal (intermediate) expression such as an anatomical tree. Then an analysis is made of the internal expression in context and a description of the problem is extracted from that. This analysis will, however, be incomplete due to omissions and the like. One of the knowledge bases used at this time is information related to the background and flow of the "conversation" taking place.

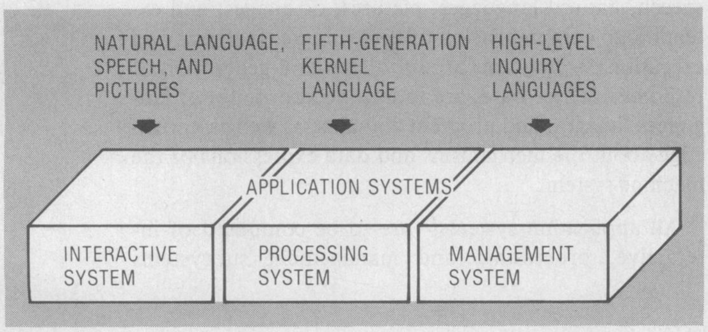

Figure 2. Application systems structure.

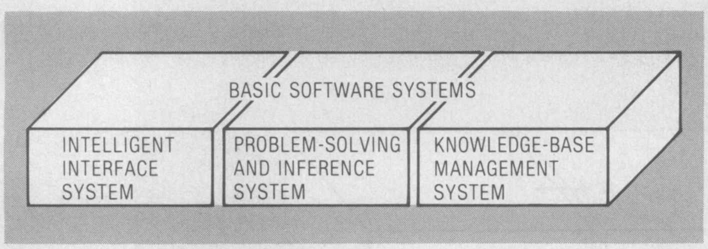

Figure 3. Basic software systems structure.

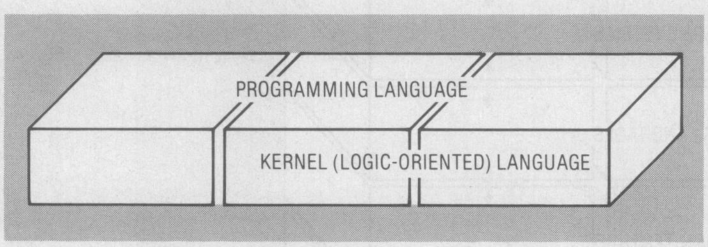

Figure 4. Programming language structure.

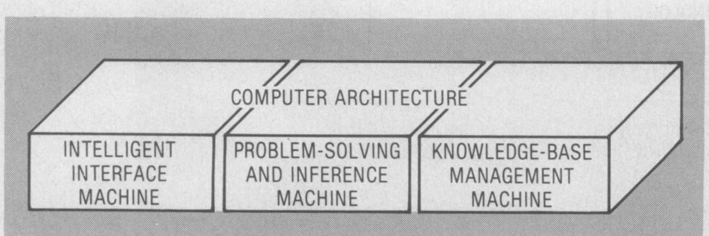

Figure 5. Computer architecture structure.

The processing system is to convert the incomplete description into a complete description, using its knowledge about problem domains, and to generate an answer to the description. At this time, operations such as effective utilization (inference) of the knowledge about problem domains and storage (learning) of new knowledge are effected. The generated answer is then converted into a summarized answer by removing unnecessary self-evident information. Thereafter, this summarized answer is converted by the interactive system into an internal expression, which in turn is converted into an understandable external expression. In this way, one conversational cycle is completed. During this cycle, the management system oversees a variety of knowledge bases used in effecting common operations of inference and learning.

Basic software system. The basic software system directly reflects the structure of the application systems, consisting of three basic subsystems: intelligent interface, problem-solving and inference, and knowledge-base management systems. This is illustrated by Figure 3.

Basic software is to consist of a group of systems that, in designing and producing optimum information-processing systems for various applications, will have knowledge about what is to be produced, production processes, and the like. These software systems include subsystems that lead from a written specification to an eventual product, subsystems for verifying correctness, and subsystems for simulating operations. In addition, they include three support subsystems, namely an intelligent programming system for handling programs, a knowledge-base design system for handling a knowledge base, and an intelligent VLSI design system for handling VLSI chips and computer architectures.

Basic software is also to include sophisticated functions to facilitate use of the system itself. These include subsystems for transferring stored programs and data bases from existing commercial machines to a target machine, subsystems for explaining the usage of functions within the overall system, and subsystems for intelligent trouble diagnosis, recovery, maintenance, and repair.

Central to the operation of the basic software are three so-called universal knowledge bases arranged as components of the knowledge-base management system. The general knowledge base, like common sense, will include components giving basic words in everyday use, basic sentence patterns and scripts, dictionaries and sentence construction rules for various languages, and other components related to natural language. The systems knowledge base will include components containing specifications for the system itself (such as a processor-specification description component and an operating-system-specification description component), language manual component, and a program module component containing highly used programs. The application knowledge base will include a basic program component, a computer architecture component, and a VLSI technology design component.

Programming languages. Three categories of programming languages may be used with a fifth-generation computer (see Figure 2). The natural language, speech, and pictures category interacts with the intelligent interface system. The high-level inquiry language interacts with the knowledge-base management system. Lastly, the so-called core or kernel language interacts with the problem-solving and inference system.

However, only the kernel programming language will be directly supported (by the problem-solving and inference machines and the knowledge-base machines as shown in Figure 4) and may be used to program the computer. The kernel language is to be a problem-solving language based on predicate logic like Prolog. In a predicate logic language[7] a program is a collection of logic statements of a restricted form—clauses—and the execution of such a program is a suitably controlled logical deduction from the clauses forming the program. The reason for this choice of language is, according to researchers' claims, that most relevant research points in the direction of this very-high-level class of languages. Other languages, such as inquiry languages for knowledge bases and a knowledge representation language, will be implemented in terms of the kernel language, which may be seen as the machine language of a fifth-generation computer system.

The designers do not envisage the whole of the current data processing community being retrained in logic programming. Instead they see such users, in the future, interacting with a system through natural languages. It is also intended that fifth-generation computer systems will support other classes of programming language such as conventional, functional, and object-oriented languages. (Many such language features may be absorbed into the kernel language as long as each language shares a common mathematical foundation.) As yet, it is unclear by which route the programs in these other classes of languages will enter a system.[1a,2] However, they may be supported by actually including a specific von Neumann or functional computer in the hardware of the target computer system.

Computer architecture. The architecture[1f] of fifth-generation systems will encompass all machine levels, from small to large, in order to support the intended diversity of applications. All these computer systems are to have three classes of component machines as shown in Figure 5. Recall that, when contrasted with conventional computers, the problem-solving and inference machines correspond to the central processing unit; the knowledge-base management machine corresponds to an integration of main memory, virtual memory, and file store; and the intelligent interface machines correspond to input/output channels and devices. A general-purpose fifth-generation computer system is to be equipped with each of these machines in substantially the same proportion.

Problem-solving and inference machines[1g] are to be based on a logic programming machine with a data-flow execution mechanism. Knowledge-base management machines[1h] are to be based on an integration of a relational data-base machine and a relational algebra machine. Intelligent interface machines are to be based on special-purpose VLSI processors for exclusive use in speech processing and signal processing. A computer system with an enhanced problem-solving and inference function will find applications in fields where consulting requires both professional knowledge and a strong ability to infer. On the other hand, systems with a reenforced knowledge-base management function will be applied to fields requiring massive storage of "knowledge." Computers incorporating an enhanced intelligent interface function are to interface with various interactive media, speech, pictures, and images, as well as those based on natural languages. In the future, it will be possible to use these machines independently or in combination.

VLSI technology. Providing machines with high functionality and high performance requires utilization of VLSI technology, and getting the most out of VLSI requires[1i]

- computational structures and algorithms suited to VLSI's two-dimensional nature,
- sophisticated CAD systems to handle VLSI design complexity, and
- quick-turnaround fabrication facilities, the so-called silicon foundries.

To achieve a quantum leap in computer technology, it is argued that VLSI must be introduced into all aspects of computer design. Although such devices have been smoothly introduced into memories, the evolution of structures combining logic and memory—a replicable computer—poses problems whose solutions will be of great importance for the future.

The actual development of the devices has been assigned to another national project, not the Fifth-Generation Computer Systems Project. However, the project is watching closely the development of not only MOS and bipolar technology but also Josephson junctions and GaAs devices. Since a number of customized VLSI machines are viewed as indispensable for fifth-generation computers, the rapid development of facilities to produce such machines is considered vital to the whole project.

To summarize this section, fifth-generation computer systems are to perform the following functions as integrated capabilities:

- intelligent interfacing capable of understanding speech, images, and natural language, etc.,
- understanding of problem description and requirement specifications,
- synthesizing processing procedures,
- optimization between machine system and processing procedures, and
- synthesizing responses based on outputs from machine systems.

These functions are to be supported by the following knowledge bases:

- knowledge of the languages to be used for man-machine communication,
- knowledge of the problem areas to be solved, and
- knowledge of the machine systems.

What the project then involves is a menu of research themes on knowledge-engineering applications (expert systems with their knowledge bases and inference mechanisms), very-high-level programming languages (centered on logic languages like Prolog), decentralized computer architectures (data-flow machines being an important ingredient), and facilities for human-oriented input/output (such as speech I/O and image I/O), all exploiting the latest VLSI technology.

Research projects

The major phase of the Fifth-Generation Computer Systems Project started in April 1982 with three stages, each to be approximately three years in duration. The general goal for the initial stage is the construction of a first version of the fifth-generation kernel language,[1j] and a personal "workstation" logic computer called System 5G.[1i] The interim stage is to construct an initial prototype computer, and the final-stage goal is the construction of a finished prototype. During each of these stages achievements are to be continuously reevaluated and new trends in computing research reviewed. At the beginning of the interim and final stages, the overall research plan is to be reassessed.

The overall research and development of the project, as illustrated by Figure 6, may be classified into seven groups which contain 26 subsidiary themes in all. Five groups—application systems, software systems, advanced architectures, distributed function architectures, and VLSI technology—are directed at identifying the structure of the computer systems. Supporting this research are the other two groups: systematization technology relates to the development and integration of software and hardware components, and development-supporting technology covers facilities such as computer networks and fabrication lines built to support research and development. As an illustration of the detailed forward planning undertaken by the research committee and the contents of the 26 research and development themes, we will examine examples from each of the seven groups.

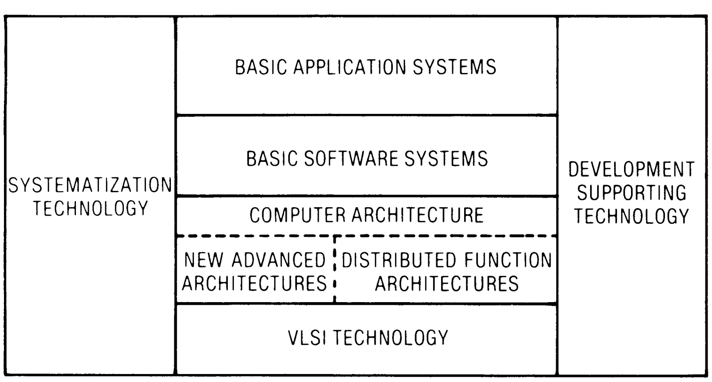

Figure 6. Fifth-generation computer systems research and development.

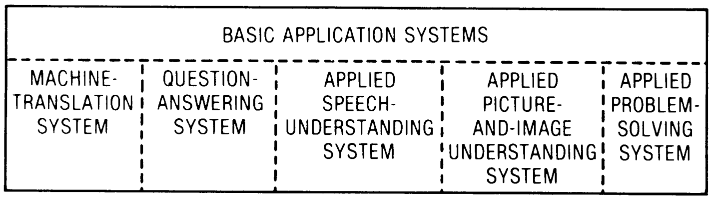

Figure 7. Basic application systems projects.

Basic application systems. This research is to study and develop systems representing functions like hearing, speaking, seeing, drawing, thinking, and problem solving. As shown in Figure 7, there is a proposal to study five "benchmark" applications.

The machine translation (of foreign languages) is an illustration of the basic-application-systems projects.[1a] The R&D effort grows out of "results of research in documentation techniques and artificial intelligence for knowledge utilization, which will be combined to research and develop an integrated, multilingual translation system."[1a] Specifically this will involve the development of

(1) a machine translation system and its core,
(2) grammars for the languages,
(3) sentence-generating grammars,
(4) an integrated machine-translation system with room for operator intervention,
(5) a specialized terminology data base (knowledge data base),
(6) a machine for the specialized terminology data base, and
(7) high-level word-processing techniques.

In addition, specific targets set for the machine translation system are

(1) the ability to handle 100,000-word documents,
(2) a 90-percent accuracy rate (the remaining 10 percent to be processed by human translators),
(3) the general-purpose ability to computerize all jobs, including text compilation and printing of translated documents, and
(4) a translation cost no more than 30 percent of that by human translators.

Basic software systems. Software research is intended to identify a group of modules corresponding to the basic information-processing functions of interaction, processing, and management. Basic software systems are to constitute the core of fifth-generation computer systems (see Figure 8). For example, the general theme for the knowledge-base management systems is "research and development of intelligent system management techniques to format and store human knowledge in a computer, to utilize it and support the user in solving problems."[1a] Specifically this is to involve

(1) research on knowledge representation and utilization techniques,
(2) knowledge acquisition and learning,

(3) research on large-scale knowledge-base systems,
(4) development of a knowledge-base management system, and
(5) development of a knowledge-base machine.

Regarding targets and specifications, the aim is a knowledge-base management (software) system and a supporting knowledge-base machine. The interim targets for *software* are simultaneous management of rules and data, a data-base access optimization mechanism, a mechanism to eliminate inconsistencies, and an interface with an inference machine; for *hardware,* storage and retrieval of 2000 rules and 1,000,000 data items. The final targets for *software* are a multiple-world knowledge base, a distributed knowledge base, and learning based on inductive inference, all integrated with an inference machine; for *hardware,* storage and retrieval of 2,000 rules and 100,000,000 data items.

New advanced architecture. Research in new advanced architectures is to enable the fifth-generation computer to satisfy the knowledge information-processing system requirements.[1k] The six themes of this area are shown in Figure 9.

To illustrate the new advanced architecture projects we examine logic-programming machines and data-flow machines. For the former, the research theme is "study and development of the necessary architectures to support inferences and a computational model based on predicate logic with a power of expression approximating natural languages." Specifically this is to involve[1a]

(1) development of languages and a processing system incorporating predicate logic
  (a) Prolog system
  (b) extended Prolog language
  (c) new (augmented) programming languages
(2) development of the basic technology
  (a) research on parallel systems
  (b) development of special-purpose mechanisms
(3) logic programming machine
  (a) firmware base machine (0.1M LIPS)
  (b) personal logic programming machine (0.1M-1M LIPS)
  (c) parallel logic programming machine (50M-1G LIPS)

For the data flow machines, the R&D theme is "research on an architecture based on a data flow model oriented to parallel processing, thereby achieving sophisticated parallel processing." Specifically this is to involve[1a]

(1) design of a machine instruction set,
(2) design of a high-level language for data flow,
(3) determination of the overall structure of the machines,
(4) configuration of the communication network,
(5) development of a structured memory,
(6) establishment of an activity control system,
(7) development of operating system functions,
(8) creation of countermeasures against troubles and problems of protection,
(9) invention of a structure allowing combination with a conventional machine,
(10) development of a prototype data flow machine,
(11) development of a personal data flow machine, and
(12) combination with the data base management functions.

Like the overall project, the data flow machine project is subdivided into initial, interim, and final stages. The initial target is a modest data flow machine with 16 processors and a memory of 8M bytes. The interim target is a computer incorporating 100 prototype processors with a memory of 100M bytes, a communications network expandable to 1000-10,000 processors, and a performance of 50 MIPS. The final goal is an extra-high-speed data flow machine with 1000-10,000 processors plus a memory of 1G-10G bytes and a performance of 1-10 BIPS.

Distributed function architecture. Here research is to be directed toward the development of a system architecture to combine the new advanced architectures, previously discussed, with the VLSI architectures to be discussed in the next section. There are five themes in this area and they are illustrated in Figure 10.

The role of the subsidiary distributed-function architecture theme is "development of a distributed-function architecture consistently assuring high efficiency, high reliability, simple use and construction, easy

BASIC SOFTWARE SYSTEMS		
KNOWLEDGE-BASE MANAGEMENT SYSTEM	PROBLEM-SOLVING AND INFERENCE SYSTEM	INTELLIGENT INTERFACE SYSTEM

Figure 8. Basic software systems projects.

NEW ADVANCED ARCHITECTURE					
LOGIC-PROGRAMMING MACHINE	FUNCTIONAL MACHINE	RELATIONAL-ALGEBRA MACHINE	ABSTRACT-DATA-TYPE SUPPORT MACHINE	DATA FLOW MACHINE	INNOVATIVE VON NEUMANN MACHINE

Figure 9. New advanced architecture projects.

NEW ADVANCED ARCHITECTURE				
DISTRIBUTED-FUNCTION ARCHITECTURE	NETWORK ARCHITECTURE	DATA BASE MACHINE	HIGH-SPEED NUMERICAL COMPUTATION MACHINE	HIGH-LEVEL MAN-MACHINE COMMUNICATION SYSTEM

Figure 10. Distributed function architecture projects.

adaptability to future technological improvements and the different machine/system levels, and sophisticated functions."[1a] Specifically this is to involve

(1) development of a basic distributed-function system
   (a) establishment of a logic model
   (b) establishment of various architecture systems
   (c) dynamic architectures
   (d) implementation
   (e) special-purpose machine development techniques
(2) development of an experimental distributed-function system
   (a) personal computer
   (b) high-level language machine groups
   (c) local networks
(3) development of an integrated system

VLSI technology. Research into VLSI technology will involve two areas—the development of architectures making full utilization of VLSI and the development of design and processing facilities for all aspects of fifth-generation computer systems from component devices to actual computers (Figure 11). VLSI architecture R&D is to involve the following:

(1) techniques for constructing new advanced architectures (basic study)
   (a) VLSI device rule book
   (b) design question answering system
   (c) architecture data base
   (d) CAD for VLSI architecture
(2) VLSI architectures
   (a) complete one-chip architectures
   (b) functional parts of the architectures
(3) function division and connection techniques

In this area the interim target is a complete one-chip architecture using one million transistors per chip, while the final target is a complete one-chip architecture using ten million transistors.

VLSI TECHNOLOGY	
VLSI ARCHITECTURE	INTELLIGENT VLSI CAD SYSTEM

Figure 11. VLSI technology projects.

SYSTEMATIZATION TECHNOLOGY			
INTELLIGENT PROGRAMMING SYSTEM	KNOWLEDGE-BASE DESIGN SYSTEM	SYSTEMATIZATION TECHNOLOGY FOR COMPUTER ARCHITECTURE	DATA BASE AND DISTRIBUTED DATA BASE SYSTEM

Figure 12. Systematization technology projects.

Systematization technology. Research into so-called systematization technology covers the integration of both basic and applied software, architecture, and devices (Figure 12). In addition it covers the development of techniques relating to the life-cycle of systems: design, development, maintenance, and management.

Perhaps the most ambitious theme in this area is that of the intelligent programming system, which is the "development of a system fetching programs from an algorithm bank (knowledge base) by user requirements and synthesizing a program which meets requirement specifications by inference. Furthermore, the system must verify by a process of inference whether the program generated meets the requirements optimally." Specifically this will involve

(1) modular programming and verification theory,
(2) a theory to specify description and program synthesis,
(3) a system for program verification and synthesis and a program base,
(4) a system to maintain, improve, and manage programs, and
(5) a consultant system for program design.

As an illustration of these, the system for program verification and synthesis has the following goals. Interim targets are (1) improvement through synthesis and conversion of programs for particular fields, which minimizes data-base retrieval, (2) development of a small-scale program base, and (3) generation of a system to verify functional, logic, and data-abstraction programs. Final targets are (1) synthesis of large-scale programs for data base management systems, language processors, etc., and (2) development of a large-scale program base.

Developing supporting technology. In this last area, R&D is to provide supporting facilities for software and hardware components developed by the whole project, specifically

(1) computer networks,
(2) support system for software development,
(3) support system for knowledge-base development,
(4) use of VLSI-CAD as a supporting tool, and
(5) use of personal computers in research and development.

An initial aim is to use VLSI-CAD to construct a number of personal logic computers—to support the other project themes—and to link these computers globally with the aid of the switched network of NTT, Nippon Telegraph and Telephone Public Corporation.

The 26 themes described represent a *first* version of the FGCS plan,[1a] which is intended to cover a wide variety of research fields. The plan will inevitably change as the project progresses. In addition, certain seemingly important areas will not be investigated by the project because they are being investigated by others. For example network architectures are under intensive investigation by NTT in cooperation with Japanese manufacturers, and high-speed numerical computation machines are the subject of another national project called the Supercomputer Project.

Impacts and effects

From the start of its preliminary investigation, the Fifth-Generation Computer Committee considered it important to try to foresee every possible impact that the computer systems will have on society[11] and established the Subcommittee for Research into Social Environmental Conditions. Possible impacts of fifth-generation computers on society include

(a) the elimination of social distortions resulting from differences between low-productivity and high-productivity fields,
(2) the expansion of man's abilities by using machines to amplify human intelligence, and
(3) the management of the deluge of information produced by information technologies.

Fifth-generation computers are envisaged as functioning efficiently in all fields of society.[11] They are expected to improve greatly the current low levels of productivity in fields such as education and medical treatment, as well as in areas of physical labor such as agriculture and fisheries. To date, productivity has largely been improved by increased efficiency in human labor. In future systems, the project states that machines should be concentrated on increasing productivity, and humans should concentrate only on what they do well.

Even today, society appears to be flooded with information. Fifth-generation computer systems will sift and distill this information and present it in an optimum form for human assimilation. Another obvious contribution of the proposed computer systems is the bridging of a gap between individuals and machines. This will stem from the fact that anyone will be able to converse with computers without professional knowledge of the machines. Some of the areas identified by the preliminary investigation[1a] that are likely to undergo significant changes because of fifth-generation computers are office automation, decision support systems, computer-aided engineering, and intelligent robots.

International collaboration

The preliminary research summarized here was undertaken by the Committee for Study and Research on Fifth-Generation Computers under the chairmanship of Tohru Moto-oka of Tokyo University. This committee consisted of three subcommittees[2]: Subcommittee for Systematization Technology (Hajime Karatsu, chairman), Subcommittee for Basic Theory (Kazuhiro Fuchi, chairman), and Subcommittee for Computer Architecture (Hideo Aiso, chairman). The organizing body of these committees is the Electronics Policy Division, Machinery and Information Industry Bureau, Ministry of International Trade and Industry. Its secretariat is the Fifth-Generation Computer Systems Project Group of the Japan Information Processing Development Center. JIPDEC is a nonprofit organization aimed at the promotion, research, and development of information processing and information processing industries in Japan.

From the standpoint of organization and execution, the project must[1a]

(1) play a pioneering role besides being creative in its approach;
(2) look far into the future;
(3) be wide enough to encompass the entire computer industry with all its ramifications, which, it is hoped, will emerge by the 1990's as the mainstay of all industrial activities; and
(4) be internationally oriented.

With regard to the last area, this seems to be the first time in its history that Japan is inviting other nations to participate and share in the results of an R&D project.[12] Basically the Japanese see international collaboration as implying mutual efforts by the different countries of the (western) world to promote further advances in information technology. To this end, the project emphasizes the importance of public relations activities as a means of averting misconceptions about the project abroad and, instead, stimulating enthusiasm in the different countries about its progress.

One of the first initiatives to encourage collaboration was the International Conference on Fifth-Generation Computer Systems,[1] held in Tokyo in October 1981, at which a number of internationally recognized researchers were invited to speak. Further efforts to encourage international cooperation involve governmental talks with the UK, Germany, and France.[12] In addition, foreign researchers are expected to be invited to work in Japan, and foreign research institutions may be entrusted with specific research projects.

In conclusion, the scope and extent of this project will ensure that, even if the initial perceptions and targets of fifth-generation computer systems prove incorrect, the future generation of computers will be identified. It can also be expected that such a stimulating project will generate numerous innovative by-products. Lastly, the project itself may be seen as an interesting test-bed for future high-technology research projects. ■

Acknowledgments

We express our gratitude to the Japan Information Processing Development Center for so readily making available documents describing the Fifth-Generation Computer Systems Project. We thank Tohru Moto-oka, Kazuhiro Fuchi, and Shunichi Uchida, senior members of the committees for fifth-generation computers, for explanations of their project and answers to our questions. We thank Donald Michie of the University of Edinburgh and Brian Randell of the University of Newcastle upon Tyne for commenting on early versions of this paper. Lastly, we acknowledge the UK Science and Engineering

Research Council for funding our own research which falls within the area of fifth-generation computer systems.

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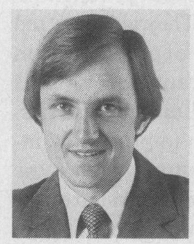

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