22

The Japanese Create a Stir

22.1 The Fifth-Generation Computer Systems Project

In 1982, Japan's Ministry of International Trade and Industry (MITI) launched a joint government and industry project to develop what they called "Fifth Generation Computer Systems" (FGCS). Its goal was to produce computers that could perform AI-style inferences from large data and knowledge bases and communicate with humans using natural language. As one of the reports about the project put it, "These systems are expected to have advanced capabilities of judgement based on inference and knowledge-base functions, and capabilities of flexible interaction through an intelligent interface function."[1]

The phrase "Fifth Generation" was meant to emphasize dramatic progress beyond previous "generations" of computer technology. The *first generation*, developed during and after World War II, used vacuum tubes. Around 1959, transistors replaced vacuum tubes – giving rise to the *second generation* – although the transistors, like the vacuum tubes before them, were still connected to each other and to other circuit components using copper wires. During the 1960s, transistors and other components were fabricated on single silicon wafer "chips," and the several chips comprising a computer were connected together by wires. Computers using this so-called small-scale integration (SSI) technology comprised the *third generation*. In the late 1970s, entire microprocessors could be put on a single chip using "very large-scale integration" (VLSI) technology – the *fourth generation*. The Japanese *fifth generation*, besides its sophisticated software, was to involve many parallel processors using "ultra large-scale integration" (ULSI).

MITI planned to develop a prototype machine, in the form of what computer scientists were beginning to call a "workstation," which was to consist of several processors running in parallel and accessing multiple data and knowledge bases. PROLOG, the computer programming language based on logic, was to be the "machine language" for the system because the Japanese thought it would be well suited for natural language processing, expert reasoning, and the other AI applications they had in mind. Execution of a PROLOG statement involved logical inference, so the machine's performance was to be measured in logical inferences per second (LIPS). In the early 1980s, computers were capable of performing around 100,000 LIPS. The Japanese thought they could speed that up by 1,000 times and more. Later in the project, because of difficulties of adapting PROLOG to run concurrently on many processors, a new logic-based language, GHC (for Guarded Horn Clauses), was developed that could run on multiple processing units.

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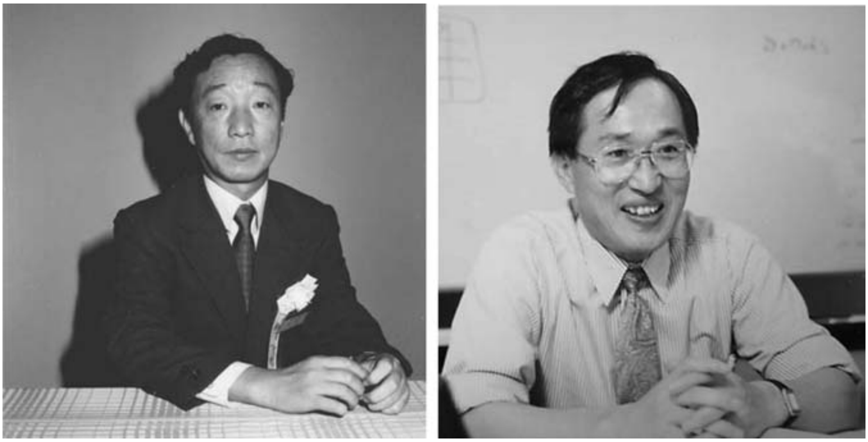

Figure 22.1. Kazuhiro Fuchi (left) and Koichi Furukawa (right). (Fuchi photograph courtesy of Tohru Koyama. Furukawa photograph courtesy of Koichi Furukawa.)

For work on FGCS, MITI set up a special institute called the "Institute for New Generation Computer Technology" (ICOT). Its Research Center, headed by Mr. Kazuhiro Fuchi (1936–2006; Fig. 22.1), was to carry out the basic research needed to develop a prototype system. According to its first-year progress report,[2] the "Research Center started with forty top-level researchers from the Electrotechnical Laboratories (ETL), Nippon Telephone and Telegraph Public Corporation (NTT), and eight computer manufacturers." The project had a ten-year plan: three years of initial research, four years of building intermediate subsystems, and a final three years to complete the prototype. In 1993, the project was extended for two years to disseminate FGCS technology.

Koichi Furukawa (1942– ; Fig. 22.1), a Japanese computer scientist, was influential in ICOT's decision to use PROLOG as the base language for their fifth-generation machine. Furukawa had spent a year at SRI during the 1970s, where he learned about PROLOG from Harry Barrow and others. Furukawa was impressed with the language and brought Alain Colmerauer's interpreter for it (written in FORTRAN) back to Japan with him. He later joined ICOT, eventually becoming a Deputy Director. (He is now an emeritus professor at Keio University.)

The architecture of the planned fifth-generation system is illustrated in Fig. 22.2. Various hardware modules for dealing with the knowledge base, inference, and interface functions were to be implemented using advanced chip technology. The hardware would be controlled with corresponding software modules, and interaction with the system would be through speech, natural language, and pictures.

According to a set of slides by Mr. Shunichi Uchida summarizing the FGCS project,[3] its total ten-year budget was ¥54.2 billion or approximately (at the 1990 exchange rate) $380 million.

During this time, the project made advances in parallel processing, in computer architecture, and in developing various AI systems. Several American and European

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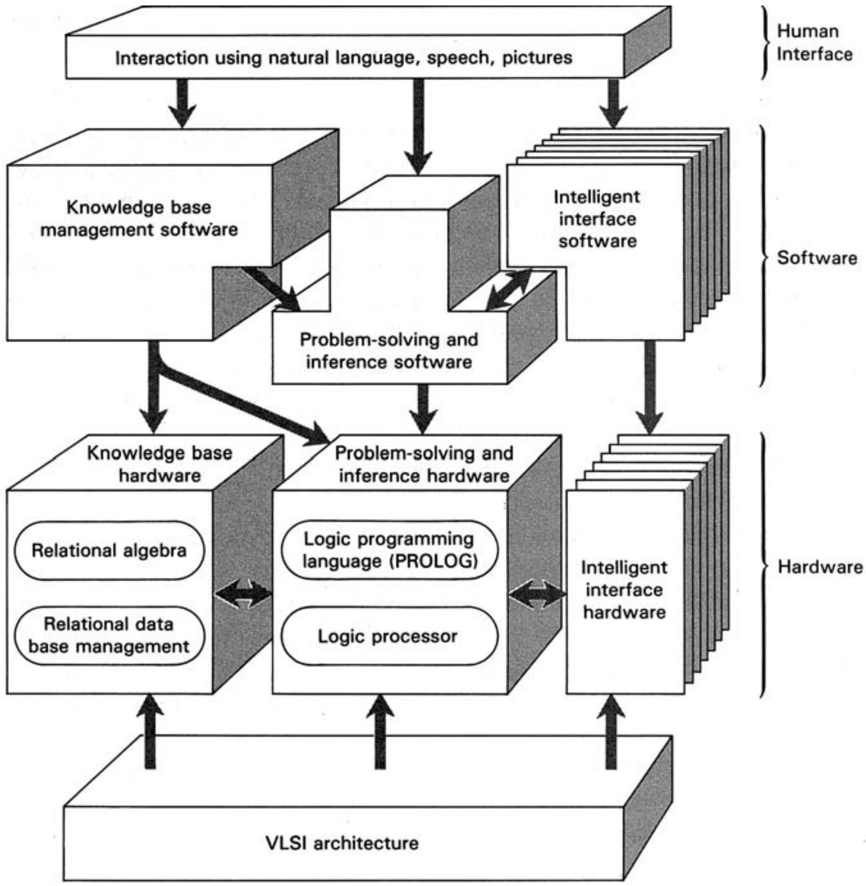

Figure 22.2. Fifth-generation system architecture. (Illustration used with permission of Edward Feigenbaum.)

visitors (especially PROLOG experts) participated in the project as ICOT visitors. Indeed, the Japanese invited international participation in the project. International conferences were held in Tokyo in 1984, 1988, and 1992.[4]

ICOT built a number of "parallel inference machines" (PIMs). The largest of these, named PIM/p, had 512 processing units.[5] (See Fig. 22.3.) Several AI systems were developed to run on these machines. Among these were MGTP (an acronym for Model Generation Theorem Prover), a parallel theorem prover;[6] MENDELS ZONE, a system for automatic program generation;[7] and HELIC-II, a legal reasoning expert system.[8]

Many observers think that most of the results of the FGCS project are now of historical interest only. The software developed did not find notable applications. Improvements in the speed and power of commercial workstations (and even of personal computers) made these superior to the PIMs. Taking full advantage of

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Figure 22.3. The PIM/p parallel computer system. (Photograph from http://www.icot.or.jp/ARCHIVE/Museum/MACHINE/pim-spec-E.html.)

the benefits of parallel processing proved difficult except for special problems susceptible to that style of computation. The development of graphical user interfaces (GUIs) during the late 1980s and 1990s provided acceptable methods for human–computer interaction – reducing (at least for a time) the need for AI-dependent natural language and speech understanding systems. One legacy of the project is the journal *New Generation Computing*, of which Koichi Furukawa was once editor-in-chief. A "Museum" Web page for the FGCS project is maintained at http://www.icot.or.jp/ARCHIVE/HomePage-E.html. The page contains links to several ICOT publications, software, and other information.

A 1993 article, with contributions from several knowledgeable people, reflected about the project.[9] Evan Tick, one of the contributors who had spent time at ICOT, had this to say:[10]

> . . . I highly respect the contribution made by the FGCS project in the academic development of the field of symbolic processing, notably implementation and theory in logic programming, constraint and concurrent languages, and deductive and object-oriented databases. In my specific area of parallel logic programming languages, architectures, and implementations, ICOT made major contributions, but perhaps the mixed schedule of advanced technology transfer and basic research was ill advised.
>
> This basic research also led to a strong set of successful applications, in fields as diverse as theorem proving and biological computation. In a wider scope, the project was a success in terms of the research it engendered in similar international projects, such as ALVEY, ECRC, ESPRIT, INRIA, and MCC. These organizations learned from one another, and

their academic competitiveness in basic research pushed them to achieve a broader range of successes. In this sense, the computer science community is very much indebted to the "fifth-generation" effort.

Separately from what might or might not have been accomplished during the project, announcements about it in 1980 and 1981 provoked similar projects in the United States and in Europe. News about the project was spread by an early document titled "Preliminary Report on a Fifth Generation of Computers," which was circulated among a few computer science researchers in the fall of 1980. Also, an international conference to announce the FGCS project was held in Tokyo in October of 1981.[11]

22.2 Some Impacts of the Japanese Project

22.2.1 *The Microelectronics and Computer Technology Corporation*

The announcements by MITI of plans for a fifth-generation computer system and the formation of ICOT caused alarm in the United States and Europe. The American computer industry, all too aware of growing Japanese dominance in consumer electronics and in manufacturing, worried that its current world leadership in computer technology might be eroded.

William Norris, the founder of the Control Data Corporation, organized a meeting of computer industry executives in Orlando, Florida, in February 1982 to discuss the creation of a research and development consortium. Its goal would be to develop technologies that the member companies could ultimately use in their products. This meeting led in late 1982 and early 1983 to the formation of the nonprofit Microelectronics and Computer Technology Corporation (MCC) in Austin, Texas. Admiral Bobby Ray Inman, a former Director of the National Security Agency and a Deputy Director of the Central Intelligence Agency, was chosen to be its first President, Chairman, and Chief Executive Officer. Among the early joiners of the consortium were the Digital Equipment Corporation, Harris, Control Data, Sperry-Univac, RCA, NCR, Honeywell, National Semiconductor, Advanced Micro Devices, and Motorola. These were later joined by several others, including Microsoft, Boeing, GE, Lockheed, Martin Marietta, Westinghouse, 3M, Rockwell, and Kodak.

The annual budget was planned to be between \$50 and \$100 million – depending on the number of member companies contributing funds and research personnel. At its beginning, MCC focused on four major research areas, namely, advanced computer architectures, software technology, microelectronics packaging, and computer-aided design of VLSI circuitry. AI research was to be carried out (under the eventual direction of Woodrow Bledsoe) as part of architecture research.

Although the member companies did make use of some MCC-sponsored innovations, MCC itself began to decline after the departure of Inman in 1987. By that time, FGCS was perceived as less of a threat, and many of the member companies were having their own financial difficulties. Also, the Internet and the explosive growth and power of personal computers began to eclipse what was going on at MCC. The number of employees fell from its peak of about 400 in 1985 to 58 in June 2000, when the board voted to dissolve the consortium.[12]

22.2.2 *The Alvey Program*

In March 1982, the British government set up a committee "to advise on the scope for a collaborative research programme in information technology (IT) and to make recommendations." It was chaired by Mr. John Alvey, a senior director of British Telecommunications. In its report, issued later that year and titled "A Programme for Advanced Information Technology," the committee noted that the Japanese FGCS project was seen "as a major competitive threat" and that anticipated responses to it by the United States "would create an equal if not greater degree of competition for the UK industry."[13] The report recommended "a five-year programme to mobilise the UK's technical strengths in IT, through a Government-backed collaborative effort between industry, the academic sector and other research organisations. The goal [was to develop] a strong UK capability in the core enabling technologies, essential to Britain's future competitiveness in the world IT market." The four major technical areas identified for support were "Software Engineering, Man Machine Interfaces (MMI), Intelligent Knowledge Based Systems (IKBS) and Very Large Scale Integration (VLSI)." The recommended budget was $350 million, with the government contributing two-thirds of the cost and industry the rest.

In 1983, the UK Government accepted the committee's report and initiated the "Alvey Programme" to carry out the committee's recommendations. A new Directorate, headed by Brian Oakley, Secretary of the Science and Engineering Research Council (SERC), was set up in the Department of Trade and Industry (DTI) to coordinate the program. Sponsorship and funds were provided by DTI, the Ministry of Defence (MoD), SERC, and industry. Among its other accomplishments, the Alvey program helped revitalize AI research in Britain. According to Oakley, "If the Lighthill Report of the early 1970s was paradise lost for the AI community, the Alvey Report of the early 1980s was paradise regained."[14]

The program reached a peak level of funding of around $45 million in 1987 and went on until 1991. It is credited with energizing Britain's computer science community by expanding research and development efforts in both academia and industry. In their excellent summary of the program, published in 1990, Brian Oakley and Kenneth Owen describe Alvey's contributions in AI, parallel architecture, VLSI, integrated circuit CAD, software engineering, and speech technology.[15]

22.2.3 *ESPRIT*

In 1983, the European Economic Community (the predecessor of the European Union) launched its ESPRIT program. (ESPRIT is an acronym for European Strategic Program of Research in Information Technology.) According to Luc Steels and Brice Lepape, who wrote an article focusing on the AI aspects of ESPRIT, its goal was "to foster transnational cooperative research among industries, research organizations, and academic institutions across the European Community (EC)."[16] It was also a European response to the Japanese FGCS program.

ESPRIT was set up to support research in three major categories, namely, microelectronics, information processing systems (including software and advanced information processing), and applications (including computer-integrated manufacturing and office systems). Information processing, where most AI research was to be supported, was further divided into knowledge engineering, advanced architectures (including computer architectures for symbolic processing), and advanced system interfaces (speech, image, and multisensor applications).

It was anticipated that the ESPRIT project would go on for ten years and would be divided into two phases, ESPRIT I and ESPRIT II. (Later, a third phase was added.) The initial budget for ESPRIT I was 1.5 billion ECUs. (The euro replaced the ECU in January 1999 at one ECU = one euro.) Funds would be provided equally between the EC and the project participants. The budget for ESPRIT II was more than double that of ESPRIT I. According to Luc Steels and Brice Lepape, by 1993, the program had "more than 6,000 scientists and engineers from about 1,500 organizations working on ESPRIT projects across EC and European Free Trade Agreement countries."

Rather than being directed in a top-down manner by program managers, the projects funded by ESPRIT resulted from proposals submitted by individual investigators and organizations. The proposals were reviewed by a distributed team of experts. The program encouraged proposals that emphasized "transnational cooperative networks," industrial activities, and short-term gains. ESPRIT collaborated with Alvey in supporting some research in Britain.[17]

ESPRIT supported several AI-related projects. Among these were ones that developed various knowledge-based systems, logic programming environments, natural language parsing systems, and knowledge acquisition and machine-learning systems. As one example, I might mention the "Machine Learning Toolbox" (MLT). It was a package of machine learning techniques from which developers could select and assemble algorithms appropriate to specific kinds of tasks. Partners in its development included teams from France, the United Kingdom, Germany, Greece, and Portugal. The article by Steels and Lepape presents a thorough summary of AI efforts supported by ESPRIT.[18] ESPRIT's accomplishments helped to overcome some of industry's reluctance about AI.

While on the topic of national efforts in AI, I'll mention the German Research Center for Artificial Intelligence (DFKI, which stands for Deutsches Forschungszentrum für Künstliche Intelligenz). It was established in 1988 and continues to conduct research in all areas of AI. More information about it can be obtained from its Web page at http://www.dfki.de/web/welcome?set_language=en&cl=en.

In the United States, a DARPA program analogous to Alvey and ESPRIT got underway in the early 1980s. It was partially a response to the Japanese FGCS project, but it also owed much to the observation that the time was ripe for a major program that would take advantage of ongoing technical developments in communications technology and in computer hardware and software. I'll describe the DARPA program in the next chapter.

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Notes

1. “Research Report on Fifth Generation Computer Systems Project,” ICOT Progress Report, March 1983. [277]
2. *Ibid.* [278]
3. Shunichi Uchida, “FGCS Project: Knowledge Information Processing by Highly Parallel Processing,” Institute for New Generation Computer Technology (ICOT), Tokyo, Japan, undated. Available online at http://www.icot.or.jp/ARCHIVE/PICS/OHP/Uchi1-FGohpE.pdf. [278]
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5. For a Web page describing the various PIMs, see http://www.icot.or.jp/ARCHIVE/Museum/MACHINE/pim-spec-E.html. [279]
6. See, for example, Ryuzo Hasegawa, Miyuki Koshimura, and Hiroshi Fujita, “MGTP: A Parallel Theorem Prover Based on Lazy Model Generation,” *Automated Deduction – CADE-11*, Lecture Notes in Computer Science, Proceedings of the 11th International Conference on Automated Deduction, Berlin/Heidelberg: Springer-Verlag, 1992. [279]
7. See, for example, Shinichi Honiden, Akihiko Ohsuga, and Naoshi Uchihira, “MENDELS ZONE: A Parallel Program Development System Based on Formal Specifications,” *Information and Software Technology*, Vol. 38, No. 3, pp. 181–189, March 1996. [279]
8. See, for example, Katsumi Nitta *et al.*, “HELIC-II: Legal Reasoning System on the Parallel Inference Machine,” *New Generation Computing*, Vol. 11, Nos. 3–4, pp. 423–448, July 1993. [279]
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10. *Ibid*, p. 99. [280]
11. See, for example, T. Motooka *et al.*, “Challenge for Knowledge Information Processing Systems (Preliminary Report on FGCS),” *Proceedings of the International Conference on FGCS*, JIPDEC, pp. 1–85, 1981. [281]
12. For a history of the first ten years or so of MCC, see David V. Gibson and Everett M. Rogers, *R & D Collaboration on Trial: The Microelectronics and Computer Technology Corporation*, Cambridge, MA: Harvard Business School Press, 1994. [282]
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14. Brian W. Oakley, “Intelligent Knowledge-Based Systems – AI in the U.K.,” in Ray Kurzweil, *The Age of Intelligent Machines*, Cambridge, MA: MIT Press, 1990. Available online at http://www.kurzweilai.net/articles/art0308.html?printable=1. [282]
15. Brian Oakley and Kenneth Owen, *Alvey: Britain’s Strategic Computing Initiative*, Cambridge, MA: MIT Press, 1990. [282]

16. Luc Steels and Brice Lepape, "Knowledge Engineering in ESPRIT," *IEEE Expert*, Vol. 8, No. 4, pp. 4–10, August 1993. [283]
17. At this writing, there are still abundant Web pages about ESPRIT. They are available from http://cordis.europa.eu/esprit/home.html. [283]
18. Luc Steels and Brice Lepape, *op. cit.* [283]