FOUNDATIONS OF FIFTH GENERATION COMPUTING

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Abstract -- The Japanese initiative in establishing a program for the development of a fifth generation of computers has triggered off responses throughout the world. This paper establishes a framework for fifth generation developments by considering the economic, social and technical foundations from a number of perspectives.

L'initiative Japonaise établissant un programme pour le développement d'une cinquième génération d'ordinateurs a entraîné des réponses dans le monde entier. Cet article établit une grille d'analyse pour les développements de cinquième génération en considérant leur fondements économiques, sociaux et techniques à partir de plusieurs perspectives.

An Information Age?

For many years we have been told that we are on the brink of an **information age** [10], a **post-industrial society** [3], in which we shall establish different relationships to one another, and to our environment, based on computer and communications technology. Toffler advances the concept of a **third wave** following previous agricultural and industrial waves:

> "Without clearly recognizing it, we are engaged in building a remarkable new civilization from the ground up... It is, at one and the same time, highly technological and anti-industrial." [56 p.10]

He rationalizes much of the turmoil around the world as "agonies of transition" between two civilizations and, in relation to the individual, notes:

> "Caught in the crack-up of the old, with the new system not yet in place, millions find the higher level of diversity bewildering rather than helpful. Instead of being liberated, they suffer from overchoice and are wounded, embittered, plunged into sorrow and loneliness intensified by the very multiplicity of their options." [56 p.224]

This emphasis on choice presents a different view of the problems of the information age from those we have come to expect, that computers will be used to restrict our freedom or replace us in the work-place. In **The Conquest of Will**, Mowshowitz fears that computer-based information systems will lead to:

> "..the alienation of individual responsibility which results from excessive bureaucratization of decision-making" [44 p.x]

and Laudon in **Computers and Bureaucratic Reform**, whilst noting the limited impact of computer, concludes:

> "the information systems we describe...illustrate the use of a new technology to further the political aims and interests of established and limited groups in society." [34 p.311]

Fears about job-displacement go back to the early years of computing. Wiener's prophetic statements of 1950 on **The Human Use of Human Beings** are coming uncomfortably close to reality today:

> "the automatic machine...is the precise economic equivalent of slave labor. Any labor which competes with slave labor must accept the economic conditions of slave labor. It is perfectly clear that this will produce an unemployment situation, in comparison with which the present recession and even the depression of the thirties will seem a pleasant joke" [62 p.189]

He is also concerned about political abuse and quotes a Dominican friar, Dubarle, reviewing his earlier book, **Cybernetics** in **Le Monde** December 28, 1948:

> "conceive a State apparatus covering all systems of political decisions...In comparison with this, Hobbes' **Leviathan** was nothing but a pleasant joke. We are running the risk nowadays of a great World State, where deliberate and conscious primitive injustice may be the only possible condition for the statistical happiness of the masses: a world worse than hell for every clear mind." [62 p.209]

Wiener discounts Dubarle's fears but notes the:

> "real danger...that such machines, though helpless by themselves, may be used by a human being or a block of human beings to increase their control over the rest of the human race" [62 p.212],

a fear which is prevalent today and is leading, or has led, to highly restrictive legislation governing the access to, and use of, data kept on computers [58]. A Luddite movement against computers is also conceivable and Weizenbaum's book on **Computer Power and Human Reason** has much in it to excite such a response:

> "Science promised man power. But, as so often happens when people are seduced by promises of power...the price actually paid is servitude and impotence." [61]

These words echo Butler's remarks of nearly a century ago about a previous era of high technology:

> "The servant glides by imperceptible approaches into the master; and we have come to such a pass that, even now, man must suffer terribly on ceasing to benefit the machines." [5]

Cause or Effect?

However, is information technology a cause of social problems or part of societies' response in solving them? We live in an increasingly over-crowded world where resources are stretched to their limits and all aspects of our existences have become inter-dependent. The **Club of Rome** reports have drawn attention to the perils involved [48], and there are technologies, such as bio-engineering, that pose far greater threats than does computing [7]. Information technology may be necessary to our survival and the problems that we attribute to it many side-effects of coping with increasingly complex world dynamics. Thus our concerns about information technology must be set in the context of a model of society as a whole if we are to begin to discern cause and effect.

The German sociologist Luhmann in his work on **Trust and Power** encapsulates the dynamics of society by postulating **complexity-reduction** as the fundamental motivation for all our social institutions:

> "The world is overwhelmingly complex for every kind of real system... Its possibilities exceed those to which the system has the capacity to respond. A system locates itself in a selectively constituted 'environment' and will disintegrate in the case of disjunction between environment and 'world'. Human beings, however, and they alone, are conscious of the world's complexity and therefore of the possibility of selecting their environment -- something which poses fundamental questions of self-preservation. Man has the capacity to comprehend the world, can see alternatives, possibilities, can realize his own ignorance, and can perceive himself as one who must make decisions." [37 p.6]

Luhmann's model seems to underly De Bono's optimism about the role of computers in **Future Positive:**

"By great good fortune, and just in time, we have to hand a device that can rescue us from the mass of complexity. That device is the computer. The computer will be to the organisation revolution what steam power was to the industrial revolution. The computer can extend our organizing power in the same way as steam extended muscle power..... Of course we have to ensure that the result is more human rather than less human. Similarly we have to use the computer to reduce complexity rather than to increase complexity, by making it possible to cope with increased complexity." [9 pp.18-19]

Evans has argued in **The Micro Millenium** that the computer has already impacted our society as a force for good in preventing war by replacing the optimism of Generals with the cold reality of war-game predictions:

"whenever the data involves confrontation between nuclear powers, the unequivocal message that spills out - to both sides - is: You will lose!" [14 p.212]

Brod in **Techno Stress** points to the human cost of the computer revolution in terms of personal life, noting:

"our devotion to the new machine prevents us from seeing the possible consequences of spending long hours - in work and at play - with a machine" [4 p.3]

It is into this debate between pessimism and optimism, between added complexity and controlled complexity, that the next stage of computer development has been introduced: the Fifth Generation computer that will be ubiquitous, accessed and programmed by all. It is a development that cannot be understood outside this social context because it is both formed by it and a major force in forming it.

The Shock of the Fifth Generation

As computer professionals we are part of information technology, familiar with the computer and perhaps comtemptuous of it, those who fear it and those who see it as savior; the VAX11/780 and IBM PC do not seem party to such high drama. However, one attraction of the technology is surely the element of surprise, that each new journal and magazine shows us something existing today that we felt was some years away. No matter how we adapt to the pace of change, its acceleration always causes it to be a step ahead of us. The most recent example of this was the Japanese announcement in 1981 of a development program for a **fifth generation** of computers [43,27,52], integrating into systems advances in very large scale integration, computer architecture, database management systems, artificial intelligence (AI), and the human computer interface (HCI). It may be difficult to recapture now the shock of this announcement: it was unforeseen, from an unexpected source, gave a status to AI research that was yet unrecognized in the West, and proposed a confluence of technologies that were still seen as quite distinct.

The response to Japan's fifth generation initiative has now taken place and around the world resources have been allocated to responsive competing activities [55,26]. We may rejoice in the funding and status now accorded frontiers computing science, but we should still remember our own surprise at the announcement. Does it presage the third wave and information age? AI was oversold in the 1960s and there was a backlash in the 1970s; is the fifth generation being oversold now and will there be a backlash? How can we avoid the surprises in future; is there a better model of the technological, economic and social dynamics underlying the development of information technology? What are the implications of achieving the fifth generation goals?

These questions are of key relevance to planning the fifth generation and responses to it. In establishing such activities we are engaged in both predictive and normative technological forecasting. Past forecasts for the computer industry have proved notoriously wrong. Some promising technologies have not matured. Some have advanced much more rapidly than expected. In addition new and unexpected technologies have emerged. In general overall trends have occurred well before predicted dates. Can we learn any lessons from this history in planning current programs? If we cannot predict how do we manage the change, unexpected failures, and unexpected opportunities? Will spin-offs outside the program be more important than the goals achieved within it?

This paper provides a framework for discussing these questions by examining fifth generation computing from a number of different perspectives, historical, social, economic and technical. We are in a time of fundamental change in the impact of computing on society, and unusual perspectives can help us to focus on the key issues for the computer industry.

Fifth Generation Objectives

There appears to be some confusion in Western publications between two Japanese computer development programs. The **National Superspeed Computer Project** is an 8 year project started in January 1982 by the Scientific Computer Research Association, a consortium of the national Electro-Technical Laboratory and six Japanese computer companies. The objective is a machine with 10 billion floating point operations a second (10 BFLOPS) and one billion bytes memory with a speed of 1.5 billion bytes a second. The most likely technology is the high-electron mobility transistor (HEMT), with Josephson junction devices an alternative. Thus, the outcome of this project could be machines highly competetive with successors to the Cray-1 and Cyber 205, and concern has been expressed about the erosion of the US position in supercomputers [1,6,63].

The **Fifth Generation Computer Project** was started in April 1982 and has a far broader base, a longer term and less specific objectives. ICOT, the Institute for New Generation Computer Technology, has 40 research staff seconded from industry and close links with a number of university projects on artificial intelligence, its technology and applications, both in Japan and abroad. The objective is:

"knowledge processing systems" using "latest research reults in VLSI technology, as well as technology of distributed processing, software engineering, knowledge engineering, artificial intelligence, and pattern information processing" and contributing "to the benefit of all humankind." [28 p.1]

ICOT policy is determined by a Main Committee chaired by Moto-oka of Tokyo University, a Social Needs Sub-Committee chaired by Karatsu of Matsushita, an Architecture Sub-Committee chaired by Aiso of Keio University, and a Theory Sub-Committee chaired by Fuchi, the Director of ICOT. The short-term objective of current work at ICOT is tools production, notably a Sequential Inference Machine (SIM) working at 30 KLIPS (logical inferences a second) operating in December 1983, and a Parallel Inference Machine (PIM) using dataflow techniques scheduled for late 1984 and ultimately capable of working at 1 GLIPS [32].

Thus, whilst Fifth Generation machines may be justly termed "supercomputers", they are not targeted against current machines but are rather the necessary support to a new generation of knowledge processing systems. The only comparable machines are the various Lisp machines of LMI, Symbolics and Xerox [45], which currently occupy only a small and specialist market

niche. There has been concern expressed about the Fifth Generation Project which recognizes its knowledge engineering content [15], but in much of the press coverage the classical supercomputer and the knowledge supercomputer have been lumped together as the 5th generation, and the essential differences between them have been lost.

It is easy to understand why the Japanese would wish to compete with the USA in the well-established world market for supercomputers. However, it was a shock to Western computer science world when Japan overnight legitimated artificial intelligence research by making it a central theme of their Fifth Generation Project. If we lose the distinction between the two types of supercomputer we also lose this sense of shock and the curiosity to understand the significance of the logic behind their decision.

Surplus Chips and the Pull of the Consumer Market

The dominant objective of the fifth generation proposals is not the classical supercomputer but a more subtle one at the HCI, the **ease of use of computers by people.** As Moto-oka notes:

"In these systems, intelligence will be greatly improved to match that of a human being, and, when compared with conventional systems, man-machine interface will become closer to the human system." [43 p.7]

and Karatsu reiterates the HCI theme:

"Until today, man had to walk toward the machine with effort to fit precisely. On the contrary, tomorrow, the machine itself will come to follow the order issued by man." [43 p.106]

However, ease of use is not a primary objective in its own right. One can see it as satisfying a market need to make computers more attractive and more widely used. Behind this need, however, is a deeper "need for a market" that stems from VLSI chip over-production. We shall soon have a surplus of chips that can be absorbed only by the worldwide consumer market.

Many people attempting to buy certain processor and memory chips today will find the concept of a surplus ludicrous. However, scarcity in the latest devices is brought about by the extreme price competition in small computer systems currently. Simplistically, that all micros are much the same hardware and differentiated primarily by cost. 64 Kbyte ram's and processors with inbuilt dma and communications make a big difference to board size and manufacturing cost. The newest devices will always be in great demand and short supply. For the previous generation of devices history suggests there will be a price war between suppliers because of over-supply.

This over-supply problem will worsen with increasing power of the coming generation of chips. The increasing number of gates in modern VLSI is achieved through decreasing element size that increases speed. Increases in complexity and increases in speed are positively correlated rather than subject to trade-off. Hence the potential power of modern ic's has already become extremely high. The problem is to know what to do with this power. Processor, memory and support chips account for the bulk of high-volume demand, with communications and graphics forming a second tier [13]. The $12 billion turnover of the semiconductor industry corresponds to some 25 chips a year for every person in the world; about one million transistor equivalents a person a year.

We are manufacturing more and more of a product whose power is already great and increasing. The professional markets absorb much of this capacity now, but only the consumer markets can support it in the long term. However, computer technology as yet plays only a minor role in these markets; one limited by the technical skills required of computer users. The thrust of the fifth generation is to overcome this limitation and make computers accessible to all by moving from information processing to knowledge processing, and from a machine-like interface to a human-like interface by speech, writing and vision.

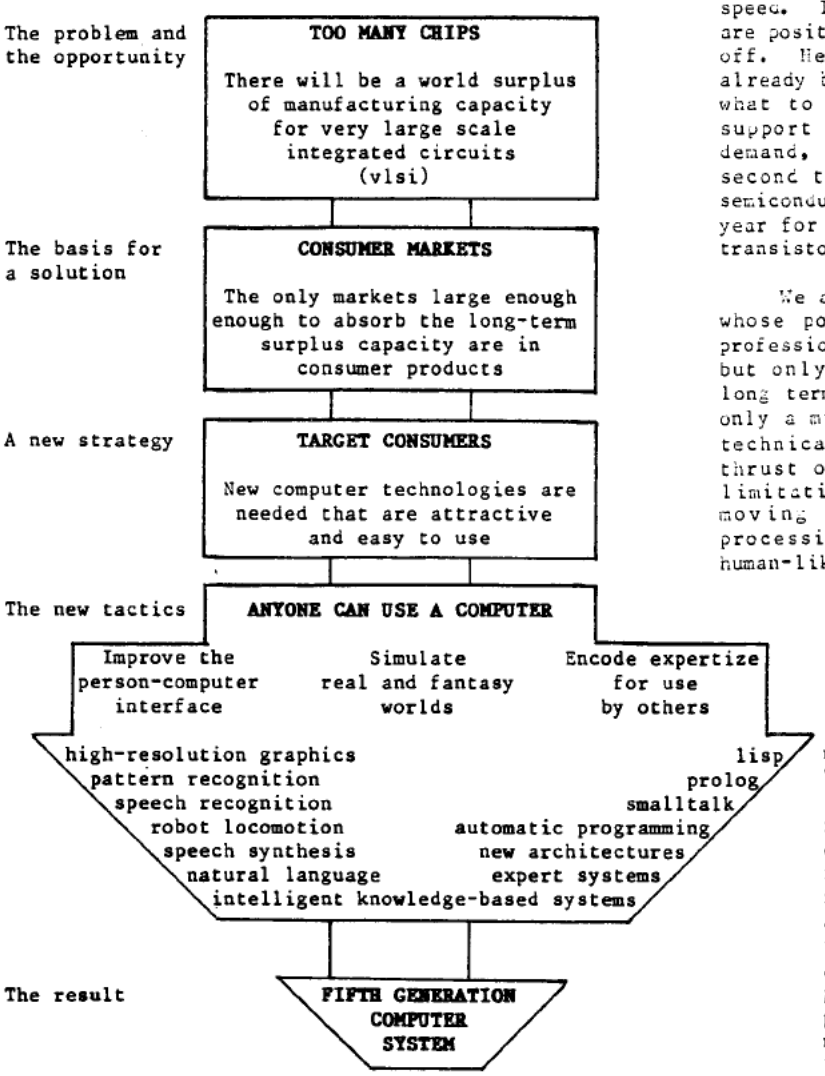

Fig.1 Logic behind fifth generation computer development

Fig. 1 shows the economic logic behind the fifth generation and the way this leads to the specified technical program [20]. The surplus capacity for chips is resolved by targeting consumer markets and this requires that anyone can use a computer and has the motivation to do so in a domestic context. This requires improvements to the human-computer interface, realistic simulation of real and fantasy worlds and the capability to encode expertize for use by others. These requirements then lead to projects for speech recognition, graphics, knowledge-processing and so on. The customizability of computers is an important feature that must not be lost and yet the volumes involved are too large for professional programming. Hence automatic programming in some form or another is also necessary. Thus the logic of the market place leads to the projects which form the fifth generation program.

Thus, the dramatic swing of computer technology into the consumer market through the advent of the personal computer will go very much further as the fifth generation objectives are achieved. There will clearly be spin-offs of technology into the military, scientific, industrial and commercial markets but these will be side-effects of the main thrust rather than the primary target. The social impact of fifth generation computing will be a universality of computer technology operating at the level of the mind of man. The key to commercial success in this technology will lie in understanding this impact and the new markets that underly it.

The following sections are concerned with perspectives on fifth generation computing that give a basis for this understanding.

Forecasting the Generations

The surprise at the Fifth Generation announcement was due to failure in technological forecasting (TF). We did not foresee AI technology being so central on the time scales scheduled by the Japanese. Such failures are common in all areas of TF [22] and have been prevalent in the computer industry from the early days when a few machines were seen as adequate for all needs. It is worth examining analyses of the early generations and forecasts about the fourth and fifth generations to look for the basis of success and failure in prediction. Withington's [65] analysis of ten years ago is particularly interesting because he is describing 3 generations and predicting the fourth, which we now know about, and the fifth, which we are also predicting ten years later. Fig. 2 presents his analysis in tabular form.

Withington's retrospective of the first three generations shows that they may be distinguished by hardware, software or use, since all three are correlated. His description of the fourth generation then coming into use emphasizes large file stores and satellite computers which came about as database and distributed systems technology. Virtual machine software also came about but did not have as much impact as expected. Other articles of the mid 1970s emphasize "universal emulators" and the need for each generation of hardware to be able to run the software of all previous generations. Many manufacturers experimented with such emulation of competitors machines but it has not become widely adopted, possibly because of software copyright and licensing problems. This was also the era of hardware/software unbundling.

Withington's projections of the fifth generation, like all at that time, fall far short of target. Magnetic bubble technology lost out to advances in semiconductors. Interactive languages and convenient simulation were a major part of the fourth generation thrust. Part of the reason for his failure in TF is that the three generations up to the fourth had been defined by IBM in introducing new families of machines. The third-generation 360, however, was upgraded to the 370 with little change in basic architecture and this has continued with the 3030, 4300 and 3000 series where greater power and cost-effectiveness has been the rule rather than architectural innovation. Some have doubted that there has been a fourth generation:

> "if the concept of computer generation is tied directly to advances in technology, we are faced with an anomalous situation in which the most powerful computers of 1979-1980, the CDC Cyber 176 and the CRAY 1, would have to be assigned to the second and third generation, respectively, while the most trivial of hobbyist computers would be a fifth-generation system." [49]

		Hardware	Software	Effects
1	1953 Ghee -58 Whizz !	Vacuum tubes & delay lines	None	Technicians & fears of automation
2	1958 Paper -66 Pushers	Transistors & magnetic cores	Compilers & I/O control	Proliferation of EDP groups & rigidity
3	1966 Commun- -74 icators	Large-scale integrated circuits & interactive terminals	Operating systems & commun-ications	Centralization of EDP as new function
4	1974 Inform- -82 ation Custod- ians	Very large file stores & satellite computers	Virtual machines	Redistribution of management functions
5	1982 Action - Aids	Magnetic bubble, & laser holo-graphic & distributed	Interactive languages & convenient simulation	Semi-automatic operating decisions

Fig. 2 Five generations as seen in 1974

This remark captures the essence of the problem of TF, for the business cycles underlying generations are related to market forces selectively emphasizing innovations in technology, not vice versa [29]. The market forces are themselves generated from social dynamics, and the technology is only a correlational, not a causal, variable. An early paper on the fourth generation in 1968 makes a plaintive remark which is another clue to the nature of computer generations:

> "Today, programming has no theoretical basis and no theories. Why? Programming need not remain a handicraft industry. The designers of fourth generation computers must regard programming as a science rather than an art." [59]

After the second generation advances in the science of programming became more significant than the refinement of computer architectures. The multi-tasking, time-sharing operating systems and database management systems of the third generation were the significant waves of new technology; they led to penetration of the market for integrated corporate information systems and computer utilities. The personal computer, word-processor, spread-sheet and games of the fourth generation led to penetration of markets for low-cost personal resources for work and play.

Withington's titles for each generation are very evocative. The 1950s were an era of "ghee whizz computers can do anything." This was necessary to support the act of faith by their users that one day they might become cost-effective. It took at least one more generation for this to happen. His name for the fifth generation is surprisingly apt; expert systems are certainly "action aids", and they will be used for "semi-automatic operating decisions." It is again an act of faith today that they, and other developments coming out of AI will become cost-effective in a wide range of applications. Withington was able to project the function of the fifth generation better than its technology because it is the continuous evolution of social needs that determine the function whereas the technology is searched out from any available and may change discontinuously.

AI Research Through the Generations

The new constituent of fifth generation systems is the central role of developments in AI and it is useful to see these developing through the generations [16]. Fig. 3 is a retrospective view of the generations based on an extensive list of significant events in computing. Generations 0 through 4 show an 8-year cyclic pattern that corresponds to the medium-term Juglar business cycle [2], and this has been projected to 5 and 6. At the beginning of each generation a new systems technology comes into existence and at the end it is mature. The technology depends upon correlated advances in a number of sub-systems technologies with variation in which one is innovative at each stage. Withington's names have been retained for all but the fourth generation which has been retitled **personal resources** to subsume both database access and the personal computer. The zeroth generation was certainly **up and down,** mainly down, and the sixth generation is seen as approaching the partnership of Licklider's man-machine symbiosis [35].

AI research existed in each generation but its tactics changed markedly from one to another. The cybernetic approach of generality and simplicity dominated generations zero through three [42], but by the end of the third generation it was recognized as an oversell and there was a paradigm shift [33] away from neural nets and learning machines to knowledge representation and performance [23]. AI researchers reacted to the failure of systems based on brain-like mechanisms and switched effort to creating human-equal performance by any means. There was also an over-reaction suggesting that the research was a waste of resource leading to the attacks of Dreyfus [11], Lighthill [36] and Weizenbaum [61].

However, the performance paradigm produced breakthroughs such as SHRDLU [64], MYCIN [51] and ROBOT [24], and the fourth generation ended with widespread acceptance of the commercial possibilities of AI: that natural language interaction with computers was possible in commercial systems; and that expert systems encoding human expertise could be used to enhance human decision making in medicine and oil prospecting. The Fifth Generation proposals are based on these results and propose to take them to their logical conclusion under the pressure of the forces towards the consumer market already noted. This generation commenced in 1980 with the commercial availability of Lisp machines and will be completed in 1988 as this technology becomes widely available at low-cost and high-speed, and is exploited in the consumer market place.

The projection of the sixth generation from this table should involve new sub-system technologies which are under investigation now, such as optical logic and organic processing elements [57]. The AI component will move down from the cortical knowledge-processing level of the brain to the limbic attention-directing level which is only now beginning to be studied in cognitive science [47] and manifests itself in human emotions and awareness [21].

Computing as a New Medium

The previous section has attempted to comprehend fifth generation developments by extrapolating them from within a framework of 8 year business cycles. It is a phenomenological approach that only hints at underlying causes. Another approach is that of analogy - rather than extrapolate computing technology can we find an existing analogy for its function in society and reason from that. One possibility is to see the computer as providing a new medium for communication [20,50].

	General Features	State of AI Research
0 1940 -48	**UP AND DOWN** Vacuum tubes replacing relays COLOSSUS, ENIAC	**MIND AS MECHANISM** Logic of neural networks Behavior, purpose and teleology
1 1948 -56	**GEE WHIZZ** Tubes, delay lines and drums BINAC,EDSAC,ACE, WHIRLWIND,UNIVAC,EDVAC IBM 701, 702, 650 Numeric control Airborne navaids **Human Use of Human Beings**	**CYBERNETICS** Turing test Design for a Brain Homeostat Gray Walter's Tortoise Chequers player
2 1956 -64	**PAPER PUSHERS** Transistors and core stores I/O control programs IBM 704, 7090, 1401 NCR 315, UNIVAC 1103 PDP1, 3, 4, 5 FORTRAN, ALGOL, COBOL Batch processing Execs, supervisors CTSS, MAC, JOSS **Communications of ACM** Petrinets	**GENERALITY & SIMPLICITY** **-- THE OVERSELL** Perceptron, GPS, EPAM Learning machines Self-Organizing Systems Dartmouth AI conference Mechanization of Thought Processes symposium IPL V, LISP 1.5
3 1964 -72	**COMMUNICATORS** Large-scale ic's Interactive terminals TSS 360 IBM 360, 370 CDC 6600, 7600 PDP6, 7, 8, 9, 10 DBMS, Relational model Intel 1103, 4004	**KNOWLEDGE REPRESENTATION** Semantic nets, PLANNER ELIZA, Fuzzy sets, ATNs Dendral, Scene analysis Resolution principle Machine Intelligence 1 First IJCAI **I.J. Man-Machine Studies** **Artificial Intelligence**
4 1972 -80	**PERSONAL RESOURCES** Personal computers Supercomputers, VLSI Very large file stores Databanks, Videotex IBM 370/168 - MOS memory & virtual mem. Intel 8080 NS PACE 16-bit micro Altair & Apple PC's Visicalc **Byte** magazine	**PERFORMANCE BY ANY MEANS** **REACTION & OVER-REACTION** Prolog, Smalltalk Frames, scripts Systemic grammars LUNAR, SHRDLU, MARGIE LIFER, ROBOT MYCIN, TEIRESIAS Dreyfus, Lighthill and Weizenbaum attacks on AI **Cognitive Science**
5 1980 -88	**ACTION AIDS** Personal computers with power & storage of mainframes plus graphics and speech processing Networks, Utilities OSI, NAPLPS standards IBM 370 chip, Intel iAPX 32-bit micro HP-900 chip with 450,000 transistors Apple Macintosh	**ENCODED EXPERTISE** **-- COMMERCIALIZATION** Lisp and Prolog machines Expert system shells Knowledge bases EMYCIN, AL/X, APES Japanese Fifth Generation project **Handbook of AI** Japanese Personal Sequential Inference Machine and Parallel Inference Machine
6 1988 -96	**PARTNERS** Optical logic and storage Organic processing elements AI techniques in routine use	**MODELING** **-- EMOTION & AWARENESS** Massive parallel knowledge processing Audio & visual sensors with capacity ear & eye Multi-modal modeling

Fig. 3 Seven generations as seen in 1984

We can see this analogy by asking is there anything fundamentally new in expert systems? Has not the purpose of work on computer systems always been to encode human expertize for later reproduction? An accountancy program may be seen as the recording of the expertize of an accountant for use by a businessman. An auditor evaluating the program may expect to be able to ask it those questions he would ask the accountant, for example, from what original information did you calculate this figure? If the program does not have built into it audit trail facilities which enable it to answer such questions then it is inadequate in exactly the same way that an accountant would be who could not answer that question -- it is a simulation of an incompetent accountant. This is more illuminating than just describing it as a poor program.

In retrospect we may see expert systems as being a more accurate term for what we have so far called computer science; a name that defines the objectives rather than the tool used to achieve it. After all we do not have pencil science but rather literature. The change of name is very significant, however, because it draws attention to the nature of the computer as a **medium** to encode and reproduce expertize. Media developments have played major roles in the growth of society and culture. It also helps to explain some of the phenomena associated with personal computing, for example that programs are being marketed using the same techniques that have been effective for program material in previous media such as books and gramophone records.

The computer differs from previous media in being two-way and interactive. Books and television are primarily one way media. They are not able to support two way conversations. They do not allow us to interact with the author of the book or with the events being portrayed. We can think of computer programs as being a way of extending **interaction** through time and space. When I listen to a gramophone record I can imagine I am at a concert hearing the artist perform. When I read a book I can imagine that I am hearing the words spoken to me by the original author, or that I am seeing and hearing what he describes. Similarly, when I enter into a dialog with a computer program I can imagine that I am interacting with a person or world the programmer has simulated. Unlike the performer or the author, the simulation is able to provide responses to my interventions -- in some way to **interact** with me although the person simulated may be far distant or dead, or may never have existed.

This emphasis on interactive simulation ties in with the notion of virtuality in computing. This is an important technical concept in third and fourth generation systems [60] and Nelson [46] has suggested that it underlies all applications of computing, that we simulate a virtual world. Smith made it the key design concept of his **Pygmalion** system [53] and later the Xerox Star [54]. Media reify the world of knowledge and create an ecology of knowledge [66] within the knowledge environment [19]. Thus, media are vital to the knowledge economy [39] in enabling knowledge products to be instantiated in concrete form, and the computer out-performs all other media by instantiating action as well as facts.

Fifth generation computer developments can now be seen as the logical completion of the computing medium to be comparable in all its capabilities with other media such as television. All new media have had initial limitations and gone through phases of improvement and development. The wax cylinder gramophone could not sustain the record industry of today and neither could Baird's spinning disk support television as we now know it. The personal computers of today already provide an impressive new conversational medium for entertainment, education and business. However, they cannot yet compete with television in their audio and video facilities. We can only converse with them by typing at keyboards, not through speech. They can give access to vast stores of information but they are not able to process it as knowledge.

These limitations severely restrict the scope of the new medium as it is now and it they are precisely what the fifth generation computer development program addresses. Fifth generation computers, if the objectives of the program are met, may be characterized as providing a two-way, interactive medium with the audio-visual facilities and knowledge processing to replicate all capabilities of the most advanced current one-way media.

Computing in the Hierarchy of Needs

All of the preceeding arguments extrapolate trends, whether in computing or in media, to provide a framework for fifth generation computing. They do not provide an underlying causal model that might indicate how the technology will be used: in commercial terms where the markets will be; in social terms what the consequences will be. One possible perspective from which to view the causal dynamics is that of Maslow's hierarchy of personal needs which gives the dynamics of individual motivations and priorities [40]. The logic of his hierarchy is that upper level needs are of low priority until lower level ones are satisfied. We need to satisfy basic biological needs before we are concerned with safety, and only when we are safe are we concerned with belonging and so on.

Maslow's theory is subject to debate [33] but it gives a logic for the social infrastructures that support individual needs. The left column of Fig. 4 shows his hierarchy of needs, and the centre column shows those social systems that have been set up to aid the individual in satisfying his needs. The right column shows the roles that computers have played in supporting these social systems. The two lowest levels account for the impetus behind the first three

INDIVIDUALS	SOCIO-ECONOMIC INFRASTRUCTURE	COMPUTERS
Self-actualization	Realizing personal potential. Facing life as it is. Aesthetics. Peak experiences.	Tools in hands of individuals to give new perspectives.
Esteem	Role in family, work and community. Other recognized achievements (artistic, horticultural).	Tools in hands of individuals to perform role better.
Belonging	Family, work, religion, politics, entertainment.	Networking, bulletin boards, games.
Safety	Social norms, police, military, medicine, insurance.	Command and control, crisis decision-making.
Basic biological needs	Agriculture, energy, housing, ecology, finance, physical communications	Planning, management and control

Fig. 4 Needs hierarchy, social support and the computer

generations of computers. They have been used commercially to support the industries necessary to basic biological needs and militarily to support safety. The levels above are all new markets that have opened up only with the fourth generation and personal computers. It is these levels that provide the new markets for fifth generation systems as they come to saturate those at the lower levels.

The hierarchy of needs model has some interesting consequences. It suggests a divergence between 1st world and 3rd world priorities in the use of computers. For countries where food and energy crises still exist the use of computers in agriculture, energy, communications, and so on, will be the main priority. For the developed nations the use at the lowest levels is taken for granted and the levels of belonging and esteem are where the fifth generation markets lie. The logic at these levels is also significant in the analysis of job displacement. Esteem is enhanced if computers provide the capability to do a task more effectively but not if the perceived role is undermined, e.g. to that of servant to a machine. This is the conflict between those who see the computer as a tool to enhance life and those who see it as destroying the social fabric.

Conclusions

The sense of shock at the Japanese fifth generation computer development program was a reliable indicator that we are moving into a new phase in the social impact of computing. Many economists are suggesting that the 1980's will be a time of major change as we move into the downwave part of a long-term cycle in which our society will be re-structured [2,41,12]. The computer is playing a major role in that re-structuring and we in the information industry need to understand this and our roles in it. Technology-based forecasts alone will tell us little about the future and we need to examine it from a number of other perspectives each of which provides the basis for some partial understanding.

This paper has examined views of the social impact of computing and sought to give a framework from which the bases of opposing arguments can be derived. Computer generations follow the basic 3-year business cycle and we may extrapolate the patterns of change but gauge little of their logic. The analogy of computing as a new medium of communication places it in on a long-term trend line outside the computer industry and rationalizes the technical objectives of the fifth generation. Examination of computer applications in terms of individual needs and the social structures that supports them indicates the probable nature of new markets for fifth generation systems and hence their applications and social consequences.

Finally, it is reasonable to be parochial and ask what is the implication of this for Canada? The USA, UK and EEC have already made plans for fifth generation programs in response to that of Japan. The USA sees a danger of being by-passed by Japan in the computer industry as it has in the car and video recorder industries [8,17,18,30,31,67]. The UK is in a similar position to Japan as an island nation with limited resources that needs to export and sees information technology as vital to its future [25]. Canada is rich in basic resources and already trades these for much of its high technology requirements. It does not have the resources to compete in high technology on a broad front. Should it attempt to do so at all and, if so, in what areas? There is no easy answer but the model of computer development presented in this paper leads to some conclusions:-

1. It is important to understand the pattern of social change underlying developments in high technology. We will be involved in these changes whether we wish it or not, and it is easier to control their consequences and take advantage of them is we can foresee them.
2. The optimum use of world resources leads to specialization with Japan taking a lead in high technology under the pressure to export knowledge products since it has limited natural resources.
3. The most significant danger of allowing Japan to become the major source of high technology is over-dependence on a single source of supply under conditions where world scenarios may change. Canada has to determine whether the triple sourcing of the USA, Japan and EEC is adequate and can be maintained, in deciding where it should attempt to establish internal sources of supply.
4. Fifth generation systems will impact all industries and those businesses that do not take full advantage of them will find it increasingly difficult to compete. It is important for Canadian industry to become an educated consumer of high technology and apply it to the benefit of current industries.
5. To understand the technology requires some depth of involvement with it, certainly in applications, and possibly in development even if this has no direct commercial benefits. Any strategy must take this into account.
6. Where development is undertaken with the intention of direct commercial applications it must be "rifle-shot" into well-specified markets, preferably based on strong home markets.
7. Canada's primary industries, such as oil, forestry and agriculture, are major home markets for knowledge products. They are also significant third world industries where there is export potential, for good-will as well as currency.
8. Canada's bureaucracy is expensive for a country with its population and forms another major home market for knowledge processing systems.
9. The new Western markets for leisure, job enhancement and personal development at the upper levels of the hierarchy of needs have a massive growth potential. Language and cultural barriers make it unlikely that Japan will be able to provide the "software" to be distributed through the new computing medium for these markets. Canada, with its pluri-culturalism, has the possibility of supplying these markets world-wide.

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