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The Computing World

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THE COMPUTING WORLD

by

J. P. Angelone

FORWARD

The computer is a revolutionary technology that is a part of every one's daily life. Pioneers in the 1800s and the early 1900s set forth the foundations for today's modern computer. The evolution of computers has brought us powerful intelligent machines that simplify research, machine operation, business accounting and put man in outer space. Over time computers have shrunk in size but became much more powerful in capability. This is primarily due to the introduction of the integrated circuit. Integrated circuits called microprocessors are the hearts of today's computer. This is where the technology is most rapidly advancing and competitive. Just over the last ten years' microprocessors have realized 100 times increase in capability. Japan and the United States are the world leaders in this technology. Are computers going to replace humans? Today's artificial intelligence applications are stretching the limits of today's computers. They may very well replace humans via use of neural networks and "fuzzy" logic.

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THE COMPUTING WORLD

INTRODUCTION

Computers are overtaking the world. Computers perform tasks for which we take for granted. Many of these tasks are mundane such as accounting, personal records, banking, automatic teller machines and bar code reading cash registers. Not so mundane tasks are where computers excel -- weapon launch controls, electronic fuel injection for automobiles, computer aided design, robotics, and many others.

The modern era of computers started in the late 1940s by three countries: the United States, Great Britain and the Soviet Union.[1] The initial uses of computers were for military weapons computations. Soon to follow in the United States businesses started to use them. Colleges started acquiring computers in the 1960s. Over time computers have become smaller and faster. What has driven the development of computers? Where did the technology come from and where is it going? What countries and companies are the industry leaders?

I am going to explore these and other questions. I will walk through the evolution of computers, the technology aspects and applications such as software and artificial intelligence.

EVOLUTION OF COMPUTERS

As I mentioned the modern era of computers started to evolve in the late 1940s. This however was not the beginning of computers. Joseph Marie Jacquard built the first programmable type machine in 1804.[2] He built an automated punch card machine to operate weaving looms. This was the first use of programmed instructions for a machine. The concept was of great importance to modern computers.

In the 1840s Augusta Ada, the Countess of Lovelace, translated and wrote several scientific papers regarding Charles P. Babbage's ideas on an analytical engine problem solving machine.[3] Babbage, "the father of computers," developed ways to store results via memory devices. Ada was his assistant and further refined his ideas. She recommended use of a binary system (1s and 0s) vice decimal system for storage. The Countess also developed the "loop," which is an automatic repetition of a series of calculations. All programmers today use this valuable concept.

Later George Boole followed the binary concept and developed "Boolean Logic."[4] The logic consisted of answering mathematic questions affirmatively or negatively. He adapted the binary system by assigning 1s for positive and 0s for negative answers.

Dr. Herman Hollerith built the first electromechanical card punched data processing machine in the 1880s.[5] His machine tabulated the 1890 census. Later his Tabulating Machine Company became part of IBM.

These pioneers set the stage for today's modern computer. The boom really started around 1940. As weapon launch calculations became labor intensive, computers became necessary to aid in the number crunching. John Atanasoff and Clifford Berry built the first general purpose digital computer in 1939.[6] Its purpose was to solve linear algebraic equations. Interestingly when Atanasoff contacted IBM about his machine they expressed no interest. During World War I Konrad Zuse built Germany's first operational general purpose computer. He later wanted to improve it by using vacuum tubes instead of electromechanical relays and use it to decode enemy wartime codes. Fortunately Adolph Hitler refused to fund the project because he thought the war would be over before Zuse would finish the machine. The British ended up receiving a smuggled replica of the German message-scrambling device. Alan Turing applied vacuum tube technology to the device and greatly increased the processing speed of the machine.[7] He also in 1950 built the first programmable digital computer.

Many of the United States industries rallied to support the war effort. IBM supported Howard Aiken in developing a general- purpose programmable computer to calculate cannon shell trajectories.[8] Many businesses started to use computers for their own purposes in the 1950s. The early modern computers were large, crude and slow by today's standards. A single computer typical for a business or school would take the space of an entire basement or floor of a building. Technology however was advancing rapidly. Since the 1950s, modern computers have evolved through four generations and the fifth one is just over the horizon.

COMPUTER GENERATIONS

There are five generations of modern computers.[9] We currently are at the tail end of the fourth generation and the fifth one is just around the corner. I will briefly discuss each generation and their characteristics.

The first generation of computers covers the period from 1951 to 1959. These machines used vacuum tubes, magnetic external storage devices (tape and drums) and punched cards both for input and output. The computers were programmed via machine and assembly languages. These were not high level languages. Changing programs involved resetting relays and wiring manually. First generation computers were very large, generated a lot of heat from the vacuum tubes and required human operators to change the programs.

Transistors, magnetic disks and high level languages characterized the second generation of computers (1959-1965). Transistors replaced the vacuum tube. They were smaller, generated less heat and each one could replace several vacuum tubes in a circuit. In addition to punched cards, use of magnetic tape became another option to input information into the computer. MIT developed magnetic core (disk) storage devices. Finding data was more rapid on these external storage devices. High level languages such as FORTRAN and COBAL allowed computer programming without resetting relays and wiring. Computers were therefore becoming flexible, smaller and more capable. Human operators were necessary only to feed a deck of punched cards through the card reader.

The period 1965 to 1971 marks the third generation of computers. Integrated circuits, operating systems, monitors and keyboards were the trademarks of this generation of computers. Integrated circuits were actually complete semiconductor circuits on pieces of silicon. One "chip" replaced as many as 1000 transistors and several circuit cards. Chips were primarily responsible for computers becoming smaller, more efficient and reliable. The operating system emerged in this generation of computers. Operating systems controlled the computer and its resources. Now computer operations could perform at processor speeds vice at human speeds. Thus operating systems meant that human operators were no longer necessary. Monitors and keyboards evolved and became the data input and output medium of choice. It was also during this period that IBM set an industry standard and introduced the "family of computers" concept with the IBM 360 series. Companies now could grow into a larger system as their requirements grow. Programs were transportable across any one of the "family" computers.

We presently are at the tail end of the fourth generation of computers. The evolution of the microprocessor and uses of magnetic disks as the media for internal storage of data highlight this generation. This does not look like much to have been in this generation for twenty years. However both of these technologies are significant and weigh heavily on all future computers. These technologies led directly to the microcomputer or better known as the desktop and laptop computers. The development of very large scale integration (VLSI) chips added the microprocessor to several thousand transistors on a single chip. I will discuss later circuit technologies and the role that microprocessors play in the future. Magnetic disks have become the medium of choice for internal and external storage of data. The disks are becoming smaller, more dense and have larger capacities. Today's disk drives are typically 3.5" wide, 1.5" high and can hold up to 1 gigabyte of data.

The fifth or future generation of computers involves artificial intelligence (AI). This means that computers will think and reason like humans. There are several components of AI such as: expert systems, natural language processing, neural networks, robotics, vision and speech. Work has begun in all of these areas. I will discuss AI in a later section in more detail.

CIRCUIT TECHNOLOGY

Throughout the discussion of the generations of computers one main item that was the centerpiece in each generation was the evolution of circuit technology. We evolved from vacuum tubes, to the transistor, to the integrated circuit and finally to microprocessors. Each of these significantly reduced the size of the computer, increased processing speed and improved reliability. Each technology had its own advantages. Before jumping to microprocessors I'll provide a brief description of each one.

Vacuum tubes replaced electromechanical relays. This all electric circuit increased computer processing speed by one thousand.[10] The vacuum tubes used in computers were about the size of a light bulb and very fragile. Transistors on the other hand were smaller, made of semiconducting material and generated less heat than vacuum tubes. They were more reliable, less fragile and could replace several vacuum tubes in a circuit.

Integrated circuits really started the trend towards miniaturization. Discovered in the late 1950s and mass produced in 1962, these circuits or "chips" contained 1000 transistors as well as resistors and capacitors all etched on silicon chips.[11] IBM was the first computer to use integrated circuits. These circuits are many times smaller (measured in microns--1/1,000,000 of an inch) and can replace many circuit cards. The real boon to miniaturization however was the development of the microprocessor.

The development of very large scale integration (VLSI) chips in the mid-1970s added the microprocessor to the integrated circuit. A microprocessor is a chip that contains arithmetic and logic functions in addition to memory on the same integrated circuit chip. This combining of several chips had a major impact towards miniaturization. This directly led to reduction in the size of computers. Today's 80286 processor based desktop computers are as capable as the IBM 360 of the 1960s. The size of a desktop computer today takes up a corner of the desk. Also there are laptop and palm computers.

The processing chip (microprocessor) is the heart of the computer. In the early 1980s the Department of Defense pursued very high speed integrated circuits (VHSIC).

The main purpose was to develop more dense and faster integrated circuits for the military.[12] The industry viewed this as dual purpose and planned applications to industry. Thus during the 1980s the microprocessor really started taking off in capability. One measures a microprocessor's performance in terms of clock speed, millions of instructions per second (MIPS) and number of transistors on the chip.[13] The clock speed is the speed (in terms of frequency) at which the chip process's information. MIPS is a measure for performance of the chip independent of the chip application. Among other things, the clock speed of the processor is the basis for MIPS. The number of transistors on the chip is a measure of chip density.

During the 1980s chip density and performance grew tremendously. For example, IBM introduced the personal computer in 1981. The computer used an Intel 8086 processing chip with a clock speed of 4.77 megahertz (MHz), processing at 0.050 MIPS and packed with 7,000 transistors. During the 1980s Intel produced faster and more capable chips as displayed in table 1.

Processor Chip	Clock Speed	MIPS*	Number of Transistors
8088	4.77, 6 MHz	0.050	15,000
80286	6, 8, 10, 12 MHz	0.125	110,000
80386	20, 25, 33 MHz	0.16	150,000
80486	25, 33 MHz	3.0	1,500,000
note -- MIPS is based on the initial clock speed of the processor			

TABLE 1

Sometime in the later half of 1992 Intel will introduce the 80586 microprocessor packed with 5,000,000 transistors and will process at 8.0 MIPS. As you can see the processing chip growth in capability during the past 10 years is phenomenal.

Intel is not the only chip manufacturer. Other companies are copying or producing their own versions of processing chips. The chip industry is large and worldwide competitive.

CHIP WARS

The chip industry is an intensely competitive and lucrative market. Most of the competition is between American and Japanese companies. The American leaders are Intel and Motorola. The Japan leaders are Hitachi, Fujitsu and Toshiba. The competition is fierce not only in the microprocessor world but also in the dynamic random access memory (DRAM), or dynamic RAM, chip world.

First lets review the microprocessor world. Intel introduced the first microprocessor, the 4004, in 1972.[14] This processor was a 4-bit chip. I am referring to the bus structure (architecture) of the chip. A bit is a binary digit, a 1 or 0. The bus is the electrical path that the data flows within the circuit. Therefore the Intel 4004 was a 4-bit wide data bus microprocessor. Referring back to table 1 you can see the progression of chips that Intel introduced during the 1980s. The 8086 and 8088 chips, actually produced in the late 1970s, are 8-bit microprocessors. In 1982 Intel introduced the 80286 chip, which is a 16-bit processor. The 80386 and 80486 chips introduced in 1985 and 1989 respectively are 32-bit processors. What is the big deal about the 8 or 16 or 32-bit bus structures? The answer is: the wider data bus allows more data to flow through the processor per a given clock cycle. This equates to faster and more powerful microprocessor's. Since the mid-1980s almost all the industry focus has been on perfecting the 32-bit processor.

As Intel was developing their chips and successfully selling them to among others the IBM personal computer community, Motorola was developing and producing their own version of the microprocessor.[15] Motorola answered Intel with a 68000 chip to counter the 8086 processor. They followed this 8-bit chip with a 16-bit chip called the Motorola 68010. Motorola's 32-bit entry was in the summer of 1984 with the 68020 and later the 68030 chip. The 68020 required two separate co-processors called the memory management unit and the floating point unit (commonly called the math co-processor).[16] The 68030 chip integrated the memory management unit, but all the co-processors became integrated on the 68040 chip introduced in the late 1980s. This chip is roughly equivalent to the Intel 80486, which also was the first Intel chip to integrate the floating point unit. Apple computer and NeXT computer are the main American users of the Motorola chips in computer designs. Japanese computers, however, are also using Motorola chips in their designs. In the mid-1980s Motorola executives estimated that 70% of Japanese computer designs were using their 68000 series chips.[17] Like Intel, Motorola's focus from the mid-1980s centered on the 32-bit processors.

Many American firms entered the 32-bit processor frenzy in the 1980s. National Semiconductor, Texas Instruments, Fairchild and RCA are just a few examples.[18] While America was hot and heavy regarding microprocessors, Japan was a late comer particularly in the 32-bit chip architecture. As of May 1986 NEC was the only Japanese firm that had indicated plans to manufacture a 32-bit processor.[19] Hitachi was delaying production on their processor, the Micro 32, hoping they could reach agreement with Motorola and become a second source for the 68020 chip.

Much of the Japanese industry was focusing on the TRON (The Real-time Operating-system Nucleus) processor. Intel and Motorola incorporated this technology, developed by Ken Sakamura of Tokyo University,[20] in their 8086, 80286 and 68000 chips respectively. The difference is that the Intel and Motorola use CMOS (Complementary Metal-Oxide Semiconductor) architecture for their chips. The full benefit of TRON occurs on chips designed with TRON architecture, taking advantage of the high speed real-time task switching. Unfortunately Japan was entering the market too late to introduce a new technology 32-bit processor.[21] Intel and Motorola had at least two or more years head start with their 80386 and 68020 processors. Performances of the Hitachi and Fujitsu TRON chips were expected to outperform their American rivals with anywhere from 6 -- 20 MIPS.[22] Even with this much performance these Japanese chips will not take a big portion of the world market.

In 1986, Intel and Motorola were the microprocessor market leaders. Together they and National Semiconductor had over 70% of the market.[23] The prevailing thought in 1986 was that the trends would continue with American companies maintaining at least 90% of the market into the 1990s. As of the fall of 1989, Japan had not produced a major breakthrough microprocessor design, thus still not capturing a significant share of the market.[24] Even with Japan competing for a portion of the remaining 10% of the market their microprocessor revenues exceeded $1 billion in 1986.[25]

The competition is drawing closer together. Digital Electronics Corporation (DEC) just officially announced on 26 February 1992 its Alpha microprocessor.[26] This chip is a 64-bit microprocessor that will deliver 400 MIPS at a clock speed of 200 MHz.[27] Referring back to table 1 you can see that this by far exceeds capability of the microprocessors available today. DEC expects to produce this chip by the end of the year. They feel that this is their most significant product introduction since the VAX computer. This should put some interesting pressures on Intel and Motorola. These two market leaders need to look over both shoulders as Japan is now entering this market. NEC announced on 3 February 1992 that it will sell engineering samples of their 64-bit microprocessors.[28] The thing that killed Japan's chance to overtake the microprocessor market before was their late entry into the 32-bit market by as much as two years. They basically are hitting the 64-bit market in step with the United States. The 1990s should prove interesting in the microprocessor market.

While the United States is currently enjoying the top of the microprocessor market (the only semiconductor market for which we do lead), Japan has a strong lead in the DRAM market. DRAMs are memory chips that interface between the central processing unit (microprocessor) and the fixed or floppy disk storage devices. When a computer accesses a software application, it reads and stores the executable files of the application in RAM. As the processor needs information it accesses the RAM and reads the necessary information. When the processor finishes its task it writes the necessary information back to the RAM. Upon completion of the application the RAM writes the changed files back to the fixed or floppy disk storage devices thereby saving the changes.

Similar to the microprocessor, chip density is a sign of the RAM chip performance. One defines chip density in terms of storage capacity on the chip. In the mid-1980s RAM chips had a storage capacity of 256k (kilobits). Today's chip densities are in the 1- and 4- megabit capacity.[29] The other measure of chip performance is the speed in nanoseconds. The earlier chips ran at 100 nanoseconds. The chips of today run as fast as 53 nanoseconds, however 60 and 70 nanoseconds are more common. Faster RAM speed is necessary to keep up with the faster microprocessors. IBM, Toshiba, NEC, Hitachi, and Fijitsu are the leaders in this market. All of these companies are racing to introduce the 64-megabit chip by 1994.[30]

This race is for a very lucrative market.[31] The first chip samples of the 4-megabit RAM were available in 1988. The peak production year will be 1994 with sales at $10.5 billion. The 64-megabit samples will be available in 1994 and sales will peak in 2000 at $25 billion. Japan owns the market share. They have owned 70% or more of the market since 1985.[32] There are many reasons for this, the main one being the development of exotic machines to manufacture the chips. The Japanese industry made this move in the 1970s with government subsidies.[33] In the 1980s they brought their improved quality chips to the United States suppliers. They cut chips' prices to below cost and bought 70% of the DRAM market in the United States. It was a bold move in that initially they lost $4 billion, however it did pay off in the long run.[34]

Intel may win back some of the market share via "flash memory" chips. One of the disadvantages of DRAM is that when you turn off your computer you lose all the data stored in RAM. RAM chips are volatile. This is fine as long as you write the RAM contents to the fixed or floppy disk prior to turning off the machine. However you lose all the data stored in RAM in the case of a power shortage or being too quick at the power switch. Flash memory is essentially a non-volatile RAM chip. You will not lose the information stored on the chip when you turn the power off. The beauty of this story is that Toshiba introduced the chip in 1986, but an American firm perfected the chip. Intel has won a dominant share of the "flash memory" market.[35] Intel now owns 85% of the over $100 million flash memory chip market. Intel just formed a partnership with Sharp to manufacture and develop flash memory products.[36] Intel and Sharp feel that this market will exceed $1.5 billion by 1995.

All these developments in chips and other hardware advances are only part of the computer story. Computer applications are where the rubber meets the road. There are all kinds of computer applications in terms of software, hardware and combination of both. I'm going to address the use of computers from the Artificial Intelligence perspective that conventionally is the fifth generation of computers.

FIFTH GENERATION -- The Future

Artificial intelligence is the future or next generation of the computer. With artificial intelligence this generation of computers will act, talk, think and reason like humans. This is a very large and interesting aspect of the computing world. I'm going to provide an overview of artificial intelligence by addressing expert systems, neural networks, and fuzzy logic.

Expert systems have been around for quite awhile. An expert system is a knowledge base of information on a particular subject combined with a rule base and an inference engine. A knowledge engineer develops the knowledge base. The engineer is an expert on the subject matter such as taxes. The expert, we'll call him Fred, develops a series of questions and answers based on his expertise in the field. This is the knowledge. Fred then develops an if-then rule base, which is a situational set of rules. By this I mean, for example, that if a person makes over a certain amount of income, then a certain set of tax laws would apply such as the tax rate, Individual Retirement Account eligibility, etc. The inference engine is the problem solving part of the system. The engine will chain through the set of rules based on user inputs to a series of questions, thus providing a final answer. Another way of stating all of this is that the "expert system mechanizes a series of questions into the knowledge base distilled from an intelligent source, usually a person."[37]

A couple of examples will show the power of expert systems. DEC developed an expert system in the late 1970s called XCON.[38] XCON helps configure DEC's line of VAX and PDP-11 computers. DEC uses this system to accurately configure the more than 7,000 products manufactured in plants worldwide. By the mid-1980s, XCON configured more than 90,000 systems with an accuracy of 98%. DEC developed another expert system to help with sales. XSEL helps the sales staff create accurate and properly defined system orders. The system interfaces with XCON's knowledge to ensure the customer is receiving properly configured equipment.

Another famous expert system is MYCIN. Stanford University developed this system in the 1970s.[39] This was a research project aimed at helping physicians in detecting bacteria infections and meningitis. MYCIN recommended treatment options as well. Another well-known expert system is the Internal Revenue Service (IRS) free telephone help service. The majority of the country's taxpayers are familiar with this service. What is not apparent is that the agent helping the taxpayer uses an expert system to derive an answer to their question. Finally, expert systems were in the Gulf War. An example is TOPSS (Tactical Operational Planning Support System). This is a system that supports division-level tactical operation planning by aiding staff officers in developing alternative courses of action.[40]

There is a limitation with expert systems. The limitation is that they operate within a finite specification. The knowledge base defines the specification of the system. The expert system cannot alter its product with the use of information outside the knowledge base. For these reasons expert systems are not very easily adaptive to changes in knowledge. When new information is available quite often the rule base must change. This can be a major project as large expert systems can have over 4,000 rules. Neural networks, on the other hand has the ability to learn from new information and make change to its rule structure.

Neural networks try to emulate the pattern recognition process of the human brain. A neural network consists of layers of neurons: an input layer, several middle layers and an output layer.[41] These interconnected layers work in parallel. A network trains itself by associating certain inputs to certain outputs. In this process neural networks develop weighting factors for each connection. As new information feeds into the network new weighted connections develop, thus learning from these new inputs. One way to program neural network is to feed in the input characteristics of a problem and provide the network several case studies. The network can learn from the case studies. Thus neural networks develop their own set of rules and modify them based on any new information as an iterative process.

AVCO Financial Services performed a study of 6000 loans they made using a conventional computer system to qualify loan applicants. AVCO found that by processing their loans via a neural network loan qualification system their profits would have increased by 27%.[42] Another company, Hecht-Nielson Neurocomputers, developed a character recognition system.[43] This system, IDEPT, processes business loans. Neural networks are gaining wide use. People are developing networks to predict the stock markets, forecasting prices, analyze medical tests and many other applications. These are software projects. Recently the Defense Advanced Research Project Agency (DARPA) awarded a contract to Science Applications International Corporation to develop neural chips.[44] DARPA expects these chips to form neuron-based pattern recognition systems when interconnected. The emphasis of this 1990 contract is to develop hardware to determine the advantages of neural network software.

However, artificial intelligence software and hardware integration began with fuzzy logic. The technology was born in the United States in 1965 by Lofti A. Zadeh.[45] Fuzzy logic combines the two schools of artificial intelligence mentioned earlier -- expert systems and neural nets.[46] They key to fuzzy logic is a set of highly flexible rules. Fuzzy computers can adapt to change, unlike the expert system, but they cannot reprogram themselves like a neural network. Fuzzy logic can accommodate shades of gray in the black and white world of digital computers. This can be a very powerful development. Japan is leading the world in this technology.

Japan is applying this technology via chips to its industry. The Sendai subway is the first application. Fuzzy logic controls the braking and acceleration of the trains in such a smooth manner that no one uses the hanging straps.[47] More applications are in use such as fuzzy logic auto focusing cameras, 600 cycle washing machines with only a start button, and air conditioners that cool a room faster if an infrared sensor detects people in the room. American industry is starting to wake up regarding fuzzy. One American firm, Togai Infralogic, is producing chips. IBM, Hewlett-Packard and Rockwell are studying fuzzy logic.[48]

Fuzzy logic is an important development if computers are going to take on human characteristics such as vision and speech recognition used in robotics. The current problem with intelligent mobile robots is their response time and the ability to handle a multitude of inputs. Take vision for example. Most of the research so far deals with vision algorithms that handle a single picture. For a robot to be truly mobile it must process a stream of different images. Fuzzy logic will aid the robot in processing a multitude of images hopefully fast enough to be effective.

There are many other aspects to artificial intelligence, which I will only mention in passing. These are natural language processing, voice recognition and virtual reality. Of these three virtual reality is the most intriguing. Virtual reality is a technology that allows a person to be in one place but see, touch and communicate with people or objects at an entirely different location. This technology will allow doctors to operate on their patients from their office while the patient is lying on the hospital operating table.

SUMMARY

Man has been in space because of the computer. You and I can take money out of our bank accounts without talking to another human being. We can get answers to our tax questions via usage of an expert system, which is an artificial intelligence application of a computer. Our daily lives are simpler because of the evolution of the computer.

The early pioneers paved the way for today's modern computer, from large simple arithmetic calculating machines to small complex and powerful integrated circuit computers. Jacquard, Babbage and Lovelace set the computer programming foundations. Boole established binary logic. Atanasoff and Berry developed the first digital computer. Konrad Zuse built the first operational general purpose computer followed closely by Alan Turing and his programmable digital computer. These pioneers thus launched the modern era of computers beginning in the late 1940s.

There have been four generations of computers. A fifth one is around the corner. Machine technology characterizes the change in each of the first four generations. The technologies range from different data storing devices, to the transition from hardware to software programming, and the rapid change in circuit technology.

The heart of the computer is the microprocessor. Born in the 1950s the microprocessor is the most active and rapidly changing part of the industry. Since 1980 alone the increase in microprocessor density and capability has been more than 100 fold. The industry leaders are the American firms Intel and Motorola. However, NEC in Japan is lock step with the United States firms in the introduction of the 64-Bit microprocessor.

The other key component of the computer is the RAM chip. Currently Japan companies are the industry leaders. However I feel in the future American firms will gain in this area. I'm thinking primarily of the flash memory chip which Intel is starting to produce.

The real power of computers will be from the evolution of the computer fifth generation. This is the artificial intelligence generation. Computers will take on human characteristics. These characteristics include reasoning, vision and speech recognition, which is necessary for robotics. Neural networks provide the reasoning capability for programs or computers. Computers will have the ability to learn from their mistakes. Fuzzy logic will provide the software and hardware integration to enhance reasoning, vision and robotics.

The computing world will remain a technology active industry for the future. The world infrastructure has a need for increased computer speed, capacity and capability. All industries today can benefit from more powerful computers. The use of computer controlled machines are already a part of every one's daily lives and will become more so in the years to come.

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