Moore's Law and Knowledge Management

INTRODUCTION

For many people who work in knowledge management, the numbers that describe the speed, size, and number of components of computer hardware have long since lost their meaning. If a number is already large (or small) beyond comprehension, making the number larger or smaller does not add to our understanding.

But, we use computers to write documents, find documents, and to access the Internet. Changes to computers, and in the Internet, will continue to change things we do every day.

Because computers have a great effect on our lives, our jobs, and our businesses, it is important to have some feel for the changes that occur in computes. Also, there is a very steady progression in these changes in computers. This steady rate of increase will help us in projecting that the changes we have personally seen in computers will continue at about the same rate for a considerable time into the future.

This white paper shows the statistics for Intel microprocessors that have been introduced over the past thirty years. The numbers are presented in a table so that a non-technical person can get a feel for the changes that have occurred over a period of three decades. In general, each of the statistics has increased by a factor of ten thousand. The processors are ten thousand times faster, the processors have ten thousand times as many transistors, and the transistors used to build the processors have shrunk in size by a factor of ten thousand (a factor of one hundred in each of the X and Y linear dimensions.)

Moore's Law

In 1965 Gordon Moore, now Chairman Emeritus of Intel, observed that the capabilities of integrated circuits tended increase at a regular percentage rate per year. At the time, the number of transistors on an integrated circuit was doubling approximately every eighteen months. This regular percentage increase has come to be known as Moore's law. It is described in great detail at: http://developer.intel.com/pressroom/archive/speeches/gem93097.htm

Will It Stop?

The study of the History of Technology shows that when a given technology stops providing a regular percentage increase in capability each year, a new technology takes its place and continues to provide a regular increase in capability each year. An example is the rate of speed increase that continued when trains were replaced by airplanes as the fastest means of travel.

Examples of Moore's Law

There are many examples of Moore's Law, one of which is the increase in the capabilities of microprocessors shown in this white paper. (Please see below.) Others exist in fiber optics, magnetic disks, and nano-technology (see http://www.Foresight.org)

Disappearing Costs

In document management, changes in computer technology have caused many system costs to decrease below the level of notice. For example, the cost to email a page is no longer a consideration. Many costs will soon drop below the level of notice, for example, the cost of delivering video over the Internet to desktops and into the home.

Quality of Information

Some costs, such as providing access to useful information will never follow the decreasing costs of technology. This is because the integrity of a knowledge management system requires management by a person. The person ensures that the knowledge stored has been checked for accuracy, for quality.

However, to the extent that technology can eliminate the need for people to perform mechanical tasks, thus freeing people to spend time managing the quality of information, the decrease in the cost of technology can help to improve the quality of information on which business and personal decisions are based.

The end use of information is to make decisions. For good decisions, the information must be available and locatable, and the information must be correct.

Conclusion

Having a feel for changes that are occurring in computer technology can be valuable in planning the future of the use of information in many types of businesses and jobs in knowledge management.

Changes in computes affect different parts of the knowledge management industry to different degrees. Understanding the value of applying computing power to different jobs in knowledge management will help planners project the rate of change in each part of knowledge management.

Computers can contribute directly to the availability and locatability of information. Computers can contribute indirectly to the quality of information by freeing knowledge workers from mechanical tasks so that the knowledge workers can concentrate on managing the quality of the information being made available.

Computer technology should continue to contribute to rapid changes in knowledge management for a very long time to come.

Sidebar: Limit on Internet Growth

Many physical systems have a limit to continuous growth. For example, in the United States, the number of persons using the Internet can only double one more time because one more doubling will bring the usage of the Internet to 100 percent of the population.

Sidebar: Ants

In 1997, about 100 thousand trillion transistors were manufactured, approximately one for each ant on the earth. [http://www.intel.com/pressroom/archive/speeches/GEM93097.HTM "An Update on Moore's Law", Intel Chairman Emeritus Gordon Moore]

The number of transistors manufactured is more than doubling each year at the present time. [Ibid]

In 2000 manufacturers are expected to ship 150 million PCs and 8 billion embedded microprocessors. ["Intel's Computing Continuum Conference Explores Next 20 Years Of Computing", Dr. David Tennenhouse, San Francisco, CA, March 15, 2000, http://www.intel.com/pressroom/archive/releases/cn031500a.htm]

Sidebar: 86ing the '86'

Intel dropped the '86' designations for the 'x86' microprocessor line when Intel learned that the number '86' could not be trademarked. The 'Pentium' followed the '486', replacing the planned '5' (with 'Penta', which means five in Greek,) in the '586' designation.

Sidebar: Shrinking in Two Dimensions

Shrinking (or growing) in two dimensions can be illustrated by a checkerboard. If the checkerboard had 4 squares on each side instead of 8, the checkerboard would have a total of 16 squares instead of a total of 64 squares.

Thus, a doubling in each of the linear dimensions (edges of the checkerboard) leads to an increase by a factor of four in the number of squares on the checkerboard.

This relationship is also useful in calculating the number of boxes (records storage cartons) that can be stored in a room that has been doubled in size along all three dimensions (height, width, and depth.) This was known as the cube – square ratio in Gulliver's Travels by Jonathan Swift (Lemuel Gulliver) (1726).

The Evolution of Intel Microprocessors

Family	Trade Name (Code Name for Future Chips)	Clock Frequency in MegaHertz***	Millions of Instructions per Second	Date of Introduction	Number of Transistors	Design Rule (Pixel Size)	Address Bus Bits
80886	(Northwood)	3,000.0 MHz	TBA	2003	TBA	0.13 micron	64 bit
80886	(Madison)	TBA	TBA	2003	TBA	0.13 micron	64 bit
80886	(Deerfield)**	TBA	TBA	2002Q2	TBA	0.13 micron	64 bit
80886	(McKinley)	1,000.0 MHz	TBA	2002Q1	TBA	0.18 micron	64 bit
80786	Itanium (Merced)	800.0 MHz	TBA	2001Q2	TBA	0.18 micron	64 bit
80686	Pentium 4	1,500.0 MHz	*1,500.00 MIPS	November 20, 2000	42 million	0.18 micron	32 bit
80686	Pentium III	1,000.0 MHz	*1,000.00 MIPS	March 1, 2000	28.1 million	0.18 micron	32 bit
80686	P III Xeon	733.0 MHz	*733.00 MIPS	October 25, 1999	28.1 million	0.18 micron	32 bit
80686	Mobile P II	400.0 MHz	*400.00 MIPS	June 14, 1999	27.4 million	0.18 micron	32 bit
80686	P III Xeon	550.0 MHz	*550.00 MIPS	March 17, 1999	9.5 million	0.25 micron	32 bit
80686	Pentium III	500.0 MHz	*500.00 MIPS	February 26, 1999	9.5 million	0.25 micron	32 bit
80686	P II Xeon	400.0 MHz	*400.00 MIPS	June 29, 1998	7.5 million	0.25 micron	32 bit
80686	Pentium II	333.0 MHz	*333.00 MIPS	January 26, 1998	7.5 million	0.25 micron	32 bit
80686	Pentium II	300.0 MHz	*300.00 MIPS	May 7, 1997	7.5 million	0.35 micron	32 bit
80586	Pentium Pro	200.0 MHz	*200.00 MIPS	November 1, 1995	5.5 million	0.35 micron	32 bit
90586	Pentium	133.0 MHz	*133.00 MIPS	June 1995	3.3 million	0.35 micron	32 bit
80586	Pentium	90.0 MHz	*90.00 MIPS	March 7, 1994	3.2 million	0.60 micron	32 bit
80586	Pentium	60.0 MHz	*60.00 MIPS	March 22, 1993	3.1 million	0.80 micron	32 bit
80486	80486 DX2	50.0 MHz	*50.00 MIPS	March 3, 1992	1.2 million	0.80 micron	32 bit
80486	486 DX	25.0 MHz	20.00 MIPS	April 10, 1989	1.2 million	1.00 micron	32 bit
80386	386 DX	16.0 MHz	5.00 MIPS	October 17, 1985	275,000	1.50 micron	16 bit
80286	80286	6.0 MHz	0.90 MIPS	February 1982	134,000	1.50 micron	16 bit
8086	8086	5.0 MHz	0.33 MIPS	June 8, 1978	29,000	3.00 micron	16 bit
8080	8080	2.0 MHz	0.64 MIPS	April 1974	6,000	6.00 micron	8 bit
8008	8008	.2 MHz	0.06 MIPS	April 1972	3,500	10.00 micron	8 bit
4004	4004	.1 MHz	0.06 MIPS	November 15, 1971	2,300	10.00 micron	4 bit

* Approximately one instruction per processor clock cycle

** Itanium, formerly codenamed Merced, may be replaced by McKinley if further delayed. Deerfield is a low cost version of Madison.

*** 1 KHz (KiloHertz) = 1 thousand cycles per second; 1 MegaHertz = 1 thousand KiloHertz; 100 KHz = .1 MHz,
1 GHz (GigaHertz) = 1 billion cycles per second; 1 GigaHertz = 1 thousand MegaHertz

TBA To be announced, Pentium 4 was formerly code named Willamette

http://www.esc-ca.com/processors/intel/future.htm (one source of data for future microprocessors)

http://www.Intel.com/pressroom/kits/processors/quickref.htm (source of data for released microprocessors)

MHz (MegaHertz) (Millions of processor cycles per second) The number of times the processor goes through one cycle. The start of a processor cycle is determined by a pulse (tick) from the processor's clock.

GHz (GigaHertz) (Billions of processors cycles per second). 1 thousand MHz = 1 GHz

1999 was the last year for PCs that had a speed measured in MHz. In 2000 GHz PCs were introduced and no one spoke of MHz PCs again.

MIPS: (Millions of Instructions per Second) with the introduction of the 80486 DX2, parallel instruction execution increased the number of instructions executed per processor cycle to approximately one instruction per cycle. Parallel instruction execution requires many more transistors, so the increase in the number of transistors has increased the number of instructions that can be executed per second faster than the clock cycle speed has increased. A larger transistor budget allows the addition of specialized instructions, which increase the microprocessor's speed in processing specialized information such as graphics by increasing the amount of information processed per instruction.

GIPS (GigaInstructions per Second) Billions of instructions per second. 1 thousand MIPS = 1 GIP

Design Rule: because the wires and components, including transistors, on chips are drawn photographically, the pixel size of the imaging process determines the width of the wires and the size of the transistors. The size of the transistors determines how many will fit on a chip of a given size. (The optimal size of a chip depends on the chip manufacturing processes. In general, chip size increases slowly over time.) The smaller the transistors, the more will fit on the chip, determining the chip's transistor budget. The size of the transistors also determines the transistor's switching speed. Smaller transistors switch faster. (One micron is one one-millionth of a meter or about 40 millionths of one inch. .1 micron, one-tenth of a micron, is one-ten-millionth of a meter or about 4 millionths of an inch.) Finally, the power required to switch smaller transistors is less, so smaller pixels in the design rules allow the batteries in laptop computers to last longer.

Number of Transistors: The number of transistors increases as the square of the decrease in design rule size. Each reduction in design rule size is chosen to about double the number of available transistors (the transistor budget). [For example: (.25 micron / .18 micron) x (.25 micron / .18 micron) = 2.] The gradual increase in die size (the size of the chip) also increases the number of transistors.

Address Bus Bits: The address bus width in bits is based on the microprocessor chip family. (In the later chips of the 80686 family, some changes have been made to make more memory addressable under special circumstances, by using 36 bits to address 16 times as much memory as is possible with 32 address bits, but the generalized addressing structure is still 32 bits.) Each time a bit is added to the address bus width, the amount of memory (RAM: Random Access Memory) that can be addressed is doubled. 4 bit addresses allow the addressing of 16 bytes of memory (and extra work is necessary to address 256 bytes of memory). 8 bits allow the addressing of 256 bytes of memory (and extra work is necessary to address 65,536 bytes of memory). 16 bits can address 65,536 bytes of memory (and extra work is necessary to address 640 KiloBytes of memory, as was the case on the early IBM PCs). 32 bits can address 4,294,967,296 bytes of memory (about 4 billion bytes). As memory prices drop, it becomes necessary to address over 4 billion bytes of memory. The 80786 family is due out from Intel in the year 2000. It will have a 64 bit address bus and will be able to address over 16 billion billion (16 quintillion) bytes of memory.

See also:
http://www.intel.com/intel/intelis/museum / Intel's history of the microprocessor