Virtual Age: Enabling Technologies and Trends

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ABSTRACT

The Virtual Age is the ultimate progress of information technology and knowledge-based environments into a three-dimensional virtual world. The enormous expansion of the information age by leaps and bounds along with the availability of the required tools and technologies, will bring about a fourth wave of change in near future. Virtual Age is an umbrella which empowers anywhere, anytime, anyone's interactions defying the existing time and space limitations we encounter today.

Existence of a wide digital gap between developed and underdeveloped countries, hardware and software limitations, and lack of appropriate infrastructure are some of the problems to be overcome before the Virtual Age can be realized. Key evolving technologies for enabling full realization of virtual age include higher-speed CPU's, higher-speed transmission media (larger bandwidths), huge capacities of memory, and a significant number of sophisticated software. These key technologies have shown exponential growth progress and it is projected that hardware and software limitations will be overcome within about two decades allowing the realization of the Virtual Age.

1. Introduction

The history of scientific and social progress has gone through three waves of change (Fig. 1). The reason behind these waves of change has always been the fulfillment of the human needs in each era. For example, in the first wave, i.e., the Agricultural Age, providing food for the human society was the greatest challenge of the time. The Agricultural Age lasted for about thirty thousand years. As the world population was increasing, the simple tools and methods of the Agricultural Age were not sufficient to provide for the added population. Furthermore, new demands for goods and materials were surfacing. Thus, a breakthrough was needed to meet these demands. This much-needed breakthrough manifested itself in the form of the industrial revolution. Industrial revolution signaled the end of the Agricultural Age and moved the human society forward towards the Industrial Age which lasted for about 500 years. In this age, great inventions, such as, the steam engine, railroad, airplane, telephone, electric power, radio, television, plastics, transistor, microprocessor, and many others, came about. Moreover, civil institutions, such as those of higher education, health, welfare and so on were created with the goal of the betterment of the human condition. The Industrial Age successfully provided the needed materials and goods and created a multitude of new jobs which replaced most of the agricultural jobs of the previous era.

The advancement of science and technology, along with, availability of food and goods, as well as, health care and welfare resulted in a population explosion in the last 100 years. Finally, the rapid progress in engineering, health and human sciences, economics, and education, as well as, the complexity of multinational and global industries created a new demand, namely, the free flow of information. Massive amounts of information and data were needed to be managed and transferred via high-speed communication media throughout the world. This was only possible through the invention of computers and networking facilities. Computers developed quite rapidly with increasing capacity, decreasing size, and reduced cost, whereby it could be purchased by individuals and placed in their homes and offices.

Upon the availability of personal computers for the public, the value of information increased tremendously. Vast amounts of information and data, however, could not be provided by the available technologies in the industrial age. Therefore, a new wave of change was needed, thus, the third wave or the Information Age began about 50 years ago. With the invention of the Internet in 1968, the Information Age entered a rapidly expanding mode. In 1974, TCP protocol was introduced; in 1989 the World Wide Web (WWW) was created which signaled the beginning of an explosive expansion in the information technology. For instance, the number of internet hosts increased from 1000 to 10,000 between 1984 and 1987 and reached 200 million in September 2002 [5].

Fig. 1: Waves of change in human history

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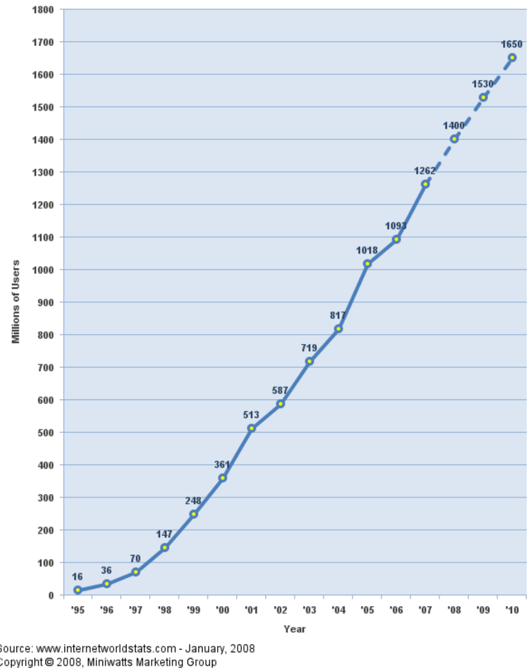

Fig. 2: Growth of internet users in million [15]

Table 1: Worldwide number of PCs in use [6]

PCs-In-Use (Millions)	1995	2000	2001	2007
Worldwide	229	530	603	1,150
Share In Homes (%)	35.2	43.5	45.1	52.3
USA	93.5	162	175	251
Share In Homes (%)	36.9	49.0	50.4	54.6
Western Europe	62.4	139	158	285
Share In Homes (%)	39.2	48.5	49.9	52.9
Asia-Pacific	43.6	139	166	367
Share In Homes (%)	29.3	35.8	38.3	53.9

It has been predicted that the number of users of the Internet will reach nearly two billion by the year 2010, and 80 percent of the world population will have access to the Internet by the year 2020 (Fig. 2).

The internet content is also evolving to 3 dimentional (3D) spaces allowing users to get immersed in the web spaces [21]. It is expected that the 3D web will result in establishment of virtual reality environemnts. Several 3D virtual spaces alredy exit on the web (e.g. Second Life), which are increasingly trurinign into realsitice spaces [21].

In 2001 the worldwide number of PCs-in-use topped 600 million units. In the next six years this number will nearly double, assuming compound annual growth of 11.4%. Despite approaching saturation, annual PC sales in the USA will be in the 60 million range after 2010 due to PC replacement sales every five years for most PC users. The worldwide PC market will not approach saturation until 2015 or later when PCs in-use will reach the 1.7 billion units range [8].

The quality of the human experience has also been affected by going through different waves of change. Looking back at history, it can be shown that proceeding from one age to the next has never been straight forward or without complications. One of the most important barriers to change is the human nature of tending towards preservation of the status quo and the fear of an unknown future. For example, at the beginning of the Industrial Age, farmers had the notion that creation of factories would eliminate many farm jobs, thus they resisted the change. A similar attitude was expressed towards the invention of computers by industrial workers who thought it would replace them; not realizing that many more jobs of higher quality would thus be created. By the same token, when we talk about the coming of the Virtual Age, we are frequently confronted by questions such as: "Wouldn't a virtual teacher in one corner of the world replace all teachers, rendering them unemployed?"

It is projected that, expansion of the information age by leaps and bounds along with the availability of the required tools and technologies, will bring about a fourth wave of change, creating a new age in which the concept of "virtual living" will be realized. In this age most aspects of every-day life and world affairs will become virtual. The possibilities are endless, however a few conceivable ones include; virtual commerce, virtual banking, virtual learning, virtual government, virtual work office, virtual corporations, and so on.

2. Attributes of the Virtual Age

Traditional aspects of the human life, such as, social, economic, cultural, and political facets are rapidly changing. Information technology which has led to the invention of the Internet has created a tremendous number of new jobs through e-commerce, e-banking, e-learning, e-government, and so on. The exponential increase in the number of users of the Internet and the ever-increasing creation of and demand for information, will eventually outgrow the capacities and speeds of the presently available software and hardware. However, in response to such increasing demands, the hardware and software technologies also keep improving at the same pace. By the same token, many people, including some scientists cannot imagine how drastically advanced the future world will be as compared to today's society.

As mentioned above, every wave of change in history has had specific goals and was expected to meet certain changing demands of the human society. Furthermore, the duration of each age depended on its ability to satisfy the new demands and needs of the human societies. Upon reaching its goals, the previous age would be replaced by a new one. The Agricultural Age which had the goal of providing food for the simple human society lasted for about thirty thousand years, while the Industrial Age, with its rapidly developing materials and goods, lasted only about 500 years. Around many years ago, an even faster changing age, namely the Information Age, started to emerge and is running its course. Within the third wave, the rapid development of new technologies, such as information technology, nanotechnology, biotechnology, and the absolute command of scientists over atom has led to the expectation of a new wave of change, i.e., the Virtual Age, or the fourth wave.

The Virtual Age is the ultimate progress of information technology and knowledge-based societies. It is an umbrella which empowers anywhere, anytime, anyone‘s interactions defying the existing time and space limitations we encounter today. The possibilities are endless, for instance; virtual-commerce, virtual-banking, virtual-learning, virtual-government, virtual work-office, virtual corporations, and so on, will become commonplace in the Virtual Age.

3. Technology Components of Virtual Age

Beside the human resistance towards change, the existence of a wide digital gap between developed and underdeveloped countries, hardware and software limitations, and lack of appropriate infrastructure are some of the problems to be overcome before the Virtual Age can be fully realized. The technology components of the Virtual Age include high-speed CPU's, high-speed transmission media (large bandwidths), huge capacities of memory, and significant number of sophisticated software (Fig. 3). These technology components have been following exponential growth to handle ever growing demand for massive amount of information processing and handling in the information age. Virtual age demands much higher capabilities for information processing and handling. Due to the significant information and computational demands of the virtual age, continuous advancements in these key technologies are needed to power us into the Virtual Age. The present state-of-the-art and the required advancements of these components are discussed in this section.

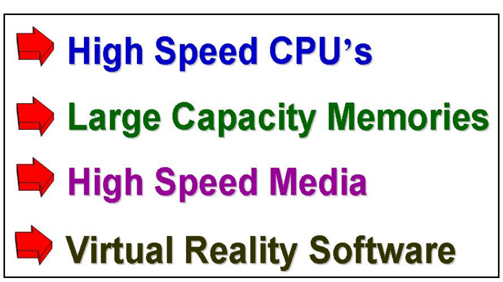

Fig. 3: Enabling technologies of Virtual Age

3.1. High Speed CPU

CPU's are computational parts of the computer, the speeds of which need to be increased to be able to perform hundreds of billions of calculations per second. At the present time, the fastest supercomputer in the world, which is built by a Japanese laboratory and has the computing power of 20 of the fastest U.S. computers combined, has 5,104 processors and can reach a speed of 35,600 gigaflops, or billions of mathematical operations per second [6].

CPU's are built using the Integrated Circuits (IC) technology. Since the invention of IC in 1960's, performance of CPU has been exponentially improving due to the improvements in the IC technology. The speed of a CPU chip depends on many factors, among which are the number of transistors on the chip (integration density) and transistor switching speed. For example, in 1980 the maximum number of transistors on a chip was 29 thousand (model 8086); in 1990 it was 1.2 million (Model 486); and in 1999 it was 9.5 million (Pentium III). The number of transistors on a chip has already passed one billion (Pentium 4 and Prescott, 1.5 GHZ chip), and is expected to reach several billions by the 2010. Higher number of transistors on CPUs is primarily used for integrating more cache memory on CPU chips which enhances the system performance. The number of transistors per chip for CPUs has been following an exponential growth (Fig. 4), owing to a trend in IC technology known as Moore's law [7].

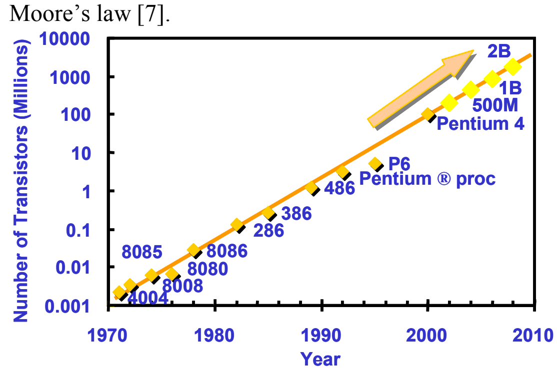

Fig. 4: Number of transistor on lead microprocessors doubles every 18 months, following Moore's law [courtesy of Intel]

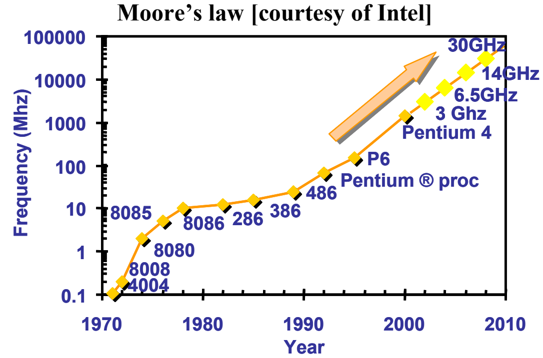

Fig. 5: Increasing clock speed of lead microprocessors [courtesy of Intel]

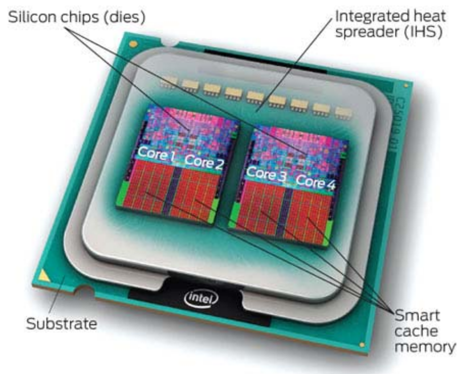

Fig. 6: Multicore processor [courtesy of Intel]

The transistor integration density and transistor switching speed are enhanced by scaling transistor dimensions from one generation of the technology to the next (technology scaling). Each scaling of the IC technology, which happens in 18 months, doubles the integration density by providing 50% reduction in transistor area (Fig. 4), and enhances CPU's clock frequency (Fig. 5) by 40%.

A new trend in CPU industry is the multi-core processor trend. In a multi-core processor, multiple processor cores are integrated on a single chip and run in parallel increasing the CPU performance (Fig. 6). Integration of more processor cores on a single chip is another way that higher number of transistors can be used to improve CPU speed. The number of cores that is integrated on a CPU chip is expected to grow exponentially, following a trend similar to the Moore's law.

Beside the above factors, the materials used in the fabrication of the chip affect the speed of the CPU. For example, replacement of Aluminum by Copper as interconnect material enhanced CPU speed by 22% since Copper is more conductive than Aluminum [17]. Nanotechnology is showing great promise in enhancing computing power. Silicon has long been the main material used for fabricating transistors. Silicon-based micro-electronics is reaching a level of miniaturization (below 50 nm) where the quantum effects cannot be avoided. As a result, the control of transistor parameters in such nano-scale dimensions is one of the greatest challenges facing IC technology scaling. Exploration of different materials for building faster transistors is also pursued (Fig. 7). For example, transistors are fabricated using carbon nanotubes that show superior performance [18]. Molecules are promising material candidates for future electronic devices because of their small size, chemical tenability and self assembly feature. Several experimental molecular transistors have recently been demonstrated [19]. Recently, carbon nanotubes are also being considered for high speed on-chip interconnects [20].

The PC today has grown into more than just a productivity tool; it has become a source of enjoyment and entertainment. While people continue to use the PC to track home finances, write letters and look up information on the Web, it is also used for advanced media and entertainment applications. More people are starting to produce their own home movies, edit their own digital pictures and mix their own music. Therefore, CPU performance is an important factor. In the Virtual Age much higher performances are required. We believe that the endless application of the virtual reality and its high performance demand will create a drive for the IC technology scaling and the CPU performance enhancement. At the present rate of progress, it is projected that the desirable CPU speed and performance which can support the Virtual Age is attainable within about two decades.

3.2. Large Capacity Memory

The second necessary component leading to the Virtual Age is large capacity memory. Virtual reality is a three- or higher-dimensional environment, requiring storage and retrieval of huge amounts of information and data. Currently available memories are 700 MB for CD-ROM, 5 GB DVD (red laser technology), 27 GB DVD (blue spectrum), 300GB for hard-drive, and 400 GB for NANO-CD. Solid-sate memory (SRAM and DRAM) capacity has been exponentially growing following Moore's law, meaning that the storage capacity doubles every 18 months (Fig. 8). This is precisely the reason why early PCs had Kilo byte of main memory whereas modern PCs offer Giga bytes of main memory.

Magnetic hard-drive storage is following a similar exponential growth (Fig. 9). A solid-state competitor for magnetic hard-drive is flash memory technology which is also a non-volatile memory technology and growing exponentially in capacity and offers higher performance than traditional hard-drives. Given the superior performance of flash memory, it is expected that flash memory may replace or complement the traditional magnetic hard-drives (hybrid hard drives)

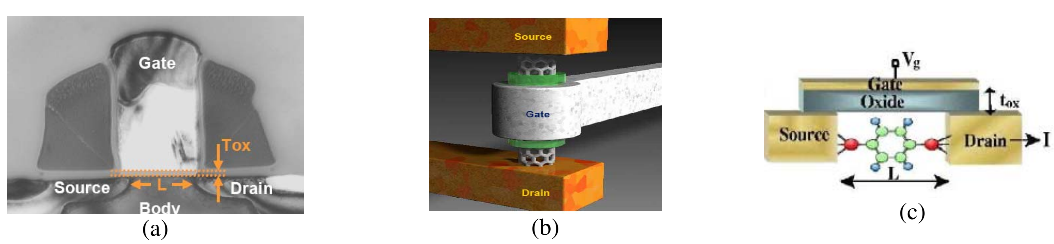

Fig 7: Exploration of different nanotechnology materials for fabricating transistors (a) conventional silicon-based transistor (b) carbon nano-tube transistor (c) molecular transistor

resulting in a significant boost in computer system performance, (Fig. 10) [16].
Material exploration in the nanotechnology area is aggressively pursued for dramatic improvement in memory capacity. Examples include carbon nano-tube based memory (NRAM [8]), phase-change memory(PRAM [9]), ferroelectric memory (FRAM [10]), magneto-resistive memory (MRAM [11]), and

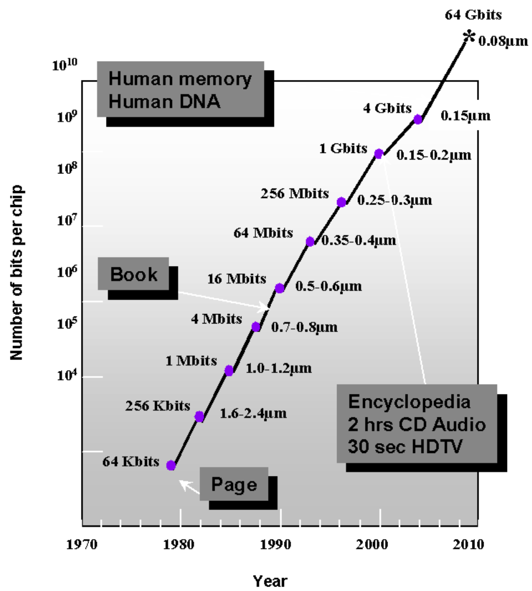

Fig. 8: Evolution of solid-state memory capacity

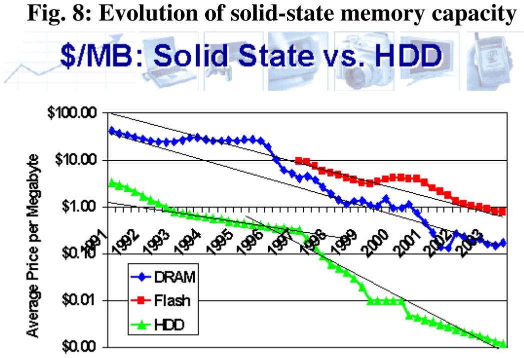

Fig. 9: Magnetic hard-drive (HDD) and flash memory pricing trends [16]

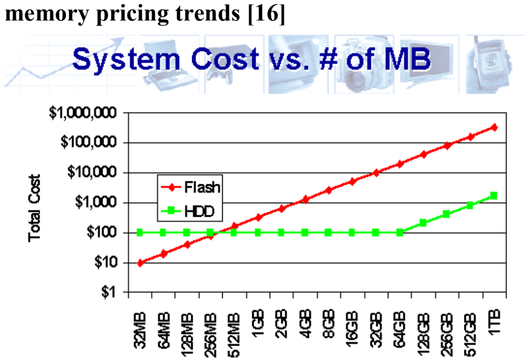

Fig. 10: Magnetic hard-drive (HDD) and flash memory system cost trends [16]

organic molecular RAM [12]. Research is being conducted on 3D laser memory with 1 Tera (1000 G) Byte, and molecular memory with 1000 Tera Byte. The latter capacity is able to store more than the present sum total of the human knowledge data. Storage Attached Networks (SAN), optical and biological memories are also under investigation. If the above claims of research are indeed made practical, it appears that components with ample memory capacity will be available in the Virtual Age.

3.3. High-Speed Media

The third component required for reaching the Virtual Age is super high-speed media (wired and wireless). Computer networks use a variety of transmission media like copper wire, glass fiber, radio wave, microwave, and infrared laser. These media are limited in their transmission capabilities. It should however be noted that optical fibers have inherently infinite bandwidth, but switches and devices connected to the fibers limit their transfer rate. For example, in order to understand the need for broadband connectivity, a real-time multimedia collaboration may need over 100 mbps transfer rate per user. Viewing a high quality broadcast movie requires 90 mbps. In the network backbones speeds are reaching to terra bits and optical switches are reaching to the production and implementation stage. Some data links such as cellular network are fully mobile and accessible form anywhere, some are accessible in a wireless fashion but in limited areas such as wireless internet hubs, and finally some data links are wired lines accessed only from specific locations such as Ethernet lines. There three types of data links are called wireless, nomadic, and wireline data links. As expected, wired links deliver higher bandwidth than wireless links. The bandwidths of all the three types of digital communication links have been following exponential growth (Fig. 11) [13]. This growth mimics the growth trend observed in computer performance, referred to as Moore's law [7].

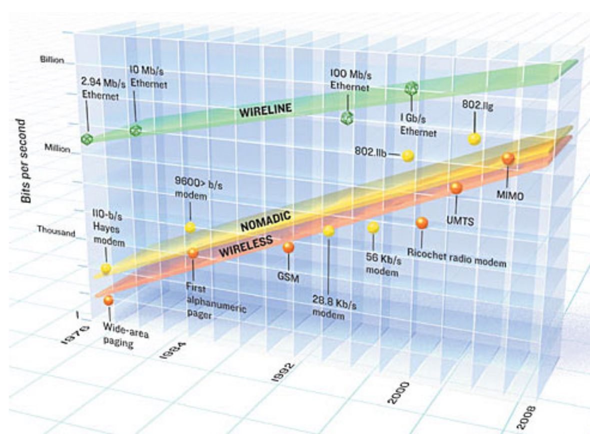

Fig. 11: Exponential bandwidth growth in communication links [13]

In order to be able to support the three- or higher-dimensional environment of the Virtual Age much higher transfer rates are needed. Therefore, new inventions in this area are required to produce the appropriate transfer rates.

3.4. Software Infrastructure

The forth component required to enable the virtual age is the availability and sufficiency of complex, real-time virtual-reality software. Recently, vast improvements have come about in the video game industry based on 3-D and virtual-reality concepts. Sims and Second Life are preliminary examples of the implementation of virtual-reality in video games.

"Second Life is a startlingly lifelike 3-D virtual world now evolving on the Internet. Unlike other shared online adventures, Second Life isn't about slaying monsters or zapping aliens. It's about building things, meeting people and expressing yourself. Even if you already have a life, you may want to get a second one" [14]. The main attraction of these games is having the possibility to select different aspect of our lives which we would normally not have control over. These softwares are still very basic. Advanced type of this software can be used for education, business and other aspects of life in the Virtual Age.

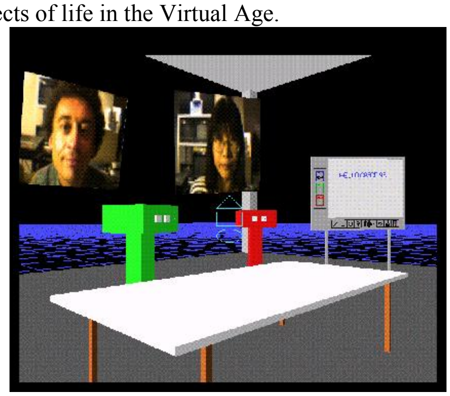

Fig. 12: Real-time virtual reality 3D-software

4. Conclusions

The information age as the most recent wave of change in human society will eventually lead to the next wave of change: virtual age. Hence, we believe the fourth wave of change will be the Virtual Age. Barriers between the third and the fourth waves include the human nature of preserving the status quo, as well as hardware limitations and software. Much higher speed CPU's, high speed transmission media (larger bandwidths), ultra-high capacity memory components, and sophisticated real-time virtual-reality software are needed to power us into the Virtual Age. At the present rate of progress, it is projected that hardware and software limitations will be overcome within about two decades allowing the emergence of the Virtual Age. The fourth wave or the Virtual Age will be all encompassing and will drastically change most facts of human life, such as social, economic, cultural, and political aspects.

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