HCTL Open International Journal of Technology Innovations and Research (IJTIR)
http://ijtir.hctl.org
Volume 14, April 2015
e-ISSN: 2321-1814, ISBN (Print): 978-1-62951-946-3

Reminiscing Genesis of Computer from Stone to Silicon Era

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Abstract

Development of modern computer is essentially a revolutionary process from stone to silicon era. It is believed to be started by the Charles Babbage's first Mechanical computer named Difference Engine. And, for this invention Babbage is considered as father of computer. For the people working in the field of Computers, it is really necessary to understand the evolution and history of computers in order to discover new technologies. Aldous Huxley quoted "that man do not learn very much from the lessons of history is the most important of all the lessons that history has to teach". Therefore, this paper is intended to provide a brief review of all the development stages of computer from its start to present day. It illustrates various landmarks during the life span of computers. History anecdotes written in the paper shows interesting and amusing parts of earlier computing era.

Keywords

Vacuum tubes, Von Neumann architecture, Transistors, Integrated Circuits, VLSI, Mini Computer, Artificial Intelligence, Super Computer

Introduction

With the invention of the abacus by ancient civilizationsaround 3000 BC, the journey of computer started. And, it took several years, and shapes to reach at its present model. In the ancient era, the word computer perhaps referred to calculator like machines. But, the Sixteen and the Seventeenth century mark the dawn of scientific revolutions and shown the footprints of modern computing age. To name a few innovations are: WihelmSchickard's (1623) calculating machine called calculating clock, Blaise Pascal's (1642) numerical wheel calculator called Pascaline, German Mathematician Leibniz's (1673) Step-Reckoner calculating machine[1].

Computer generations dramatically improved from the development of vacuum tubes, transistors, integrated circuits, microprocessors and countless other inventions leading to the development of today's contemporary computers [2]. This paper briefly explores all the generations that a computer had gone through while transforming from abacus to Apple.

Era of Massive Computers (1940-1956)

World War I gave rise to several developments and started the era of first generation computers. Cumbersome vacuum tubes for circuitry, magnetic drum for memory, and punch card for input have been used in this generation. Vacuum tubes were turned on to represent one and off to zero. It wasn't a efficient technology, and required a lot of tubes. A high-speed electrostatic store was the heart of several early computers. In this generation computers relied on machine language to perform operations, and they were hardly able to solve one problem at a time. ENIAC and UNIVAC are example of first generation systems. ENIAC (Electronic Numerical Integrator and Calculator) was the first general purpose computer capable to perform 5000 additions per second. It consisted of 18,000 vacuum tubes and 7000 resistors [3]. It also had modules to perform operations like multiply, divide, and square root. High speed memory was limited to 20 words (about 80 bytes). Eckert and Mauchly received IEEE Computer Society pioneer award for the innovation of ENIAC [4].

Although, ENIAC was a great machine of its time, it wasnot able to store computer's program inside the computer. Later, Mathematician John Von Neumann's design led to the development of the improved machine named EDVAC (Electronic Discrete Variable Automatic Computer). And, the design becomes so popular that any discussion of computer architecture is incomplete without making reference to Von Neumann architecture.Mainframe computers were invented in this era and still used in high performance computing, but, withincorporating lots of technological enhancements. IBM developed first Mainframe computer named Automatic Sequence Controlled Calculator (ASCC), the largest electromechanical calculator of its time. It's surprising to know its length was 51 feet, height was eight feet and weight was nearly five ton [5].First generation systems were bulkier, occupied several rooms, emitted lots of heat, and demanded giant cooling systems. Input was based on punched cards and paper tape, and output was displayed on printouts. Biggest of all, they were quite slow in computation and limited storage capabilities due to less efficient vacuum tubes. In 1947, a moth was found in one of the relays of the malfunctioning Harvard Mark II, an electro mechanical computer at Harvard University, and it is believed that the term "bug" was first coined when moths or other insects squashed on light of the tubes and blow them out [27].

Transistor Effect (1956-1963)

The invention of Transistors marked the beginning of the second generation of computers and over took the vacuum tube rapidly. The first transistor was about the size of the palm of a hand, with a depth of two matchbox stacked on top of each other. Transistor was much better than a vacuum tube, allowing computers to become smaller, faster, cheaper, and energy-efficient. John Bardeen, William Shockley and Walter Brattain at Bell Labs were jointly awarded Nobel Prize in Physics for the discovery of transistor effect [6].

Second generation replaced machine language with assembly language, thus allowing programmers to specify instructions in words. This generation of computers behaved much like modern day computers with utilities like printers, disk storage and operating system. Batch processing in this generation provided better resource usability by

collecting batches of non-interactive jobs written on punch card and processing them at once [7]. In fact, year 1965 witnessed the footprint of modern Internet as a packet switched network by connecting MIT's experimental computer TX-2 to the Q-32 in California with a low speed dial-up telephone cable. TX-2 computer is believed to be in between first and second generations as transistors largely but not completely replaced vacuum tubes in it [8]. Nevertheless, issues of heat emission and gigantic size of systems continued to be an overhead in this generation too.

History Anecdote: Computing was not free before 1980s

Up to mid 80s, punch card or Hollerith card (named by its inventor Herman Hollerith) was the oldest method to write and store the programs. A punch card was a write once medium that typically stores a line of program hence it takes group or pack of cards to store a program. When computers were not easily available and computing was not free; to run a FORTRAN [10] program, one has to queue up in-front of computer center (e.g. IBM like center) with a pack of punch cards. And, if unfortunately, code had some errors then debug it, write it again on different punch cards and queue up again in the next morning with lot of patience [9].

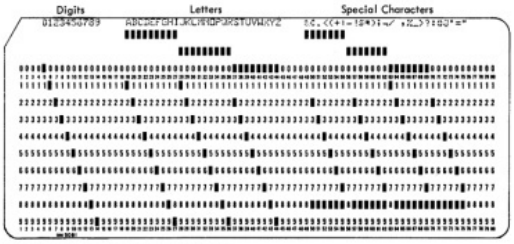

Figure1: Punch Card [9]

Era of Microelectronics (1964-1971)

In the earlier days of electronics, i.e. before the 1950s, the basic electronic device was the electron tube aka vacuum tube, it was initially built as a modified light bulb, and remained in that size for a long time. Old electronic devices like Radio developed with electron tubes, but, they had some serious limitations too. Their filaments burned out like a light bulb, and lot of tubes are required to execute significant computations, for example, ENIAC needed 18,000 tubes to function; nevertheless, electron tubes were incredibly useful. After World War II, as the weapons like missiles, rockets emerged;there was an increasing demand for compact, robust electronic systems for communication and navigation. Hence, the search of small tubes continued and Transistors miniaturized and fabricated on Silicon Chips [10]. And, the fabrication of transistors on silicon chip was termed as Semiconductor, it radically increased the speed and efficiency of computers. Development of Integrated Circuits (IC) marked the dawn of a new field called "Microelectronics". ICs were small in size and superior in performance, therefore, ICs were used as an electronic component in computers. Size of computer that earlier occupies rooms can now takes refrigerator like space only. Hence, the term "Minicomputer" gained popularity in this generation. Minicomputers were equipped with operating system and time sharing features allowing many different applications to run simultaneously under the control of a central program. Digital Equipment Corporation's little used Programmed Data Processor -7 (PDP) and 9 (an upgrade of version 7) were the earliest systems to witness execution of first UNIX operating system developed by

Ken Thompson and Dennis Ritchie in 1969 at Bell Labs. Initially, UNIX was written in Assembly language but after the invention of C language, UNIX code was rewritten and installed successfully on 16 bit Minicomputer PDP-11 [11]. It is worth mentioning that the most popular, cost effective, and best seller Minicomputer of its time was 12 bit PDP-8. It is claimed to be first successful commercial minicomputer of its time [12]. Later, Apple II replaced PDP-8 with much better microprocessor technology and stylish look. However, major limiting factor of this generation was manufacturing of IC which was a complex task requiring highly sophisticated technologies not prevalent at that time.

Arrival of a Modern Computer System (1971-1982)

Fourth Generation computers were much like modern day computers. 'Microprocessor' was the key concept behind fourth generation. Microprocessor is a single chip consisting of thousands of Transistors and ICs fabricated on a single chip. It, further, reduced the size and cost of the computers and increased power, efficiency and reliability of computers by locating all the components (CPU, I/O, etc.) on a minuscule chip. Today's latest microprocessors fulfill the Moore's observation by containing tens of millions of microscopic transistors. Moore believed that: "the numbers of transistors on ICs would be doubled after every 2 years". Home users heavily benefited due to the price reduction and increased availability of the computers. On August 12, 1981, IBM introduced its first computer model no. 5150 for the home users. IBM announced it as its smallest and lowest priced computer system and named it as IBM PC. May be, this was the first system coined by the today's popular term 'PC'. On that occasion C. B. Rogers Jr., IBM vice president said "This is the computer for just about everyone who has ever wanted a personal system at the office, on the university campus or at home" [13]. In 1971, Intel released its first general purpose, single chip microprocessor 4004 in the market. It contained around 2,300 transistors, ROM, DRAM, and serial to parallel shift register chip [14].

Figure 2: IBM PC 5150

Computer generations are widely studied according to their time duration. Nevertheless, Figure 3 illustrates a comprehensive representation of computer generations as per their switching technologies. It indicates that computing power of 40 vacuum tubes was almost equal to one transistor [15] and of tens of transistors was equal to Small Scale IC respectively. Afterwards, the number of transistorson single chip increased from ten to hundreds of thousand that generated successors of Integrated Circuit from Small Scale

Integration (SSI), to Very Large Scale Integration (VLSI). Technologies updated and IC Technology enhanced to Ultra Large Scale Integration (ULSI) consisting of billions of transistors on a single chip, first 2 billion transistors based CPU is developed by Intel and code named Tukwila, from year 2010 onwards, it is now available in the market by the name Itanium® processor 9300 series [16]. In the 1980s, user programmable logical circuits were developed called Field Programmable Gate Arrays (FPGA). These chips can be configured and reprogrammed by a suitable Hardware Descriptive Language (HDL), unlike Application Specific ICs (ASIC) that are customized to a specific purpose by the integrated circuit manufacturer. In this journey of technological revolutions, microprocessor architecture drastically improved from initial 4-bit versions to faster multi-cores (e.g. dual core, quad core, etc.) and Reduced Instruction Set Computer (RISC) [17][18]. Continuous progress in technology paved the path for next generations of Computers.

History Anecdote: Booting was not so Trivial before arrival of Microprocessors

Initially built computers were not capable to boot by themselves, because CPU was just a PCB having separate ALU and components. Programmer has to initialize all the registers and set the program counter manually, and then the computer runs.

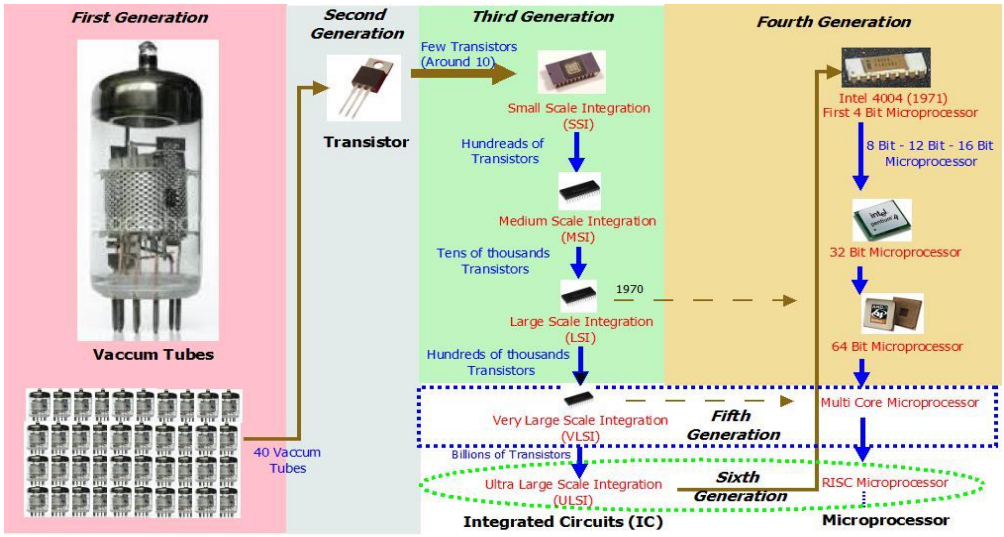

Figure 3: Computer Generations as per their switching technology

Thinking Humanly (1982-1992)

The seeds of modern Artificial Intelligence (AI) were planted by classical philosophers who attempted to describe the process of human thinking as the mechanical manipulation of symbols. In 1950, the pioneer computer scientist Alan Turing proposed idea of Turing Test thatdecides whether a machine can think or not.Historical perspective of the fifth generation shows that Japanese computer industry worked hard in collaboration with Japanese Government to compete with US and other developed nations. Japanese put a

step forward to other conventional flow control based computers and tried to explore future of computers in the fields of Artificial Intelligence, Parallel Computing and VLSI technology [19]. Japanese took the initiative of the fifth generation computers and focused on knowledge processing rather than data processing approach used by all the previous generation systems. As a result, the demand of Artificial Intelligence increased rapidly to process knowledge [20].

According to Merriam-Webster dictionary Artificial Intelligence is the capability of a computer/ machine to imitate intelligent human like behavior. Artificial Intelligence based algorithms may take commands in an audio visual way and carry out instructions more like a human being. During this time Parallel Processing and Multi-Core architectures were showing the possibility that processing capabilities of many CPU's can be usedconcurrently to solve large computationally intensive applications more precisely and rapidly [21]. In 1989, researchers at the University of Alberta led by Jonathan Schaeffer have created an unbeatable checkers program called “Chinook”. It was the first program of its kind to defeat human opponent in the world man-machine championship. It had a limitation that best playing efforts made by both the sides lead to a draw in the match [22]. Later, in 1996, IBM Deep Blue super computer titled first machine to defeat world chess grand master GarryKasparov.At this point of time, public interest also developed in AI due to its popularity. Applications such as voice and character recognition for the Apple Macintosh and IBM compatible computers were now available [23].The integration of AI with other emerging technologies promises to play a significant role in shaping the future of computing.

History Anecdote: 'Fifth Generation' Became Japan's Fiasco

On June, 05, 1992, The New York Times published that the bold 10 years long project of Japanese computer industry with government support could not achieve their ambitious goals even after spending nearly $400 million. Speculations about its outcome are divided that it was a success or failure. Some wise people think that it was ahead of its time. Nevertheless, this Japanese challenge alarmed and feared the American and rest of the world. In response, they also commenced collaborative research in building artificial intelligence based expert systems [24].

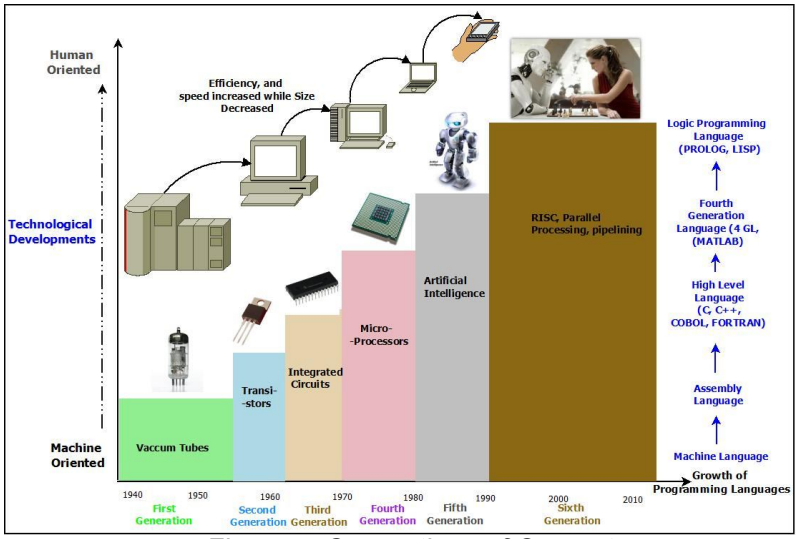

Figure 4: Generations of Computer

Figure 4 portrays generations of computer with timeline and indicates increase in speed and efficiency while size of machine reduced when moving in to every next generation.

Generation Next (1992-Present)

This current generation focuses on parallel computing in hardware and improved understanding towards development of algorithms to exploit parallel architectures. Technology continued to improve, with processor designs using a combination of Reduced Instruction Set Computer (RISC) i.e. computer based upon small and highly compacted instruction set, and pipelining. The next generation Quantum Computing encodes information in quantum states that can be zero and one simultaneously, and have the ability to solve daily problems, such as breaking of encrypted text that are beyond the reach of 'classical' computers. Quantum computers of the future will have the potential to give artificial intelligence a major boost [25].

Very soon, conventional chunky desktop computers will be bypassed by portable, highly interactive, and more intuitive systems. Oblong Industries' three-dimensional interface has revolutionized the remote collaboration techniques to a great extent. In 2009, a wearable gestural interface called Sixth Sense was unveiled at TED community. The portable device mesmerized the technology world and provided a deep insight into the next generation of computing devices. The Sixth Sense prototype, translates natural physical gestures into interactive information that portable device can understand and use. Recently, Google has also launched its wearable computer called Google Glass to fulfil the dream of Ubiquitous Computing i.e. everywhere and anywhere computing.

Conclusion

Most of the developments in the computer systems since 1990 were not fundamental but merely a gradual improvement over earlier established systems. Every generation of computer witnessed considerable technological developments leading drastic changes in the way computers operate, resulting in increasingly compact, cheap, and powerful devices. Wide area networks, bandwidth, speed of operation and networking capabilities are improving tremendously leading to an impending era of supercomputers. China has recently developed world's fastest super computer named Tianhe-2 (Milky Way-2) with a performance of 33.86 petaflops. It has 16000 nodes; each one consists of two Intel Xeon IvyBridge processors and three Xeon Phi processors leading to a total 3.12 million processor cores [26]. It will not be exaggeration to believe that soon supercomputers will exceed the computational capabilities of entire human race.

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