In the Midst of Digital Transformation

Before beginning this writing, I would like to wish all my readers good health, love, peace and prosperity in 2021. I also wish to express my gratitude for the various encouraging comments regarding my articles. If those articles are able to generate further thinking in your minds, the raison d'être of my blog is well served.

In June 2020, I published an article titled *The New Normal in Japan*, explaining that the new normal we were observing was the acceleration and intensification of digitalization of human activities, complemented by the development of Artificial Intelligence. Therefore, everybody had to deepen their knowledge in the language of applications, that is, the computer language, which I call the fourth language, after our mother language, the mathematical language, and the foreign language for international communication, in order to avoid becoming an illiterate in the digital world.

Actually, the computer language is already ubiquitous in this planet, and no longer the sole domain of the computer programmer. And, although this is not one of my areas of expertise, I have been drawn into this field to support the effort of the consulting firm Alan Kei Associates (AKA) to promote *Edge Computing* in Japan. This new phase in computer technology is preparing the way for the proliferation of artificial intelligence, machine learning and decentralized data management.

Besides, my natural curiosity compels me to continue feeding my brain with new knowledge to further advance my personal and professional development, but more importantly, to leave an intellectual legacy for my almost 3-years old daughter, who will start kindergarten this year and will be using a tablet as a tool of learning in the classroom. In fact, when she becomes 20-years old or earlier, she will be interacting with robots and a multiplicity of smart devices, which already will be talking to each other. I just hope my blog (sunao.co) will serve to later connect my daughter with my worldview, once she has a better understanding of her surroundings and I am no longer in this world.

So, let's make a pause on my reflection and start to look at what is happening in today's digital world, navigating through a very succinct history of computing. And please forgive me for any unvoluntary omissions I may incur as I always try to make an honest effort to write short articles that tell you a lot of things in a few lines.

As you already know, the pandemic has put restrictions on our social interaction, forcing us to use digital means such as video conferencing to perform daily teleworking, carrying out business meetings, delivering lectures, teaching and learning lessons, organizing concerts among many other in-group human activities.

The people of my generation, born between 1965 and 1980, also called Generation X, and those of the previous generation called the Baby Boomers, born between 1946 and 1964, grew up together with the process of digital transformation after the second half of the XX century and had to adapt to his new reality, while the Millennials, born between the early 1980s and 2000 and the Generation Z or post-Millennials, are much better prepared for this transformation and able to master very well the use of digital devices.

Indeed, it was during the 1980s, in the music industry, when we started to observe the change from analogue devices, such as vinyl records and tape recorders to digital devices such as the Compact Disk (CD), from which later came the CD-ROM to store and distribute software and data in computers using a drive. Actually, the emergence of CDs became an important turning point in the transition from analogue to digital devices in practical terms.

As you may know, the term digital derives from the word digit, a numerical concept whose Latin root mean fingers as people in ancient times used their ten fingers as a way to count things. Later on, the digits 1 and 0 became the base of the binary code used by computers to translate and reproduce text, audio, video, graphic and other information into the monitor. For example, in the binary language, the word WATER would read as follows:

01010111 **(W)** 01000001 **(A)** 01010100 **(T)** 01000101 **(E)** 01010010 **(R)**

Thus, each numerical set represents an alphabetic character written **IN CAPITAL LETTER**.

As Bill Gates wrote in *The Road Ahead*, a book describing the personal computer revolution, the binary system is the alphabet, the language to which all information is translated into the computers. By the end of 1950s, this binary language was further improved and put into practical application by Claude Shannon, an American mathematician, electrical engineer and cryptographer, who was influenced by the algebraic logic of the English mathematician, George Boole. In view of his 1948's seminal work *The Mathematical Theory of Communication*, Shannon became known as the Father of Information Theory, who introduced the term ***bit*** as a unit to measure information.

Shannon's work followed another great development in the field of computing: *the Turing Machine*. This machine was an abstract mathematical design of a computer created in 1936 by Alan Turing, a British mathematician, logician and cryptanalyst, who finally established the foundation of modern computer science and artificial intelligence. The Turing Machine included the basic computer components such as input/output, central process unit and storage.

It is important to mention that the Turing Machine was preceded by the Analytical Engine of Charles Babbage, an English mathematician, philosopher and inventor, who in 1837 developed a conceptual design of a *mechanical general-purpose computer* with the essential elements of computing. Over a century later, Babbage's Analytical Engine provided the basic principles for the development of Harvard's Mark I computer. Therefore, Babbage is considered as the Father of Computer in general, while John Vincent Atanasoff, a US physicist and mathematician, was one of the few pioneers who contributed to the invention of the *digital computer* in the late 1930s when he was serving as professor at Iowa State University.

Another central figure in the development of computers was John von Neumann, a mathematician, physicist, computer scientist, engineer and polymath, who also contributed to the programs running on the Harvard's Mark I computer. He created a logical design for computers paying special attention to data storage and the processing of instructions. In his 1945 *First Draft of a Report on the Electronic Discrete Variable Automatic Computer* (EDVAC's First Draft Repot), von Neumann stated a new concept of *stored-program computer* where instruction data and program data were stored in the same memory. Also, unlike its predecessor the Electronic Numerical Integrator and Computer (ENIAC), which used decimal encoding, EDVAC pioneered the use of *binary notation*, which is the basic encoding scheme used by virtually all modern computers to this day. This new paradigm became known as the *Von Neumann Architecture*, and is still used today as a reference to understand the main computer structure.

I should point out that the various intellectual contributions to computer development were carried out in the context of World War II or for defense and academic research-related projects sponsored by the British and US governments. As for the British contributions during the war are Turing's Bombe developed for the decoding of signals from the German Enigma machine, and Tom Flowers' Colossus developed to decode higher-grade German military ciphers, which can lay claim to being the world's first programmable, electronic digital computer. While both of these machines predate EDVAC by several years, the intense security at the UK's Bletchley Park, forerunner of the General Communications Headquarter (GCHQ) means that their contribution to the development of computing technology remains less well known. The same can be said of the Konrad Zuse's Z3, another pioneer programmable, digital computer built in Germany in 1941, which the Nazi regime did not consider important for the war effort and was destroyed in a 1943 Allied bombing. Other efforts in the development of computing technology were also carried out in other nations in Europe and the Soviet Union, however, no other nation advanced at a fastest pace as the US.

In the early 1950s, computing technology moved to another level when companies started to develop and manufacture computers for commercial use. In this period, we saw the emergence of the *mainframe computer*, which was a huge machine occupying a large space. This was an expensive computer and was mainly used by large corporations such as banks, airlines, scientific research institutions, governments and other large organizations since this big computer could carry out a large-scale transaction processing. With the introduction of 700/7000 series, and especially, the system/360 series, International Business Machine (IBM) became the dominant player in the production and sale of mainframe computers for the next 30 years.

Mainframe computers are centralized systems. They receive data requests from clients' computer terminals such as booking information from airlines, process the data and send it back to the airline's computer terminal where a counter attendant check the passenger information in front of the monitor.

In 1971, the computer industry took a big turn with the development of Intel's 4004 single-chip microprocessor, which is an integrated circuit capable of carrying out instructions of a computer software program. In other words, it is a miniature brain inside the computer. The microprocessor paved the way for the emergence of the *microcomputer* in the 1970s, and especially the production

of the Apple II from Apple, the PET 2001 from Commodore and the Radio Shack's TRS-80 which became very popular in 1977.

Observing the growing market of microcomputers, IBM introduced in 1981 the IBM PC 5150, giving birth to the era of *the Personal Computer or PC*. IBM built this model using components from other companies such as the Microsoft's operative system MS-DOS, and Intel's 8088 processor, departing from its traditional style of manufacturing its own equipment, and also using various retailers instead of its own sales channels. Thus, IBM created an open structure which allowed other developers to manufacture its PCs.

Unlike mainframes, personal computers were developed for individual users, making it accessible to the general consumer, and not just for large corporations or institutions. It allowed for direct interaction between common people and a computing machine. Thus, individuals could perform specific tasks such as writing documents or organizing the office accounting on the computer, managing their own data locally.

PCs also boosted the development of computing distributed systems. An example of computing distributed system is a group of personal computers (processor-memory), communicating with each other through a local area network (coaxial cable) within a physical space such as home, office, university, industry or any other setting or geographical area.

The late 1980s and early 1990s saw the world of the mainframe and the personal computer come together with the development of the first so-called *client server* systems, where a server-computer perform specific tasks or services requested by a client-computer through the Internet. This allowed the deployment of sophisticated Graphical User Interfaces, replacing the *green screen* dumb terminals of the mainframe era. In a nutshell, we observed an important evolution from the *mainframe-centralized computing system to the personal computer distributed system*.

Another important technology that first saw widespread deployment at this time was *virtualization* – pioneered by IBM's mainframe operating system MVS/VM but first used at scale on IBM's midrange System/38 and AS/400. Virtualization allows multiple applications running on the same computer to behave as if each application had its own dedicated hardware and software stack, greatly improving price-performance and reliability. Virtualization ultimately lead to the development of *Cloud Computing*, which I will refer to later.

The next big step in computer development was the creation of the *World-Wide Web* by the British scientist Timothy Berner-Lee in 1989 while he was working at the European Council for Nuclear Research also known as CERN. The World-Wide Web is usually interchangeable with INTERNET; however, this last term was used much earlier when the predecessor of the World Wide Web, the Advanced Research Projects Agency Network or ARPANET incorporated the Transmission Control Protocol and Internet Protocol (TCP/IP) as a communication mechanism to connect computers in a network.

ARPANET was funded by the US Department of Defense in 1966 to build a computer wide network for military and scientific purposes. By 1969, ARPANET managed to send an e-mail between two separate computers located at the University of California-Los Angeles (UCLA) and

at the Stanford Research Institute (SRI), and in December 1969, two more computers located at the University of California-Santa Barbara and the University of Utah joined the network. Thus, 1969 became the birth year of the e-mail, while the ARPANET expanded his network to other military and research institutions in the US, including the National Science Foundation Network (NSFNET) which functioned between 1985 and1995. NSFNET played an important role in the transition to the full commercial use of the World-Wide Web in 1995, while the ARPANET, the main pioneer computer networking project, was decommissioned in 1990.

The commercial use of the World Wide Web, made possible the connection of all computers around the world, creating a sort of *information superhighway*, a widely used concept during the 1990s, particularly by former US Vice President Al Gore. Thus, in the first years of INTERNET, especially the second half of 1990s, we observed the development of e-mail communications, the emergence of electronic commerce with Amazon pioneering sales of books on line, the proliferation of personal and commercial websites and the creation of web browsers such as Netscape Navigator and Internet Explorer to browse the Web.

With the introduction of 3G mobile phone network in 2001, smartphones technology started to improve dramatically. 3G network provided cellphones with a wireless connection to the INTERNET, better multimedia and data capacity, faster data transmission as well as support for other applications. It paved the way for the creation of Apple' smartphone, the iPhone, in 2007, which revolutionized the whole smartphone industry. Indeed, the iPhone allowed people everywhere to browse the INTERNET just as they would do it from their laptop or desktop computer. In other words, the iPhone became a small-size mobile computer connected to the INTERNET, providing a number of applications for the convenience of consumers.

As a result of the large traffic of data generated by millions of computers, tablets cellphones/smartphones and other computing devices connected to the INTERNET, a new paradigm called *Cloud Computing* emerged in 2006 to manage the massive generation of computing power and computer memory as well as the enormous explosion of applications.

To explain Cloud Computing in imaginary terms, just think of the information superhighway (INTERNET), with a number of computing services-equipped warehouses (Clouds) along the Web. Then, imagine individuals and companies traveling (browsing) along the Web and stopping at any of these warehouses (Google, Amazon or Microsoft to name a few big ones) to buy computer infrastructure (servers, storage, OS, etc.), computer platforms to develop applications or just to buy applications. In short, Cloud Computing is an ecosystem where computing power is centralized to provide individuals and companies all type of computer services upon request and adjusted to customers' needs.

Cloud providers host remote and big data centers, which interact with millions of computers, smartphones and other computing devices. Every time you use your smartphone, you are interacting with a public, private or hybrid (a combination of public and private) Cloud either for searching or storing information. This system adapts well to the corporate or individual needs as it allows faster innovation, great flexibility, economies of scale, and increasingly, artificial intelligence and machine learning functions.

Nowadays, Cloud Computing is a billion dollars business, where Microsoft became the No.1 vendor in 2020 with a revenue of US$59.5 billion, followed by Amazon with US$45.2 billion and Google with US$13.0 billion, according to the article *Microsoft Wallops Amazon in 2020 Cloud Revenue; Bigger than AWS and Google Combined*, posted by Bob Evans on February 8, 2021.

Despite the dominance of Cloud Computing, we are now witnessing a transition to the world of *smart devices or machines*, such as self-driving vehicles, ships, drones, robots or what is known as the *Internet of Things (IoT)*. These devices or machines are computer-operated with total autonomy and capacity to sense, infer and make decisions based on data collected from their immediate environment. Therefore, they must have the computing power, storage and analytics right at the *edge* of the network or locally built-in.

This new computer architecture is called *Edge Computing*, and unlike Cloud Computing, it is a decentralized, real-time decision-making model of computing, performing a specialized function such as the autonomous operation of a vehicle. The data center or processing power is not only in the Cloud but also in the device or machine. As well explained by Peter Levine in the presentation the *End of Cloud Computing*, "a car becomes a data center on wheels, a drone becomes a data center on wings, the ship becomes a floating data center and the robot a data center with arms and legs".

Yet, these localized data centers (in every device or machine) will collect, filter and deliver relevant information to the Cloud for the purpose of further machine learning. Thus, the Cloud will not disappear or lose its main functions; on the contrary, the Cloud will be in a continuous feedback loop with machines and devices at the edge of the network to make them smarter. In a nutshell, Edge Computing is a complement, rather than a competitor of Cloud Computing.

If with computers, tablets, smartphones and other devices, Cloud Computing generated a billion dollars business in the past 15 years, industry analysts and consultants believe that the next wave of IoT devices will make Edge Computing a trillion dollars business in a very few years.

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