Some Remarks on "The Computer and the Brain"

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Abstract[1]

This paper contains some remarks, comments and explanations about some statements and calculations of the unfinished book written by John von Neumann with the goal to publish his Silliman Lectures at Yale University, USA. The book with the title „The Computer and the Brain" was first published in 1958, while John von Neumann passed away in February 1957. This book should be used as one of the basic studies for all engineers, information technology and computer people.

Keywords - brain, computer, comparison, speed, memory

1. Introduction

In the next pages some remarks will be explained concerning the unfinished book written by John von Neumann. Neumann had the goal to publish his Silliman Lectures at Yale University, USA, when he realized then his health was very poor. The book with the title „The Computer and the Brain" was first published in 1958, while John von Neumann passed away in February 1957.

The following 9 words to start are borrowed from John von Neumann:

"Since I am neither a neurologist nor a psychiatrist" and – the author has to add: I am not even a mathematician, but an electrical engineer", my view on most discussed topics could be radically different from the mostly used, accepted views in the community for which Neumann prepared his lectures. This was a virtual problem, only.

In some main issues we try to compare the different solutions of Neumann with the solutions of the past 60 years in computer technology and in brain research as well.

To show Neumann's position and role in the science of the USA in the first part of the 20th century some background information is given below:

People learned a lot from the First World War, and the United States became a very advanced and rich country, with a better and better educational system with much more personal freedom (for the most) than in Europe. Then before the second World War Hitler's power and his politics made several, mostly Jewish people understand that it is better to move and work in the USA. Several famous scientists, artists, musicians emigrated to the US and they got good working possibilities good salaries and a peaceful life.

A short biography of J. v. Neumann is just interesting to show his origin, his studies and his unbelievable career: how he became one of the best mathematicians ever lived.

He was dealing with mathematical aspects of military, economical, computer technical and other related, or not related topics, as for example the human nervous system, etc. and achieved and published remarkable results. And to be sure not to misunderstand anything he had a chemical engineer's diploma in his pocket.

The most valuable publications on Neumann's life and work were written by Győző Kovács [1,2], who were deeply involved in the first Hungarian computer projects, admired Neumann and took advantage of all possibilities to make him and his work known and appreciated worldwide.

Neumann was born in a wealthy, open minded Jewish family in Budapest. He was a child prodigy understanding and solving complex problems rather fast, and he kept this quality during his short life. Von Neumann studied in the "Fasori Evangelikus Gimnázium" from 1911 to 1919. This was one of the best highschools in Budapest, having excellent teachers and high-level study programs in all disciplines, including natural sciences and humanities as well.

The school gave the world several top-level scientists (and researchers), some of whom were awarded by the highest awards, including the Nobel Prize as well. Just some names to mention (with Hungarian Christian names):

Tódor Kármán, György Hevesy, Leó Szilárd, Dénes Gábor, Jenő Wigner, Ede Teller, and Pál Erdős . All of them were born in a rather small time span from 1881 to 1913, they left Hungary to study and then to work in the Western hemisphere, but still remained Hungarians.

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They were often addressed as Martians (People from the Mars, speaking a funny, very different language). Wigner was a year ahead of von Neumann at the Lutheran School.

When he was asked why Hungary had produced so many geniuses of his generation, Wigner, who won the Nobel Prize in Physics in 1963, replied that von Neumann was the only genius.

Neumann absolved his university studies in Budapest, Berlin, Zürich and Göttingen, got his Chemical Engineering Grade fist and doctorate of Mathematics only a little later.

He was invited to the University of Hamburg to work there, and he wanted to accept the position, when an invitation arrived from the USA to the Princeton University in Princeton, New Jersey, which he could not refuse, and then moved to the USA.

All main achievements of J.v. Neumann can be taken into account as contribution to the Intelligent Decision Making. He gave equally valuable, unique and important new results to the world in the fields of Set Theory, Cellular Automata, Quantum Mechanics, Nuclear Pphysics, Computer Architectures, Game Theory (and behavior of economy), etc. See [1,2,3,4,5] for more.

Before of going ahead we have to mention that the first electronic digital computers were designed and made and used by the American John V. Atanassof and by John von Neumann in the late 1940th.

The history of computers is rather long, as several attempts were to build mechanical computing machines from the 17th century. Let us mention the chess playing computer and robot of Farkas Kempelen from the 18th century, or the music boxes or some clockworks with moving figures from the same times. Now only some important persons are mentioned, who really added knowledge, science, research to the development. These are Blaise Pascal (1623-1662), Gottfried W. Leibniz (1646-1715), Charles Babbage (1791-1871), George Boole (1815-1864), Clifford E. Berry (1918-1963), Conrad Zuse (1810 – 1995), Howard Aiken (1900-1973), Presper Exkert (1919 – 1995), J.W. Mauchly (1907 - 1980).

To build “real” computers the development of electro technique and electronics had to be very strong, from electron bulbs through semiconductors and integrated circuits until all the way of supercomputer networks with huge memories and speeds, using advanced software solutions, as AI, DBMS, KB, etc.).

All these things are supposed to be well known by the reader, as well as the types of computers, computer networks, etc.

2. The Computer and The Brain

The “Computer and the Brain” (1958) is a published version of the Silliman Lectures which John von Neumann was invited to deliver at Yale in 1956. The lectures were finally not given, just an essay of 82 pages was almost finished. It is structured in two (three) parts.

The first part discusses the computer: its procedures, control mechanisms, and other characteristics.

The second part focuses on the brain. The neural system is systematically compared with the computer.

In the third part, which is not organized as a separate part - Von Neumann draws some conclusions from the comparison with respect the role of code and language. The way Neumann approaches most problems could be called the way of an AI pioneer.

2.1 The method of this study is generally the following:

Try to understand Neumann’s view on different relevant problems and solutions and compare them to old and more recent explanations and solutions

The following are the most important issues – more or less as they are in his book:

- Analog and digital procedures.
- Parallel and serial schemes.
- Operation and structure of the brain, how it works, control procedures, function of the neurons, digital and analog parts, control systems.
- Operation of digital computers, control procedures, memory-stored control, hybrid (mixed) control.
- Capacity (memory size) of the brain (and its environment), estimation of the memory capacity.
- Capacity (memory size) of a computer (and its environment).
- Structure (building blocks) of a digital computer – Structure of the brain.
- Precision of Computers - Precision of the Brain.

2.2. Some data of Neumann’s book

These are data taken as the best available equipment and building blocks, which are produced by leading firms and used at the best universities to make experiments and calculations..

Memory access times:

- ferromagnetic core memories: 5-15 microseconds;
- first electrostatic memories: 8-20 milliseconds;
- drums: 2500 -20000 rpm (a revolution per 24 to 3 milli-seconds), 1000-2000 words may get fed in the given time;
- magnetic tapes, speeds up to 70 000 lines per second, 1 line in 14 microsec; a word consists of 5-15 lines.

Precision:

- analog machines – 1: 10^3;

- differential analyser – 1: 10^4 - 10^5;
- digital machines – 1:10^{12}.

Number of active components requested: 3.000 – 30.000.

Active components' speed:

- relay: 10^{-2} sec;
- vacuum tubes: 10^{-5} - 10^{-6} sec;
- solid state devices: 10^{-6}.

Try to understand Neumann's view on some relevant problems and solutions and compare them to old and more recent explanations and solutions.

The following are the most important issues – more or less as they appear in his book:

- estimation of the memory capacity;
- analog and digital procedures;
- parallel and serial schemes;
- operation and structure of the brain, how it works, control procedures, function of the neurons.

Size data

- brain cell membrane thickness: 10^{-5} cm;
- vacuum tube grid to cathode distance 10^{-2} - 10^{-2} cm;
- transistor relevant distance: 10^{-3} cm.

The Brain would win by a factor 10^3.

Volume data:

- the central nervous system is about 1 liter in the brain, i.e. 10^3 ccm;
- number of neurons: 10^{10};
- volume of one neuron: 10^{-7} ccm;

The size of memory needed in the brain is 2.8 x 10^{20} bits.

Costs are rather different, and not always published: just one information: an analog computer was 1 000 000 USD

Just one example before a short list is given:

Computer architecture meant in Neumann's time the building of one computer, no one dealt with the different computer networks. As a reminder the Neumann architecture and the Harvard architecture are given below in Fig, 1, and Fig, 2.

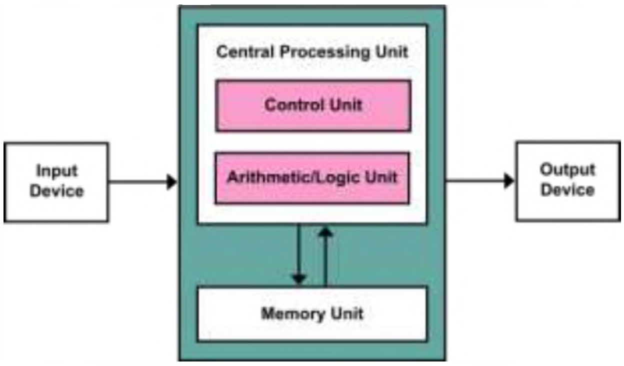

Fig. 1. The Neumann computer architecture

Fig. 2. The Harvard computer architecture

Neumann uses the above data (and some more) to compare the brain with the digital computers and to draw some conclusions.

One can accept that he knew all important data and information of the mid-fifties, as he was a very well educated and informed scholar and scientist

But there are plenty of new results, theories, experiments, etc. both in computer studies and in brain research, which were invented, found, researched, experimented, concluded, etc. in the past 60 years that he could not even dream about them in the 1940th and 1950th years.

2.3. Some up-to-date problems

Now a list of issues and solutions in the field of computers and computer technology, which Neumann could not have a chance to know, even the words did not exist in his times, still some of his results can be mirrored in them:

- Computer Networks, Interfaces Token-passing, Internet, WWW, Grid, Cloud;
- Integrated circuits, memory cards, Processors, Multi-processors, Time-sharing;
- Floppy, Winchester, Gigabyte, Terrabite, FLOP, Hierarchy, Heterarchy, OO:
- Big Data, Data Mining, 2D/3D;
- Cellular computers, Quantum computers, Cellular Neural Networks, Operational System, Remote Control, Supercomputers, etc.;
- New Materials, New Technologies, High Precision;

- The expression Artificial Intelligence (AI) and its proper understanding were born in 1957 (Dartmouth, USA) when his cancer was discovered.

In connection to the human brain the same kind of rather simplified list could be given, which were unknown before 1957, including the years of Neumann's life. Instead, some views and opinions and research conclusions will be given.

2.4 A few recent statements and results concerning the computer and the brain

Now let us turn to some statements and numbers, which consist of several expressions and notions Neumann would not have been able even to understand, and, which are preliminary results or unproved statements from the past couple of years.

However, if the reader goes through Neumann's book the roots of several ideas can be found or at least felt, i.e. Neumann could feel the future of research results and of technical and technological development. Some statements and rationalize:

a. Today if a competition could be organized and evaluated between a Computer and a human Brain the result would be in favour of the computer in speed and in smartness as well.

b. If the same competition would have been managed some years ago, there would be no question… **the human brain would have been the winner in both disciplines, in smartness and in speed as well**.

c. The "brains are analogue, computers are digital". This makes it seem like computers are the winners, as today digital computations are taken as superior in every sense. The truth is, that the human brain is far more advanced and efficient and possesses more raw computational power than the most impressive supercomputers that have ever been built.

d. Some years ago, the **fastest supercomputer** in the world was the Tianhe-2 in Guangzhou, China, and had a maximum processing speed of **54 902 petaFLOPS**. A petaFLOP is a quadrillion (one thousand trillion) floating point calculations per second. That is a rather huge amount of calculations, and yet, that is still far behind the processing speed of the human brain.

e. In 2014, some researchers in Japan [8] tried to match the **processing power in one second from one percent of the brain**. That doesn't sound like very much, and yet it took the 4th fastest supercomputer (the K Computer) 40 minutes to crunch the calculations for a single second of brain activity!

A surprising statement and conclusion: brains are very different from computers

Computers - in our mind - are carefully designed machines that are based on logic, reproducibility, predictability, and mathematics. The human brain, on the other hand, is a tangled, seemingly random mess of neurons that do not behave in a predictable manner.

For example, the brain is both hardware and software, whereas there is an inherent different in computers. The same interconnected areas, **linked by billions of neurons and perhaps trillions of glial cells, can perceive, interpret, store, analyze, and redistribute at the same time**. Computers, by their very definition and fundamental design, have some parts for processing and others for memory; the brain doesn't make that separation, which makes it hugely efficient.

The same calculations and processes that might take a computer a few million steps can be achieved by a few hundred neuron transmissions, requiring far less energy and performing at a far greater efficiency – due to the specific organization of the brain.

The amount of energy required to power computations by the world's fastest supercomputer would be enough to power a building; the human brain achieves the same processing speeds from the same energy as is required to charge a dim lightbulb. Biological processes have had billions of years to evolve perfect, efficient organs that far supersede technology, and we are beginning to reach those artificial "limitations".

Brain has its advantage in raw computing power supported by its flexibility. Essentially, the human brain can rewire itself, a feat more formally known as neuroplasticity. Neurons are able to disconnect and reconnect with others, and even change in their basic features, something that a carefully constructed computer cannot do.

3. Preliminary Conclusions

We see this amazing transformative feat in a wide variety of brain functions, such as the formations of memory, knowledge acquisition, physical development, and even recovery from brain damage. When the brain identifies a more efficient or effective way to compute and function, it can morph and alter its physical and neuronal structure, hence the term "plasticity". Until we achieve true Artificial Intelligence (in which computers should theoretically be able to re-wire themselves), neuroplasticity will always keep the human brain at least one step ahead of "static" supercomputers.

If there is one thing about human beings, it's that we don't like being told something is impossible. Therefore, now that we have a clear goal that is nearly in sight (a computer that operates at the exaFLOP level), we have begun to pay more attention (and spend more money) towards achieving it.

For example, the Human Brain Project [9] has the ultimate goal of reaching exascale computing (computing at the same processing power and speed as the human brain; an artificial brain, so to speak). Launched in 2013, the Human Brain Project has already sourced billions of euros for this project, which could have hugely important ramifications in many different industries.

The following statement: Computers are good at storage and speed, but brains maintain the efficiency lead

For decades computer scientists have strived to build machines that can calculate faster than the human brain and store more information. The contraptions have won. The world's most powerful supercomputer, the K from Fujitsu, computes four times faster and holds 10 times as much data. And of course, many more bits are coursing through the Internet at any moment. Yet the Internet's servers worldwide would fill a small city, and the K sucks up enough electricity to power 10,000 homes.

The incredibly efficient brain consumes less juice than a dim light bulb and fits nicely inside our head.

Biology does a lot with a little: the human genome, which grows our body and directs [10] through years of complex life, requires less data than a laptop operating system. Even a cat's brain smokes the newest iPad—1,000 times more data storage and a million times quicker to act on it [11].

An artificial intelligence project recently funded by Silicon Valley aims to find a new way to compare supercomputers to the human brain. Instead of trying measure how quickly wetware or hardware can do calculations, the project measures how quickly the brain or a computer can send communication messages within its own network. That benchmark could provide a useful way of measuring AI's progress toward a level comparable with human intelligence.

The AI Impacts project is the brainchild of two PhD students from the University of California, Berkeley, and Carnegie Mellon University [11]. They have developed a preliminary methodology for comparing supercomputers to brains: traversed edges per second (TEPS), which measures how quickly a computer can move information around within its own system. A typical TEPS benchmark requires computers to simulate a graph and search through it. That's not possible with the brain, so instead, the researchers compared the computer's performance to a rough estimate of how frequently the brain's neurons fire off electrical signals.

This method provides a relatively independent estimate of the price of computing hardware roughly comparable to the brain. IBM's Sequoia supercomputer currently holds the TEPS benchmark record with 2.3 x 1013 TEPS. At the upper end, their max estimate of the human brain's capabilities suggests that it's 30 times as powerful as IBM's number cruncher at 6.4 times 1014 TEPS.

They've pegged the cost of the human brain's performance at somewhere between $4700 and $170000 per hour in terms of current computer prices for TEPS. There was a "fairly wild guess" that TEPS prices could improve by a factor of 10 every four years. That means computer hardware costing $100 per hour to operate could become competitive with the human brain during a time period between seven to 14 years.

But don't panic, worrying that AI will replace humans en masse just yet. The researchers point out that there are many "ifs" and assumptions baked into their calculations. For example, they don't have much information about how quickly TEPS performance might progress in computer hardware. It's possible that progress could slow down in the near future. Still, the TEPS benchmark [12] may provide another useful way to compare AI with human-level intelligence in the coming years. Measuring communication within the brain's neurons is somewhat easier than trying to measure computations, because nobody knows exactly how computations are represented in the brain [12].

To find more examples, the researchers recently introduced "research bounties" paying between $20 and $500 to anyone who submits examples of either "discontinuous technological progress" or people acting to prevent a risk that was at least 15 years ago.

The above statements and opinions reflect that the idea of Neumann is still active and alive, several researchers and groups of researchers would like to compare the computers and the brain and have some final decision. However, the problem is too complex, new ideas and findings in biology and in technique regularly and make the work harder and more and more beautiful, and the score Computer vs. Brain remains a secret for a while.

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