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THE CHIP: AN ELECTRONIC BRAIN

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Abstract

The human brain is still a 21st century mystery, an organ of impassable complexity. It has being compared to various inventions, it was sometimes compared to a telephone switchboard and also compared to mathematical logic by renown scientist Gorge Boole but it is now seen as a sort of biological computer, with mushy hardware and software evolving from life experiences. This paper elucidates and also makes a critical review on the analytical study of the computer chip with the human brain exploring their similarities, differences, the latest trends, prospects and the challenges ahead. It however concludes that due to increasing parallel processing of computer chip, the prediction that the processing power of the hardware will match the human brain might be realistic.

Keywords: Chip, MIPS, Microcontroller, Brain and Neural network.

1. Introduction

The drastic changes in electronics from vacuum tube down through the transistor to IC and eventually microprocessor have caused a revolutional breakthrough in the processing power of computer. Gordon Moore law forecasted that chip processing power doubles every two years (Casey Research, 2011), entailing that companies that keep up with the pace would survive in the market while those that could not keep up with the pace might lose their business. The number of transistors on a chip in 1971 was approximately 2300 but in 2011, it has increased to approximately 2.3 billion on a single chip (Casey Research, 2011).

Chips at times are being referred to as integrated circuits and constitute an important component of the modern computer. A chip is a minute piece of semiconducting material, having an electronic circuit that may consist of hundreds, thousands, or millions of transistors, with other microelectronic components. A chip can also be referred to as a microprocessor, which is also known as the brain of a computer system and a microcontroller which is sometimes referred to as a specialized computer system or an embedded system. An embedded system refers an electronic design that utilizes the power of a small microcontroller. The microcontroller comprises a microprocessor unit like the CPU in a desktop PC with some additional circuits on the same chip that produce a small control module requiring few other external devices. This chip can then be embedded into other electronic and mechanical devices for low-cost digital control. In this paper, the chip is referred to as a microprocessor in a computer system.

Brain is also conceived as a sort of biological computer, with mushy hardware and software evolving from life experiences, and is considered to function in line with the emerged field

known as neural network. Neural Networks try to imitate and bring the information processing capability in the brain into a computer.

Extensive computer models of the neuron have been constructed by computational neurobiologist for extensive simulations of particular circuits in the brain, and model neurons have been implemented in hardware electronic circuits, often integrated on VLSI chips. Artificial neuron mimics the function of a biological neuron and the main body of an artificial neuron is referred to as node or unit which is the basic computational element. They may be connected together by wires and the neurons are represented as integrated circuit. The node receives input or signals from some other node, or an external source. Such signals are multiplied by a weight and each input has an associated weight, *w*. The node computes some function *f* of the weighted sum of its inputs in a form that can be represented as follows:

$$y_i = f(\sum_j w_{ij}\, y_j) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

The output on a particular node, in turn, can serve as input to other units as can be seen from Figure 1.

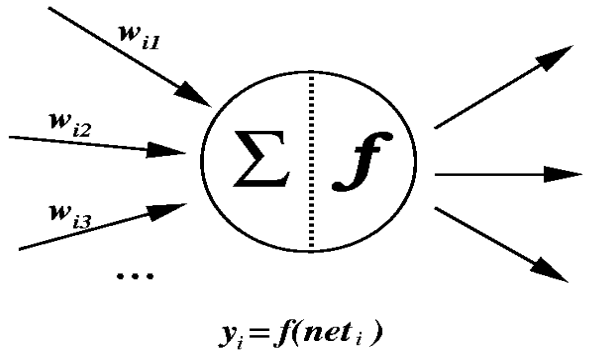

Figure 1: The main body of an artificial neuron which is referred to as node or unit.

In Figure 1, the weighted sum $\sum_j w_{ij}\, y_j$ is called the **net input** to unit *i*, usually written as net_i.

w_{ij} refers to the weight from unit *j* to unit *i* and not from i to j. Where y_i represent the node

The function *f* is the unit's **activation function**. Thus, f is the identity function, and the unit's output (y_i) is just its net input. This is referred to as a linear unit.

2. Current trends

The study of the neural architecture of the human brain still remains a 21st mystery yet to be resolved. Studying the neural architecture of the human brain is still very difficult due to the interwoven of 100 billion of neurons and its complexity but the main challenge is its opaqueness. The jelly-like substance known as lipid molecules of the brain which assist and surround the inner circuitry of the brain, causes light impassable. The lipid cells is the main driving force for the brain's neural network but the lipid cells have really caused mapping the brain a complex issue with a lot of drawback (MITOpencourseware,2013). Recent progress in magnetic resonance imaging (MRI) technology has assisted researchers to imagine the internal structure of the activity in some part of the brain through the variation in heat and blood flow.

A team of researchers at Stanford University in April 2013 rendered the tissue of the brain almost completely transparent. The brain was completely immersed in a transparent hydrogel that surrounds the brain tissue joining its entire cell except the lipids cells. The precise mixture of chemical and electrical charge was used by applying heat to remove the lipid cells. The lipid cells were replaced by the hydrogel, making the brain tissue almost completely transparent with nerve network undamaged and together (MIT Opencourseware, 2013). Various researches have being going on in the field of Artificial intelligence to develop a machine that can think logically as a man, if not outsmart man, but the fundamental question has been can machines be able to out-think a man? The IBM Deep blue machine defeated the world best chess player Garry Kasparov in 1997; it examines 200 million chess positions per second, by using specialized chips to make moves at a the speed equivalent to a 3 million MIPS otherwise known as millions of instruction per second, universal computer which is estimated to be 1/30 of the estimate for total human performance (Moravec, 1998). Also, a program written by Jonathan Schaeffer called Chinook from University of Alberta in 1994 has consistently won the world's human checker champion (Moravec, 1998).

Computer has proved retrospectically to have some level of intelligence more than man, it perform logical computations without mistakes and performs calculations thousands of time faster than man. Machine intelligence has being compared to human brain by using MIPS has a yardstick. MIPS (Millions of instruction Per Seconds) is a standard for measuring the computer speed and performance. The CPU, MIPS rating is the number of low level machine code instructions a processor can execute in one second. It can be computed by dividing the number of instruction to be executed by the execution time and the final result should be divided by 1 million, to get the MIPS

MIPS = ((number of instruction to be executed/execution time)/ 1 million) (Athena, 2010).

If a computer completed 200,000 instructions in 0.02 seconds, the calculation would be (200,000/0.02)/1 million = 10 MIPS

Also, the number of cycles per second of a CPU can be divided by the number of cycles per instruction (CPI) and then divide by 1 million to get the MIPS (Athena, 2010). For instance, if a computer with a CPU of 400 megahertz has a CPI of 4, the calculation will be

(400/4)/1 million = 0.0001 MIPS (Athena, 2010).

With the increase in robot and computer power, computer vision has shown that 1 MIPS can be adequate for real-time imagery tracking of a white line or a white spot on a mottled background. Also in the late 1980's, at 10 MIPS good optical character reading (OCR) programs were able to read typewritten and printed text. At 100 MIPS, trainable optical character reading programs appeared that could learn unusual typestyles from examples and the latest and best programs learn their entire data sets (Moravec, 1998).

The brain is visualized also as a circuit connected with wires, a field known as neural network. There is no quantitative measure of the processing power of the human brain but usually estimates are usually through comparison to vertebrate eye that its function and structure is well known (Think Quest, 2000). It is estimated the brain contains about 100 billion nerve cells, called neurons, immensely connected with complex wiring connections and different types of inter-neuronal connections instead of one-one connections (Casey Research, 2011). Research has shown that there are sub-cellular computing going on within the neuron, making the human brain to be seen as a network of nodes with billions of sub nodes all working together in a parallel network (Casey Research, 2011).Typical neurons in the human brain are connected with 10,000 other neurons, with some categories of neurons possessing more than 200,000 connections (Microsoft Encarta, 2009). Although, from the mode of operation, neurons typically operate at a maximum rate of about 100 Hz and the brain consist billions of these neurons but a CPU carries out several hundred million machine level operations per second.

The retina is a light sensitive tissue at the back of the eye that receives image from the lens and sends such image via the optic nerve to the brain. A human retina is half millimeter tick, less than a square centimeter and human retina comprises about 100 million neurons, the retina process about ten one-million-point images per second (Moravec, 1998; Think Quest, 2000).

The 1,500 cubic centimeter human brain is about 100,000 times as large as the retina which implies overall human behavior using 1,500 cubic centimeter of the brain will take about 100 million MIPS of computer power (Moravec, 1998; Think Quest, 2000).

Robot vision programs take about 100 computer instructions to detect single edge or motion detections from similar video images. A million detections need 100 million instructions, and 1,000 MIPS to repeat them ten times per second to match the human retina (Moravec, 1998).

In 1998, the most powerful experimental supercomputer which had thousands of the fastest microprocessors and with cost of tens of millions of dollars can do a few million MIPS. Also, the 1999 fastest PC processor chip which performed 4200 MIPS and was of the 700MHz Pentium,

would need 24,000 of processors to match the total speed of the brain, since the brain is equivalent to a 16,800,000 MHz Pentium computer (Think Quest, 2000). The Defense Advanced Research Projects Agency(DARPA) had awarded a research grant to firms in 2010 to build machines that can perform a quintillion computation per second and the first prototype is expected to be ready by 2018 (Casey Research, 2011).Table 1 shows the differences between the brain and the CPU.

TABLE 1.0: Difference between the brain and the CPU

	Processing elements	**Element size (m)**	**Power use (W)**	**Processing speed (Hz)**	**Style of computation**	**Fault tolerant**	**Learns**	**Intelligent, conscious**
Brain	10^{14} synapses	10^{-6}	30	100	parallel, distributed	yes	yes	usually
CPU	10^{8} transistors	10^{-6}	30	10^{9}	serial, centralized	no	a little	not (yet)

3. Convergence between the human brain and a chip

The human brain and chip also share some features. Microprocessor otherwise known as a chip is referred to as the brain of a computer; it is also referred to as the central processing unit (CPU) of a computer. It produces logical result based on a predefined instruction and controls activities of a computer such as peripherals under certain logics or instructions. The human brain controls various activities in the body such as: breathing, heartbeat, balance of weight, body temperature regulation, and body movement to mention a few.

Computer can do many tasks concurrently in a process which is known as multitasking, that might be difficult for the brain. However, the brain also does some multitasking, for instance the brain controls heart rate, breathing and blood pressure concurrently (Eric, 1996). They both need energy to function; the computer chip needs electricity to function while the brain needs oxygen and sugar to function (Eric, 1996). The microprocessor otherwise known as the CPU consists of the arithmetic and logic units as well as the control unit, thousands and millions of transistor and logic gates are embedded on a single chip. The Arithmetic and logical unit is where comparison and arithmetic computation is done. The control unit monitors and ensures all parts of the computer system do their job according to instruction. The brain has about 200 billion nerve cells, which are connected to one another by trillions of synapse. Each synapse can be compare to a microprocessor. They both can be damaged, the brain can be damage by disease or neurological disorders such as Parkinson's disease and if a pathway in the brain is damaged, there is always an alternative pathway that will perform the function of the damaged pathway (Eric,1996).

They both can do calculation and perform some logical tasks. The computer chip performs both arithmetic and logical computations without mistakes and performs calculations thousands of time faster than the brain but the brain is capable of intuition and imagination (Eric, 1996). They can both be in the on or off state, the computer use a switch button to be in an on or off state while the neuron in the brain can either be on or off by either firing an action or not firing an action, it is constantly getting information from other cells through synaptic contacts (Eric, 1996). Both uses electrical signals to send messages or transmit information. The computer uses electricity to transmit information through the wires and the brain uses chemicals to transmit information (Eric, 1996).

Despite the similarities they still share some basic differences as follows:

(a) Sense: This has to do with faculty of perception or feeling, a computer chip cannot interpret its surrounding environment the way the brain can. A standard set of rules are used in computer chip which serve as instruction, leaving it with no reasoning potentials just response based on the set of rules (Brockman, 2012).

(b) Intuition: This has to do with instinct insight without conscious reasoning. The brain's intuition enables it to be aware of certain things that a computer chip can only compute to arrive at a conclusion. For instance if someone tries to hide his/her feeling, a computer chip will only calculate the surface evidence while the brain can intuitively be aware of the little changes in state of mind, speech or body language (Brockman, 2012).

(c) Conscious: This has to do with awareness. The brain can act and respond to emotion while the computer only functions through logic. The brain also has the natural tendency to be imaginative and creative while a computer chip function based on what is already programmed (Brockman, 2012).

(d) The brain is a biological system while the computer is a physical system. Also, the brain consists of network of neurons that forms a massively parallel information processing system. In conventional computers, a single processor executes a single series of instructions but such processor might contain more than one CPU.

(e) The brain performance tends to degrade when partially damage but partial recovery from damage can occur if healthy units can learn to take over the responsibility previously carried out by the damaged areas. In contrast, the CPU will cease to function if any part is damaged.

4. Challenges

Knowing the difference between a cat and a dog might be very challenging even for the most advance computer, something that can be done within a twinkle of an eye by a cat (Sandra and Sam, 2009). Also, the human brain can go through a database of experiences and emotions.

Intuitively the brain can recognize the face of friend, parent and objects whether during day time or in the darkness, a sort of task the computer vision system built in the state of art robot can achieve haltingly. Human can multitask without much effort for instance removing an handkerchief from the pocket and mopping off the sweat and at the same time having conversation with a friend but to design an electronic brain that can be embedded in a robot that multitask effortlessly still remains a distant prospect (Terry and Tobi, 2012)

One of the major challenges in building such powerful computer with computer speeds that will match human brain is the structural, management, power and software issues (Casey Research, 2011). The more memory a computer has the slower it becomes because it takes more time to run through its memory during instruction execution (Think Quest, 2000). Computers with less memory have more MIPS, but limited to less space to execute large programs (Think Quest, 2000).The early electronic computer performs few thousand calculation per second and had few thousands bytes of memory. Also, medium/desktop computers of the 1980 perform a million calculations per second and had million bytes of memory. Nowadays, Supercomputer has a trillion bytes of memory and can perform trillion calculations per second (Moravec, 1998).

5. Prospects

New research in quantum theory will also give birth to a new computer known as quantum computer. We will be having an evolutional breakthrough from silicon based computer to quantum computer. Researchers use the concept of the behaviour of subatomic particles to perform calculation in quantum computing. Because quantum computers carry out computations at the atomic level, they are theoretically expected to find all possible answers to a query concurrently, and perform calculations or computations in parallel connections. This feature would make quantum computers thousands or even millions of time faster than the present computers (Microsoft Encarta, 2009). Also, groups of scientists at the University of New South Wales in Australia are on the verge of implementing the fundamental building blocks for silicon-based quantum computers instead of quantum computer alone, by using silicon instead of atoms electromagnetically suspended in a vacuum. They are close to implementing a quantum bits otherwise known as qubits in silicon atoms. Qubit is the building block for quantum computer for the nearest future (Michael, 2013).

6. Conclusions

The human being has accomplished supremacy over all living creatures due to the human brain. Its processing power cannot be compared to the state of art digital computer and perhaps the evolving quantum computer. However due to increasing parallel processing of computer chip, the prediction that the processing power of the hardware will match the human brain might be realistic. In the design of such computer chip that will match the human brain, the software aspect must also not be taken with levity; artificial intelligence software must be developed to

achieve this aim. Such software will have general intelligence by having independent initiative and decision making capability. Man has come out with various inventions from airplane, cars, mobile communication and now down to the computer. All these are a gift of nature. Though the computer cannot replace man natural intuition, it can augment the senses in man.

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