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Neuro-Morphic Vomputing: A Survey

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ABSTRACT

Classical In recent years, there has been an active development of computers and they have become very fast and efficient. Simply, the traditional computing is reaching its limit soon it will reach threshold which we cannot move past without making some big changes to the way we design computers. In this report, we will explore the potential of neuromorphic computing and the exciting strides which have been made in this field in the past years as neuromorphic chips could possibly be the best option to integrate the concept of neural network with. Neuromorphic hardware being able to transmit a gradient of understanding from neuron to neuron and to have them all working together simultaneously neuromorphic chip could be more energy efficient than the traditional computing. With the development of neuromorphic chips we are edging towards achieving the best performance so far.

Keywords: ML, AI, Neuromorphic chip, Neural Computing, Traditional Computing;

INTRODUCTION

Traditional computers think in binary everything is either a 1 or 0 or a yes or no so, the code and architecture of these computers has to be structured in a very rigid way. Neuromorphic computers work more flexibly, it takes inspiration from biology. To find a more efficient alternate to traditional computers neuromorphic computing aims to design and engineer computer chips which use the same physics of computation used by our own nervous system. In addition, these chips emulate the biological neurons and synapses in the brain. To do this researchers need a kind of electric current and this technology gives us more computational options than just your basic yes or no. The neuron on these chips can learn as they compute. [13, 14] talks about ML algorithms in detail.

Figure 1: Neurophormic chip

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Neural Networks

Neural networks are large group of interconnected neurons which can provide you abstraction of data necessary for techniques such as reinforcement learning. A traditional neuron have two main parts- first a value which is the sum of weighted inputs a neuron also has outputs each with a specific weight which determines how impactful its predecessor is to its successor. The value of a neuron can be limited and these values can be treated as continuous or discreet. Neuromorphic computing is a bit different. It takes inspiration from biology where neurons pass information by spiking at various intervals rather than passing a specific analogue values. This makes neuromorphic computing much closer to cognitive processes than traditional neural nets which are really just abstractions that can enable computer learning. Neuromorphic chips use orders of magnitude and less power than traditional computers. Also, these chips are fully parallel which means any number or algorithms can be running simultaneously.

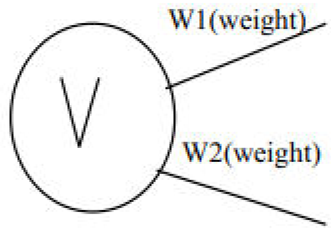

Figure 2: Traditional Neuron

Architecture of Neurobiological Computer

Neurobiological chip architecture enables machines to solve different kinds of problems than traditional computers, the kinds of problems that we previously thought only humans can tackle. The structure of these chips is based on neurons. The ultimate goal is to optimize the density of the nano wires.

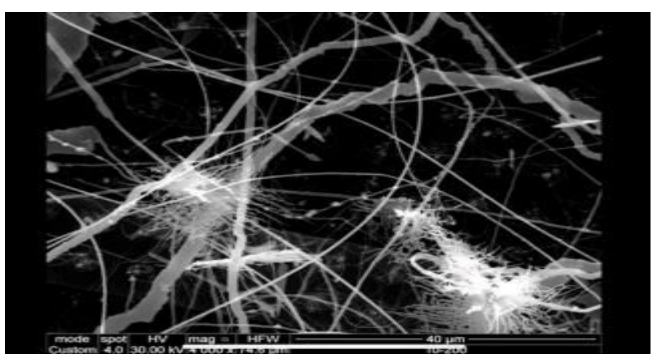

Figure 3: Internal Embedding of neuromorphic chip

When developing or implementing a scientific algorithm for neuromorphic computing we need to take into consideration few aspects-

- We need to design fully parallel algorithms, it is important to take advantage of this feature of neuromorphic hardware.
- It is also required to design linearly scalable algorithms this is aided by parallelization.

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Material Requirements

The ultimate goal of the researcher is to optimize the density of the nano wires, which requires-

- Silicon
- Polymer
- UV Light
- Electrodes

The accumulation of all these materials provides us with the base of a system which very efficient and controlled. The thermodynamics of this system is based on the number of ions which are used essentially to transmit information and perform the required computations. A team from MIT uses different materials- single crystalline silicon and silicon germanium layered on top of one another, applying an electric field on this device provided a well-controlled flow of ions. Another team in korea used tantalum oxide to precisely control the flow of ions.

neuromorphic system
SpiNNaker

A team of professors at the University of Manchester develops this system, the team uses traditional digital parts like cores and routers, connecting and communicating with each other. The researchers have shown that they can use SpiNNaker to simulate the behavior of the human cortex. The team that has developed this system claims that it has matched the results we would get from a traditional super computer.

Figure 4: Spinnaker made by university team of Manchester

True North

IBM develops this product, initially the chip was able to perform simple cognitive tasks efficiently despite having a limited number of neurons. Over the years, the size of the chip has been reduced by fifteen times to create a neural synaptic core. The TrueNorth mimics the brain architecture quite well it also mimics its efficiency. This chip has proven to be proficient at machine learning applications.

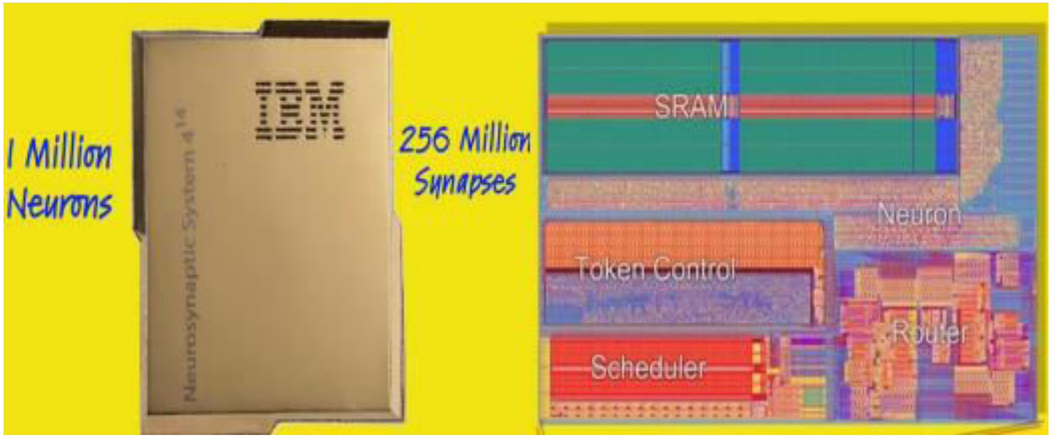

Figure 5: True north chip developed by IBM

Benefits

- These chips can help us achieve low power fully parallel aspirations. With the implementation of neuromorphic architecture, we have the potential to sort n numbers in big O of one, every number sorted at the same time which if done by traditional method, provides output in big O of n.
- These systems are much more energy efficient than the computers that we use nowadays.
- These chips can be used as memorizers and distribute the activity throughout the network.
- Alternate to the AI and ML softwares – these chips would be able to perform several tasks on their own without having to install additional software. These chips enable us to run digital softwares on the analog chip.

Limitations

- Interpretation- the biggest challenge with these microchips is to encode the output and decoding the output to provide the most accurate output possible.
- Security Issues- in some cases the researchers were able to achieve the desired speed but those chips ended up causing security breach.
- To allow a system to learn on its own and solve problems on its own, the system has 10 to be given a level of error. These chips need a significant scope of providing an erratic output.
- As material faults in the chip hardware can threaten to render the whole system useless, preventive measures are needed.

Recent findings

Recently scientists have discovered a carbon allotrope, it is an arrangement of 18 carbon atoms in a cyclic structure with alternate single and triple bond between the carbon atoms. Researchers are expecting it to be a significant element for the development of neuromorphic chips and many says that this allotrope of carbon can be used as a unit of neuromorphic chip with the carbon atoms acting as neurons and the bond between the carbon atoms performing the task of synapse between the neurons. Though, the application of this structure is yet to be explored as carbon being highly reactive element it is a challenge to stabilize this allotrope of carbon to use it in neuromorphic computing.

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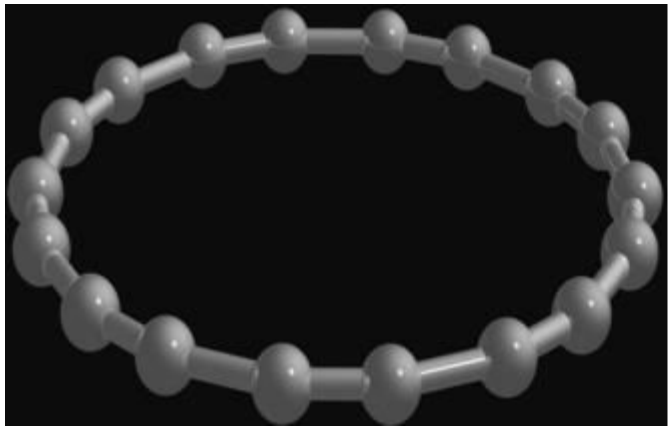

Figure 6: Cyclocarbon

Conclusion

The neuromorphic architecture offer the possibility of higher speed, more complexity for less energy cost. Changing computer hardware to behave more like the human brain is one of the few options we have for continuing to improve performance, and to get computers to learn and adapt the way humans do. The technology of neuromorphic computing works on just manipulating the currents. This hardware will soon be integrated as a part of high performance computing clusters tasked to perform specific massively parallel operations. This concept has a lot of potential to be explored in the years ahead.

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