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Neuromorphic Computing: Bridging the Gap between Human Brain and Advanced Computation

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Abstract: The rapid advancement of technology in contemporary society has led to unprecedented growth in data generation across various fields. This surge in data creation has necessitated a proportional increase in computational power for efficient processing. However, conventional computer systems are encountering limitations in handling extensive calculations and complex tasks. Drawing inspiration from the remarkable capabilities of the human brain, researchers are exploring novel avenues to augment computational capabilities. This paper delves into the emerging paradigm of neuromorphic computing, which seeks to replicate the intricate computational architecture of the human brain. Unlike conventional computers, the human brain boasts an exceptional capacity for parallel processing, owed largely to its intricate neural network configuration. Neuromorphic computers are engineered to emulate this neural structure, giving rise to a new generation of computing systems capable of cognitive tasks and data-intensive operation.
Key-words: Neurons, Neuromorphic, Human Brain, Fugaku, Computation Power, New Generation Computers.

INTRODUCTION

As the information technology and its infrastructure is growing in all the fields, new and fast computer's requirement is accrued. This is due to the new evolution of technology in various field. As moving to new technology like Artificial Intelligent, Big data Analytics, Machine Learning, Deep Learning etc., huge computational power is become necessary for it. Current computer architecture is not able to support that much huge computational power so it becomes compulsory to look into some new kind of computers[1].

At this point of time worlds fastest computer is Fugaku. Fugaku is a supercomputer developed by RIKEN and Fujitsu, located in Japan. It features a novel architecture designed for high-performance computing tasks, as well as efficient energy usage. The supercomputer employs ARM-based processors, specifically Fujitsu's A64FX processors, which are custom-designed to deliver high computational power while maintaining energy efficiency. Key hardware features of Fugaku include, the A64FX processors, each of which incorporates 48 cores. These processors are optimized for HPC workloads, with a mix of scalar, vector, and matrix processing units to accelerate a wide range of applications. The system employs a sophisticated memory hierarchy, including a large shared memory, high-bandwidth memory (HBM), and traditional DDR4 memory. This arrangement ensures that data can be efficiently accessed by the processors, enhancing overall performance. Fugaku employs a combination of different storage types, including SSDs (Solid State Drives) and HDDs (Hard Disk Drives), with high-speed storage for temporary data and large-capacity storage for long-term data retention. Fugaku employs advanced cooling techniques to manage the heat generated by its processors and other components, ensuring stable and reliable operation[3]. With this high configuration The Fugaku supercomputer is capable of performing over 442 petaflops (quadrillions of floating-point operations per second). Where as human brain can perform 1 exaFlop calculation per second only with 20 watts of power[5].

Brain does this complex task because of neurons network. Our brain has two parts each do its own task. One of the part is responsible for the all logical and arithmetical task and another is for pattern recognition, learning etc. The current architecture is able to do all the logical and arithmetical task but it might not be a best option for the pattern recognition or learning part. For the Neuromorphic computers may become better option[9].

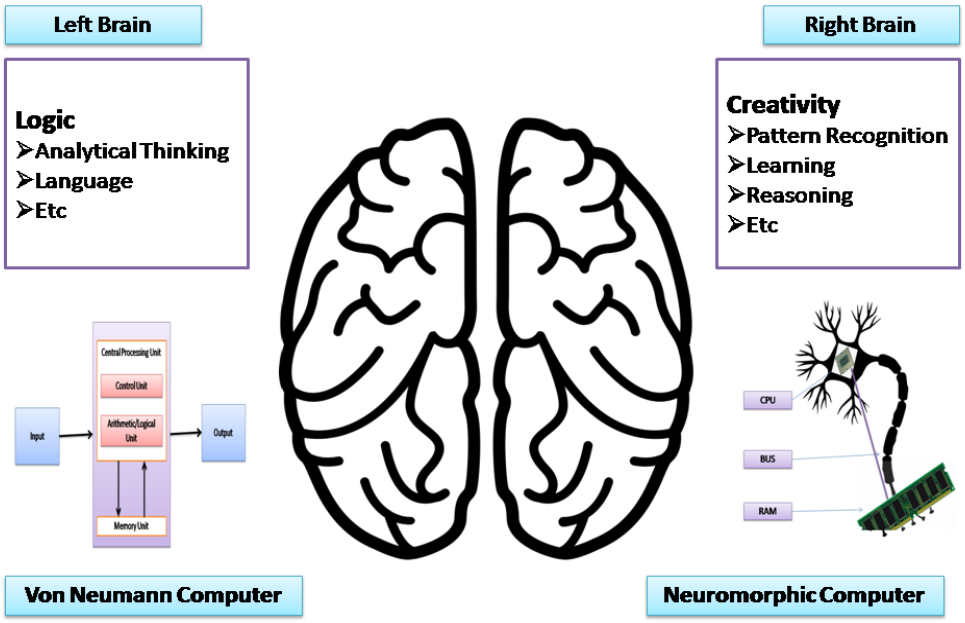

Figure 1: Computer architecture compare to brain. [1,7,8]

As shown in figure 1, Neuromorphic computer best suit for the works like pattern recognition, learning and reasoning like task. All the latest technology need this on huge amount of data. ML is all about pattern recognition so in this field Neuromorphic computers can serve better then current Von Neumann computers.

NEUROMORPHIC NEURAL NETWORK

In this new generation of computer, it has the connection like the human brain. Human brain is made up of neurons which can work as a memory as well as the CPU. And a single neuron is connected with next thousands of neurons and so on making a huge network. On the same way, neuromorphic computers are made up from the neuro chips which is connected with next thousands neurochips and so on making the same structure as human brain. This is also a combination of CPU, BUS and RAM[11, 12]. This way Neuromorphic computers replicate the structure of human brain.

For functioning of this network, SNN (Spiking Neural Network) is used. In this network each neuron are connected with next thousands neurons in network. Each neuron performs a specific task and store the information. In future when same kind of calculation is need to performs then, the neuron which learn and remember the things can responds too quickly. If the all neurons of first layer is busy or learn some particular pattern then the new computation task will transfer to the next layer of neuros. In this way it becomes too easy and to fast to compute and generate the required output.

APPLICATION OF NEUROMORPHIC COMPUTERS

As and now all sectors require AI and ML so Neuromorphic can serve in all the area. Here some of the major applications are address.

VISION BASED SYSTEM

Neuromorphic computers can give new strength to the Vision based system. It can be used at the place where deep monitoring is need. As this computer works as brain does, it can be helpful in brain monitoring system. It can also used in medical vision-based system, as it can work on deep monitoring and compute billions of operations per second so it can make real time decisions.

IMAGE PROCESSING

To identify and classify any image by the computer is very difficult as images are combination of numbers. To recognize any pattern from various images, neuromorphic computer can play a vital role. These computers are best in pattern recognition so that image processing, classification and recognition becomes too faster than the current working system on Von Neumann systems.

ROBOTICS

With growing world demand of robots are also increasing. For a real-time robot, it must perform huge number of operations per second and for that it is not possible to join it with super computer. As neuromorphic chips are smaller in size, it can fit in any robots and robot can work at its own. This computer will change the field of robotics.

SOUND RECOGNITION

As advance system requires to recognize the sound waves. All the new firmware is working on sound base input. Sound recognition is a difficult task and need huge computation in identification of voice. Neuromorphic computers can easily identify the sound waves and work accordingly.

CONCLUSION

In conclusion, neuromorphic computing stands as a promising bridge between the intricacies of the human brain and advanced computational systems. By mimicking neural architecture and leveraging parallelism, it offers potential for efficient and adaptable processing. Despite progress, challenges in achieving true brain-like capabilities and integration remain. As research continues, the synergy of neuroscience insights and innovative hardware design holds the key to unlocking enhanced AI, cognitive computing, and sensory interfaces. Neuromorphic computing's transformative potential offers a compelling path forward, converging biological inspiration with computational prowess for a new era of intelligent technology.

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