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TECHNOLOGY FEATURE Artificial Intelligence / Emerging Computing

Neuromorphic Computing: Building AI Systems That Think More Like the Human Brain

Due to the increasing strength of artificial intelligence, its energy and computing resources consumption is increasing rapidly. Neuromorphic computing is an alternative way out: computers that are capable of more brain-like processing, rather than simply calculating.

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Introduction

Consider that there is a tiny medical sensor that tracks the heartbeat of a patient. It does not transmit all the signals to a cloud server. It does not take time to have a huge data center to manipulate the information. Rather it signals abnormal trends in real time, with a minimal power consumption. Such is the future with which neuromorphic computing is attempting to render possibilities. There are powerful AI systems today, yet they are costly to operate. Big models, high-performance GPUs and data processing at all times demand serious energy. In the case of nations such as Pakistan, where digital transformation is being ramped up in the fields of healthcare, smart cities, banking and education, the issue of how to make AI smarter is a question; however, how to make AI efficient, affordable and practical is a question. One of the possible answers can be found in neuromorphic computing. Based on the human brain, it seeks to develop computer systems, which process information in an artificial manner using artificial neurons and synapses whereby the signals used are called spikes. The concept is still in its early stages but has already become the focus of key research institutions like Intel, IBM and NIST.

> ***" Neuromorphic computing does not involve recreating the brain, but rather learning the lesson of the brain on how to achieve the same in the future of AI. "***

Technology Overview

Neuromorphic computing comes in the form of brain-inspired computing. Unlike traditional computers, which process information similarly, neuromorphic systems attempt to implement similar processing of signals to those of the brain.

The human brain consists of billions of neurons which are linked to each other by synapses. Such neurons do not operate in the manner of a typical computer processor. They are electrochemical and transmit brief electric pulses also known as spikes. The neuromorphic system employs a similar concept in spiking neural networks where artificial neurons pass information only in response to need.

This is important as the brain is incredibly energy-saving. It can identify a face and react to sound, know movement, and make decisions using much less power than most contemporary AI systems. According to NIST, neuromorphic computing is striving to enhance efficiency in activities such as perception and decision-making since the existing systems based on neural-networks are still highly inefficient as compared to the human human brain.

Conventionally AI hardware is typically fed with large quantities of data at any given time. This is not the case with neuromorphic hardware. It is also event-based that is, it responds to the occurrence of an event of importance. Indicatively, a neuromorphic camera can be a smart camera that only pays attention to movement rather than processing each pixel at any given time.

Why Traditional AI Hardware Is Reaching Its Limits

The latest AI has gone beyond impressive performance, but at a price. Rather, large AI models can be trained and run with powerful chips, sophisticated cooling abilities, and consume a lot of electricity.

It is easy to manage when dealing with major technology companies but it becomes hard to manage when dealing with smaller organizations, universities, hospitals and the developing economies. In case AI is to be incorporated in the daily gadgets, it cannot necessarily rely on the cloud servers or costly networks.

And this is where neuromorphic computing comes in. It is not created to be used as a substitute to all forms of AI hardware. Rather, it can be applicable to those scenarios in which speed, low power, and real-time response are more important than brute-force computation.

How Neuromorphic Computing Mimics the Human Brain

Artificial Neurons and Synapses

Artificial neurons in simple terms are little computing units that are inputs to external signals process and send them onwards. These neurons are connected by the synapses.

These connections can be implemented to act more like biological networks in neuromorphic systems. Rather than working on everything simultaneously, the system responds to trends and time.

Spiking Neural Networks

One of the primary concepts of neuromorphic computing is spiking neural networks (SNNs) or spiking networks. SNNs are different compared to traditional artificial neural networks; such representational information using discrete spikes. Recent studies define SNNs as handy in event-driven and time-processing, particularly in systems where the energy consumption and the time-dependent data matter.

An easy one would be sound recognition. An ordinary AI system can work with audio data being continuous. A spiking system is able to concentrate on signal variations where it reacts when something significant happens.

Key Applications: Robotics, Healthcare, IoT, and Edge AI

Neuromorphic computing has the potential to be particularly useful in systems that require a fast rate of operation and which are constrained in terms of available power.

Robotics and Autonomous Systems

Robots are required to respond to the real world. An example is a delivery robot that has to sense something in its path and adapt its movement and react to the evolving environment. Neuromorphic systems can be useful in assisting robots in processing sensory data more quickly and efficiently.

Healthcare Monitoring Examples of wearable health applications might include neuromorphic chip-based detection of abnormal heart rhythms, breathing and movement patterns without necessarily transmitting data to the cloud. This may decrease the amount of power consumed as well as enhance privacy.

IoT and Smart Cities

Thousands of sensors in smart cities monitor the traffic lights, cameras, energy and infrastructure. Neuromorphic computing may enable these devices to make decisions at the local level rather than fully rely on central servers. To Pakistan, it might be applicable in fields like traffic sensors, low power sensors in agriculture and low-cost healthcare devices.

Energy Efficiency and Real-Time Decision Making

Energy efficiency is one of the strongest arguments to support neuromorphic computing.

One such neuromorphic research chip is Loihi 2 by Intel, which aims to enable spiking neural networks and more practical brain-inspired algorithms. Intel has stated that Loihi 2 is faster, more densely resource-based and more energy efficient than the prior research systems in neuromorphic.

Another method IBM has tried to employ to solve the increasing power requirements of future AI is by investigating neuromorphic computing. According to IBM Research, neuromorphic systems are a brain-based method of computing that seeks to enhance computational efficiency with the increasing size of AI models.

The pragmatic advantage is apparent: when an AI is capable of operating closer to the device with a lower amount of power, it will be applicable in practice.

Challenges in Building Brain-Inspired AI Systems

Neuromorphic computing is an exciting potential, but not a complete solution yet.

Hardware and Software Complexity: It is hard to create chips which act like neural systems. New programming tools, algorithms and training techniques are also required by developers. Existing AI programs are not necessarily compatible with neuromorphic computers.

Performance and Standardization: The other issue is to demonstrate in which areas neuromorphic systems obviously perform better than the current AI hardware. There are still more practical tasks that GPUs and traditional AI accelerators can be used in. Researchers are trying to determine the most efficient applications of neuromorphic computing as opposed to viewing as a blanket solution.

Limited Expertise: Talent gap also exists. Neuromorphic computing is found on the borderline of neuroscience and computer engineering, AI, and semiconductor design. It makes it fun, yet hard to implement in many institutions, which makes it exciting.

Key Findings & Impact

Neuromorphic computing would impact on a number of key industries:

- Healthcare: Monitoring devices with low power and increased rate of the medical ability to analyze.
- Robotics: On-the-fly machine control in dynamic settings.
- Autonomous Vehicles: Visual and sensor data processing are increased.
- Cyberspace: Network behavior pattern detection and anomalies.
- Smart Cities: Effective traffic, energy, and public safety sensor networks.
- Edge Devices: Processing AI in small devices without the need to access the cloud.

In the case of developing markets, the effect might be more significant. The world requires AI solutions that are not only powerful but also low cost and energy conscious, such as those in countries such as Pakistan. Neuromorphic computing can assist in the implementation of intelligent systems into a setting where it is not always possible to have costly computing infrastructure.

Nevertheless, technology is to be taken in the real sense. It is not prepared to substitute mainstream artificial intelligence devices in all places. Its greatest strength will most probably be seen in the niche markets where low power, quick reaction and sensor-based intelligence is a requirement.

What's Next?

Neuromorphic computing is at the research and development stage, and it is significant in its direction. With the further development of AI, the world will require not only more intelligent, but also more sustainable systems.

The following years will probably be devoted to the development of more advanced neuromorphic chips, more advanced spiking neural network algorithms and more obvious applications in real life. According to research done

by organizations like NIST, Intel, IBM and the academic publishers the field is moving in the right direction although it may take a long time to realize the high scale adoption levels.

The universities and technology sector in Pakistan has a good opportunity to begin to take notice. Neuromorphic computing is not mainstream yet, but it is the type of future-oriented research that can inform the creation of smarter, lighter, and more efficient AI systems.

It might not be only larger models that will bring about the next AI revolution. It can be supplied by smaller machines that are quieter and learn by the most efficient computer which we know: the human being.

About the Author

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