THE REVOLUTIONARY POTENTIAL OF NEUROMORPHIC COMPUTING

Patricia GORGAN

Group TI-221, Faculty of Computers, Informatics and Microelectronics
Technical University of Moldova, Chișinău, Republic of Moldova

* Author correspondent: patricia.gorgan@isa.utm.md

Coordinator: Corina TINTIUC, university assistant, Department of Foreign Languages, TUM

Abstract. *Neuromorphic computing is a cutting-edge field of artificial intelligence that seeks to emulate the structure and function of the human brain. By designing computer chips that mimic the behavior of neurons, researchers hope to create more energy-efficient, adaptable, and resilient systems than traditional computers. These systems have the potential to revolutionize a wide range of industries, from robotics and self-driving cars to image and speech recognition. However, the development of brain-inspired computing also raises important ethical and social questions, such as the impact on privacy and employment. The given paper outlines the pros of neuromorphic computing that is a milestone in the development of computer science and engineering.*

Keywords: *artificial intelligence, robotics, neural network, challenges*

Introduction

When we think of machines imitating the human brain, the first thing that comes to mind is the concept of artificial intelligence (AI) and machine learning, a system or a robot that can perform human tasks better and faster. Computers work as humans; they need eyes to see and a "mouth" to speak [1]. A neuromorphic computer is a little more like a human brain due to the fact that it uses computer chips that use the same physic of computation used by our nervous system [2]. It is a type of computer that can learn from experience and avoid mistakes made in the past.

How does Neuromorphic Computing work?

Our traditional computers assimilate in binary, where everything is 0 or 1. So this means that we are limited, we have only two choices and the code we write must be structured in a very rigorous way. But, neuromorphic computers are more malleable. Instead of using an electric signal to mean zero and one, the creators of these chips wanted to make their computer's neurons talk to each other the way biological neurons do [2]. The word "neuromorphic" comes from the fusion of "neuro," which indicates our brain neurons, and "morphic," which means "having a special shape or structure." Furthermore, this computing system uses hardware based on the structure, processes and capacities of neurons and synapses in the biological brain [3]. Neuromorphic computers use hardware, and the most common is the neural network which is a type of computer program that learns by analyzing vast amounts of data. Scientists "feed" the computer with information and details about the field in which it will be used.

For instance, it can be trained to recognize facial features on Face IDs, such as mustaches. The computer will absorb the information, will compare it to everything it already knows, and, in the end, it will give you a response.

A neural network is composed of many processors operating in various tiers. The first group receives the new information and passes it on to the next tier. Each processing node in the network has its own sphere of knowledge, which it uses to apply the information. The last group of processors provides the final output (see Fig.1).

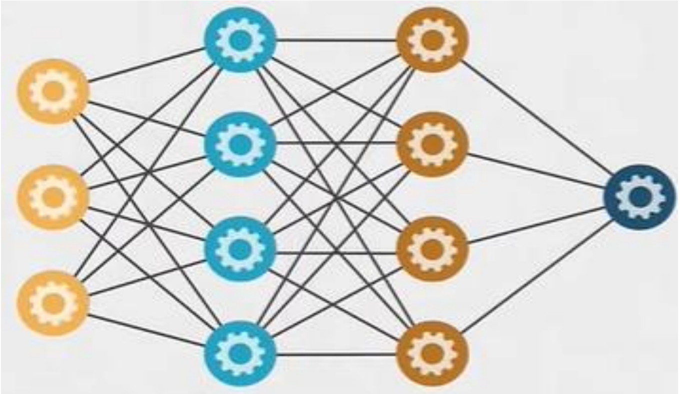

Figure 1. How the Neural Network works [3]

Characteristics of Neuromorphic Computing

Neuromorphic computers have the following features [4] :

- collocating processing and memory;
- event-driven computation;
- inherently scalable;
- massively parallel;
- high in adaptability and plasticity;
- fault tolerance.

These characteristics make them differ fundamentally from traditional computers.

Implementations of Neuromorphic Computing

Robotics: Neuromorphic computing can promote more worldly-wise and versatile robots that can communicate easily with the outer world. Due to the feature which allows them to mimic the human brain's, robots can process information like us human beings. For instance, researchers at the University of Zurich invented a robot with a neuromorphic computing system that can detect and respond to changes in its environment in real time. This robot learned to navigate through a maze and avoid obstacles using a combination of sensory inputs and decision-making algorithms based on neural networks. Moreover, scientists' main goal is to integrate neuromorphic perception and behavior using hardware neuromorphic computational primitives so that, in the end, they will create a robot with end-to-end neuromorphic intelligence [5], as represented in Fig.2.

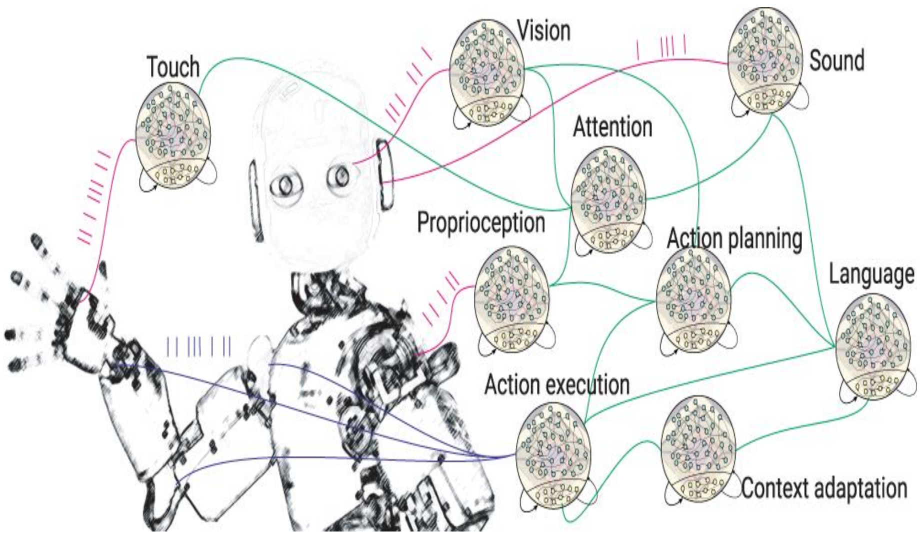

Figure 2. Robots with end-to-end neuromorphic intelligence [5]

Self-driving cars: Some California researchers developed a neuromorphic system called "NeuFlow" that empowers self-driving vehicles to analyze the environment better and make decisions based on sensory data. NeuFlow uses a neuromorphic chip that mimics the way that the human brain processes data, empowering the car to decide in real-time based on sensory and visual information.

Medicine: "Neuralink" is Elon Musk's brain chip company. This company was founded in 2016 and till present the company is building a brain chip interface that can be implanted into the skull (see Fig.3), which eventually can help disabled patients to move again, communicate and even restore vision [7]. The company hopes that a person with one of the conditions mentioned above will be able to control a mouse, make a phone call, or watch again the sunset. These chips are based on neuromorphic computing and transmit neural signals to the brain [7]. The chip communicates with brain cells with 1,024 thin electrodes that penetrate the outer layer of the brain [8]. Also, the device has a Bluetooth link so the neural signals could be controlled from a phone or a computer.

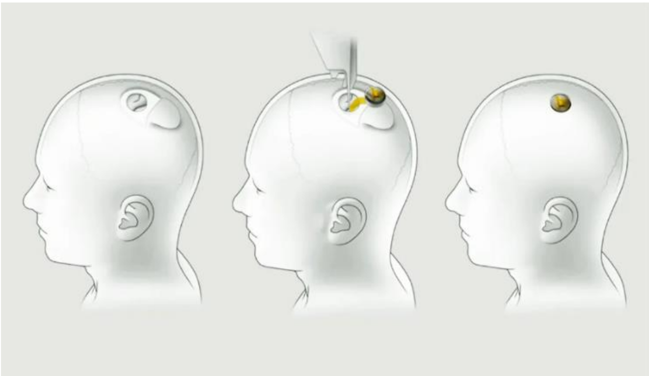

Figure 3. Neuralink's brain-machine implanted into skull [8]

Energy management: Neuromorphic computing has the ability to revolutionize the sphere of energy management by implementing the development of more effective and knowledgeable systems that can supervise energy usage in a better way. One example of using neuromorphic computing in energy management is the research done in Paris on a neuromorphic system called "Memristive Crossbar Arrays" that uses memristive devices to mimic the behavior of biological synapses in the brain, enabling more efficient and intelligent energy management. Memristive Crossbar Arrays can be used to optimize energy spending in various ways. For instance, they can be used to predict energy demand based on patterns in data traffic, allowing for more efficient energy allocation [9].

Limitations and Challenges of Neuromorphic Computing in day-to-day life

While neuromorphic computing has the ability to revolutionize many fields, there are also a lot of challenges and constraints that must be overcome before it can be accomplished. These are a few main limitations and challenges that neuromorphic computing faces:

1. ***Complexity:*** Neuromorphic systems can be highly complex in terms of hardware and software. This complexity can make it challenging to design, test, connect devices between them and optimize these systems.
2. ***Programming***: Neuromorphic systems require a different programming approach than traditional ones. This situation can make it difficult for companies that need specialists, and also, it can be challenging for developers to learn and work with these systems.
3. ***Limited applications:*** Neuromorphic computing is still a new technology for many scientists, and there are limited applications where it has been shown to be effective. This limits its potential impact in many fields because people don't understand this technology's real purpose and capability.
4. ***Cost:*** The cost of developing and expanding a neuromorphic system can be eye-watering because it uses the newest technology, making it difficult for smaller organizations to adopt it.

Conclusions

To summarize, the potential benefits of brain-inspired computing are enormous. Creating an artificial neural system that is similar to the human brain architecture, neuromorphic technology will impact various fields such as healthcare, economy, environment, science (AI, robotics, self-driving cars) and human potential. This new way of architecture promises to create systems that are more efficient, more flexible, and more scalable than current computers.

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