Survey Of Neuromorphic Computing and Neural Networks in Hardware

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Abstract: A biologically inspired method of computing known as "neuromorphic computing" promises to give computers the capacity to learn and adapt in a manner similar to the human brain. With the help of highly connected synthetic neurons and synapses, this technology has the ability to solve difficult machine learning issues and model neuroscientific theories. These systems were developed to address the limitations of traditional von Neumann computers, which rely on sequential processing and are inappropriate for tasks requiring parallelism, low power consumption, and real-time computing. In recent years, the field has made great progress with the emergence of various hardware platforms that use spiking neural networks (SNNs) to perform complex computations. The goal of the field of neuromorphic computing is to create machines that function similarly to the human brain.

Index Terms: Neuromorphic computing, machine learning, neurons, human brain, spiking neural networks, materials science *(key words)*

I. INTRODUCTION (HEADING 1)

Neuromorphic computing is a new computing paradigm that mimics the structure and function of the human brain. In 1980's the term "neuromorphic engineering" was first used by Carver Mead. Who has dedicated more than 40 years to creating analysis systems that imitate the senses and thought processes of the human body, including hearing, seeing, touching, and thinking. A branch of neuromorphic engineering known as 'neuromorphic computing' focuses on the "processing" and "thinking" aspects of th human-like structure. Neuromorphic computing is the method of computer engineering that models both the hardware and software after the nervous system and human brain. The goal of topic is to give computer systems the power of the human brain. These system can carry out the difficult work more easily than the convolutional computing systems because they mimics the structure and operation of the human brain. Then the attendees will learn about the latest developments in neuromorphic hardware , including new chips and processors designed specifically for the neural networks. And the aim is to create more efficient, versatile and scalable for computing system and also it creates bio-inspired computer systems and hardware. Artificial intelligence (AI) is a term for the development of intelligent computers that are capable of carrying out tasks that typically call for human-like intelligence. The structure and operation of the human brain are mimicked in neural networks, a particular type of AI that is useful for tasks like image identification and natural language processing. Neurons are considered the fundamental units of the brain by neuroscientists.

Then by the study of papers which shows the importance of neuromorphic computing in neuroscience, AI, and robotics. In these papers, different aspects of neuromorphic computing, such as unsupervised feature learning, binary tasks, and hardware platforms, are discussed. The performance and uses of neuromorphic computing should be improved and enhanced, according to the authors, who suggest more study and development in the area. Neural network hardware and neuromorphic computing are fields that are quickly developing and have a wide range of possible applications. These systems offer many benefits over conventional computer systems, including low-power devices, real-time computation, and scalability. The continuing advancement of this technology has the potential to transform computing and result in fresh discoveries across a variety of sectors. Overall, these works advance our awareness of and use of neuromorphic computing across a variety of fields and areas.

II. LITERATURE REVIEW

[3]An STDP-based unsupervised feature learning approach for Convolutional SNN-based neuromorphic computing is presented in a study by Srinivasan, Panda, and Roy in 2018. The technique minimizes the number of storage needed while achieving accurate feature learning with less training patterns. Convolutional SNNs present a promising way to mimic the effective processing capacity of the brain.

[4]James S. Plank, Catherine D. Schuman, and Christopher Dean present networks for 24 different binary operation and encoding implementations in their paper "Spiking Neuromorphic Networks for Binary Tasks", 2021. These networks can serve as the building

[1] The Human Brain Project uses neuromorphic computing (2013) to provide feedback on neural models through two different computing paradigms, making it an essential instrument in neuroscience. The Human Brain Project aims to understand the brain's neural network and develop neuromorphic computing systems by shifting from current computing models to techniques that exploit the random behavior of low-power computing devices embedded in recursive architectures.

[2] "Neuromorphic computing refers to brain-inspired computers, devices, and models that contrast the traditional computer architecture. The technology aims to create a brain-like ability to learn and adapt, but requires significant advances in neuroscience models, materials, engineering, programming, and applications. A comprehensive survey of the field, including its history and motivations, has been conducted by Catherine D. Schuman et al. in their preprint at 2017. The goal of their work is to review the field and highlight areas for future research."

blocks for bigger neuromorphic networks and are a more affordable option than conventional hardware. The research will be expanded to include numerical inputs and outputs in the future work, enhancing machine learning strategies for RSNN training. The networks can be animated using a user-friendly interface.

[5]"In a 2022 Viewpoint, Sandamirskaya, Kaboli, Conradt, and Celikel study neuromorphic hardware for AI in robots. The authors call for more research in neural computation and hardware that is inspired by neurons in order to unlock new applications in robotics and autonomous systems and compete that advances in the field could improve neuromorphic algorithms and hardware through the application of insights from neuroscience."

[6]An overview of the concerns big data presents for conventional computer systems and the potential answer provided by neuromorphic computing are given in "A survey on Neuromorphic Computing: Models and Hardware." It explains the unique attributes of this biologically relevant paradigm, such as asynchronous event-driven communication and processing that uses little energy. The study analyses hardware platforms, neuron and synaptic models. (Source: Amar Shrestha, Daniel Patrick Rider, Haowen Fang, and Zaidao Mei, IEEE Explore, 2022).

[7]The authors of "Neuromorphic computing hardware and neural architectures for robotics"(2022) describe that neuromorphic hardware and algorithms can provide quick and power-efficient AI for robotic applications. They suggest creating neural network designs based on biological brain systems and neuromorphic algorithms that to neural computing principles. New applications in robotics and autonomous intelligent systems can be created through enhancing signal processing, computing primitives, and algorithms.

[8]The author of the paper “Neuromorphic computing using non-volatile memory (NVM)” (2016) describes the use of non-volatile memory (NVM) in massively parallel, energy-efficient neuromorphic computing systems is discussed in this work. Spiking neural networks (SNNs), "Memcomputing" can all use NVM and deep neural networks. The article reviews the attributes of numerous types of NVM devices that have been proposed as neurons or synapses, including conductance dynamic range, retention, linearity, and variability.

III. SURVEY DETAILS ABOUT NEUROMORPHIC COMPUTING

Neuromorphic computing and neural networks in hardware are the growing fields in the computer science and engineering. Then the technology that mimics how the human brain works. Spiking neural networks (SNNs) and analogue the circuits are both employed for computing. In order to accelerate neural network training and inference, neural networks in hardware employ specialised hardware. The main goal of current neuromorphic computing research has been to improve spiking neural network implementation and mimicking hardware. Research has been focused on developing neural network topologies that are less energyintensive. Neuromorphic computing is a type of computing that was inspired by the human brain, as opposed to conventional computer design. Neuromorphic hardware systems has various types of synapses, neurons and learning rules to produce information from data. One of the another benefit of neuromorphic computing is scalability. Also neuromorphic computing have features, some challenges and applications.

1. FEATURES OF NEUROMORPHIC COMPUTING Rapid Response System:

With their incredibly quick processing, neuromorphic computers are particularly well known in their quick response times. They have a rapid response system that is a huge plus because it works like the human brain. Also they work like human brain and there processing is highly rapid. For a computing system producing output as soon as possible is the main goal, since neuromorphic system can produce the result rapidly, they are best for computing.

Low Consumption of Power:

Neuromorphic machines function when messages or electrical spikes are transferred through artificial neurons according to the idea of Spiking Neural Networks (SNN). These synthetic neurons only function when electric spikes are delivered through them, using little energy in the process.

Higher Adaptability:

The ability to adapt is a strength shared by neuromorphic computers and modern computers. Neuromorphic computers function efficiently in accordance with the changing demands of technology due to their better adaptability. Computers can change and adapt as needed to keep up with changing times, producing effective working. Fast-paced Learning:

Machine working is principle of neuromorphic computing are highly placed when it comes to learn. Neuromorphic computing enables machines to learn quickly by creating algorithms based on the interpretation of data and constructing algorithms as and when fresh data is introduced into such computers.

Mobile Architecture:

The mobile architecture of neuromorphic computing is one of its most striking characteristics. The computers are simple, as opposed to previous computers that required a lot of space to operate. They don't take up a lot of space and have a high system occupancy.

2. CHALLENGES FACED BY NEUROMORPHIC COMPUTING

Creating computer architectures that are modelled after the structure and operation of the human brain is the goal of the developing branch of technology known as neuromorphic computing. Recent advances in neuromorphic hardware, that are still in the research stages, have the potential to increase the performance of current neural networks, which rely on GPUs today. If it's still a ways away off, developing a working human brain chip.

One of the main challenges facing the field of neuromorphic computing is a [1]lack of software developers and engineers. To bring neuromorphic systems into researchers, developers, production, and engineers need to move beyond the traditional von Neumann framework and develop new ways of thinking about computer architecture. They will also need to create a set of APIs, programming models, and languages to make neuromorphic computers accessible to non-experts.

In order to improve these future architectures, neuromorphic computing researchers will [2]need to create new techniques for measuring and evaluating performance. This would necessitate cooperation with other new technologies, such as predictive computing, which attempts to assist AI in managing uncertainty and noise.

Also one of the other challenges facing in neuromorphic computing is [3]technical challenges in creating efficient and scalable hardware and software system. It is hard to make compatible hardware systems for neuromorphic software. Even if we make hardware it will be very expensive.

Next challenge is that [4]uncertainty about the commercial viability and practical application of neuromorphic computing. Neuromorphic computing's commercial feasibility and potential applications are not yet known because of the technology's limitations, a lack of standards, and expensive development costs.

Despite these difficulties, the industry has attracted a lot of investment. Although there are many opponents, also many experts think neuromorphic computing has the potential to significantly improve the power, accuracy and general capabilities of AI while also providing fresh insights into human brain.

3. APPLICATIONS OF NEUROMORPHIC COMPUTING

Neuromorphic computing is a field that seeks to build electronic systems that are modeled after the human brain. These systems are designed to perform complex tasks that are difficult or impossible to achieve using traditional computing methods. Here some applications for neuromorphic computing:

[1]Artificial intelligence: Advanced machine learning algorithms that can draw conclusions based on input data and learn from experience can be created using neuromorphic computing. This has uses in computer vision, natural language processing, and speech recognition, among other fields.

[2]Robotics: Robots with intelligence that can perceive and react to their surroundings instantly can be built using neuromorphic computing. This can be helpful in many fields, including manufacturing and healthcare.

[3]Brain-machine interfaces: Brain-machine interfaces that enable people to operate things with their thoughts can be created utilizing neuromorphic computing. Applications for this can be found in the gaming, assistive technology, and prosthetics industries.

[4]Autonomous vehicles: Autonomous vehicles that can make judgements in real time depending on their surroundings can be created using neuromorphic computing. Autonomous vehicles also known as self-driving car, are becoming an increasingly important technology in the transportation industry. Overall the application of neuromorphic computing is still an area of ongoing research and development.

[5]Cybersecurity: One of the main advantages of neuromorphic computing is cybersecurity its ability is to process large amount of data in real time. Advanced cybersecurity systems that can recognize and respond to cyberattacks in real time can be created using neuromorphic computing. This has uses in the government, financial sectors, healthcare and among others.

IV. CONCLUSION

As a conclusion, neuromorphic computing will release previously unavailable AI capabilities and create revolutionary new standard in the years to come. Neuromorphic computing is a relatively new approach to computing that seeks to mimic the structure and function of the human brain, using networks of artificial neurons and the synapses to perform computation in a highly efficient and parallel manner. Making devices that perform similarly like the human brain is the aim of the field of neuromorphic computing. And the goal is to build systems with a huge number of synthetic silicon neurons that can transfer electric spikes and act like the human nervous system. The field holds enormous potential for artificial intelligence (AI) and the future of computers, with the possibility to uncover untapped potential and set new standards.

In conclusion, neuromorphic computing is a complex topic that could lead to the development of ground-breaking new capabilities in the following years.

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