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Neuromorphic computing: a review of brain-inspired hardware and algorithms for next-generation information processing

***¹Raghuram K. S**

^{*1}Department of Electronics and Communication Engineering, Dayananda Sagar Academy of Technology and Management, Bengaluru, India

**Corresponding Author: Raghuram K. S
Email: meghadhote76250@gmail.com*

Abstract:

Inspired by the extraordinary computational capabilities of the biological brain, neuromorphic computing presents a transformative paradigm for achieving intelligent, energy-efficient, and adaptive computing systems. This review explores the fundamental principles underlying neuromorphic systems, including spiking neural networks (SNNs), synaptic plasticity, and event-driven processing, emphasizing their advantages over traditional computing architectures. We delve into the hardware realizations of neuromorphic computing, from established CMOS-based chips to emerging frontiers like memristive devices, 2D materials, and nano-electronic components, highlighting their potential for high-density, low-power neuromorphic circuits. Furthermore, we showcase the diverse applications of neuromorphic systems across computer vision, robotics, biomedical signal processing, and scientific simulations, underscoring their capacity for real-time, adaptive, and efficient computation. Despite notable progress, challenges persist in scalability, programming complexity, standardized benchmarking, and efficient training algorithms for SNNs... Ultimately, this review underscores the transformative potential of neuromorphic computing to revolutionize information processing and contribute to a deeper understanding of intelligence.

Keywords:

Neuromorphic computing; spiking neural network; Nano-electronics; BioNN;