Challenges and Opportunities in Neuromorphic Computing

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Cloud computing, which is largely a consequence of a need to concentrate shareable high performance computing systems at select locations, is contributing to global environmental degradation because of the need for large energy resources to power these systems. Every online search has an energy cost. Billions of such searches globally add up to significant waste of scarce energy resources, while contributing to climate change effects. Today, training of machine learning algorithms is a prime example of one of the applications that consumes inordinate amounts of energy at data centers. It is estimated that data centers today consume about 200 terawatt-hours of energy every year, an amount expected to increase by an order of magnitude by 2030, if nothing is done to lower the energy needs of these systems[1].

A number of researchers are investigating ways to lower the energy consumption of key components of computing systems. The majority of these investigations are inspired by the human brain, which is able to perform feats of computing that no data center is capable of, while consuming energy at a rate of only 20 W. This brain-inspired computing paradigm, called neuromorphic computing, borrows the concept that information processing and storage in the brain appear to be co-located. This is contrary to the von Neumann conception of computing, where data processing is separated from where it is stored. This is the leading cause of the inordinate energy consumption in most computing systems today. It is inefficient because time and energy must be expended while shuttling data back and forth between processor and memory.

There have been a few promising demonstrations of neuromorphic computing systems performing certain computations more efficiently than is possible in classical von Neumann architectures. A number of challenges in building neuromorphic systems have emerged. One of them is the fact the field is cross-cutting, requiring expertise in neuroscience, computer science, electrical and computer engineering, and materials science. This challenge also represents opportunities for new entrants into the field—in this case for neuroscientists and materials scientists—because of the need for a better understanding of the brain mechanisms essential for information processing and storage, and for new materials that can implement the necessary neural functions in electronic or optoelectronic devices. Perhaps one of the major challenges facing neuromorphic computing is the lack of a model hierarchy that could simplify and promote universality. Classical computing is successful because of the Turing completeness model of the von Neumann architecture. The stack hierarchy allows different hardware to accept software to function in the same way irrespective of the details of the hardware. There is currently no such hierarchical model in neuromorphic computing. It will be required so that the details of the neuromorphic hardware can be abstracted away at the higher levels of the hierarchy. This presentation will briefly discuss some of the challenges and opportunities in neuromorphic computing.

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[1] N. Jones, "How to stop data centers from gobbling up the world's electricity," Nature, September 12, 2018: https://doi.org/10.1038/d41586-018-06610-y