Neuromorphic Computing using Oscillatory Processor Arrays to Resolve the AI/AGI Bottleneck

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Abstract

Cutting-edge AI and Deep Learning technologies demonstrate outstanding performance in many important tasks requiring intelligent data processing under well-known conditions, supported by massive computational resources and big data. However, advance AI/AGI has multiple serious challenges:

- The performance of **AI/AGI may drastically deteriorate** when the data are perturbed, or the environment dynamically changes, either due to natural effects or caused by manmade attacks. Moreover, advanced AI/AGI **demand enormous resources, energy, data, and compute**, which lead to the AI/AGI bottleneck when the required resources are not easily available. This is especially true when researchers aim at superintelligence, which would exceed human cognitive capabilities. The exponentially increasing resource demand produces a growing anxiety in large segments of the population, when the **AI/AGI systems are perceived as threats to human existence.**

Neuromorphic designs, including spiking neural networks, deep Q reinforcement learning, and memristor technologies have shown important benefits in addressing the bottleneck encountered in advanced AI/AGI.

- Neuromorphic technologies have the potential to provide drastic improvement in using resources, establishing a path towards sustainable AI, with many **orders-of-magnitudes (OOMs) reduction of energy and computer demands**. Brain-inspired, spatio-temporal oscillations over interconnected processing nodes can help to develop a novel **pattern-based computing paradigm** and hardware implementations, which has the potential of Million (10^6) times improvement in computing resources. Prominent examples of neuromorphic architectures are the cellular automata, implemented as **cellular neural networks (CNNs).** CNNs can model spatially decentralized systems with a number of individual processors, which interact and produce collective dynamic oscillatory patterns.

This talk introduces **Cellular Automata (CA)** which are typically defined over regular lattices. However, some level of rewiring of the connections can be beneficial, producing intermittent phase transitions between high-organized (synchronized) metastable patterns and disorganized (desynchronized) transitionary states. **Phase transitions** play a major role in brain computing and cognition, and their role in neuromorphic systems is crucial. We describe models and statistical tools to analyze phase transition in neuromorphic models. **Applications include intelligent control and decision making, autonomy, and brain-computer interfaces.** Due to their simplicity, regularity, and the option of having hard-wired neighborhoods, neuromorphic arrays are natural candidates for hardware implementation. Implementations on **neuromorphic hardware platforms** will help to build intelligent machines with a path to develop sustainable AI, which is a true partner of humans in future endeavors.