Soutenance de thèse

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Physics-Grounded Neuromorphic Computing : From Spiking Neurons to Learning Algorithms

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Abstract :

In our digital era, marked by an exponential growth in computational power and memory capacity, we are confronted with a pressing challenge: the escalating energy consumption of information technology. The increasing demand for data-intensive services, notably artificial intelligence and cloud computing, underscores the urgent necessity for energy-efficient computing solutions that are environmentally sustainable and foster innovation. This thesis explores the potential of memristors for neuromorphic computing to achieve energy-efficient AI.

Because Spiking Neural Networks could offer the promise of low-energy learning, we first focused on hardware neurons composed of volatile NbOx filamentary memristors. These components emerge as appealing alternatives to conventional CMOS devices because of their scalability and spiking behaviors. These devices were characterized and reproduced numerous neuronal spiking and bursting behaviors, such as Leaky-Integrate-and-Fire characteristics and phasic bursting.

We then focused on the algorithmic side and tackled the challenge of adapting the Equilibrium Propagation (EqProp) algorithm to physical systems. EqProp, rooted in physics rather than calculus, offers an attractive prospect—harnessing the inherent physics of hardware systems for on-chip learning. This work revolved around addressing the challenges posed by continuous-valued gradients in a memristor-based environment, where the mode of programming is a series of pulses.

Next, we tested the resilience of the discretized version of EqProp by replacing the ideal software synapses with HfOx memristor data, reaching more than 91% accuracy on the MNIST dataset.