UNIVERSITÉ DE SHERBROOKE

(MSc-PhD) Neuromorphic circuits and AI: study of memristor crossbars for the implementation of bio-inspired computing

Record number : OPR-515

Overview

RESEARCH DIRECTOR

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Information
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ADMINISTRATIVE UNIT(S)

Faculty of Engineering
Department of Electrical and Computer Engineering
Interdisciplinary Institute for Technological Innovation

LEVEL(S)

Master's degree
Ph.D.

LOCATION(S)

3IT - Institut interdisciplinaire d'innovation technologique

Project Description

Context: Artificial Intelligence (AI) based on 2nd generation Artificial Neural Networks (ANN) has become ubiquitous thanks to the ever-increasing computing power, the availability of data sets and breakthroughs in learning methods. However, the execution of such algorithms relying massively on vector-matrix multiplications (VMM) by sequential von Neumann computing hardware poses significant problems of performance and power consumption. Energy-intensive cloud computing is therefore mandatory, which represents an obstacle to the development of low-power AI. In this context, neuromorphic electronics that natively implement bio-inspired computing is seen as one of the most promising ways to improve AI performance and energy efficiency. This interest is fueled by Spiking Neural Networks (SNN), where encoding, communication and data processing are performed using binary spikes. State-of-the-art performance can be achieved through unsupervised learning in the case of spatio-temporal data. In addition, event-driven information processing allows consumption in the range of biological neural networks (< 1 pJ/spike). Our research group at 3IT is currently working on the development of such neuromorphic integrated circuits on silicon, whose artificial synapses are based on crossbar arrays of resistive memories (memristors). The latter are passive metal-insulator-metal components whose resistance (= synaptic weight) can be modified in a non-volatile and reversible way by applying a current. We propose a research project focused on the implementation on silicon of spiking neural networks, involving the micro-nanofabrication of memristor arrays, their electrical characterization and the development of bio-inspired computational methods taking advantage of the unique properties of memristors. This project can be started at the Master's level and continued at the Doctoral level, or started directly at the Doctoral level.

Project: This research project is part of a large research program in neuromorphic engineering, led by Prof. Dominique Drouin at 3IT in collaboration with numerous academic partners including the University of Toronto and Aix-Marseille University (AMU, France). Using the expertise and manufacturing processes of 3IT, the student will (i) conduct a review of the scientific literature to establish the state-of-the-art in relation to the research project; (ii) perform the complete process of micro-nanofabrication on silicon of memristor crossbar arrays in clean room; (iii) analyze the performance and synaptic behavior of the memristors via DC and pulsed electrical characterizations. This work will be carried out using a probe station and neuromorphic PCBs developed by our group; (iv) develop unsupervised learning and spike-based computation methods on crossbars connected to one of our neuromorphic PCBs. Simple pattern recognition and classification tasks will finally be demonstrated.

Supervision and work environment: This project will be carried out under the co-supervision of Prof. Dominique Drouin, Prof. Serge Ecoffey and Prof. Yann Beilliard. Regular interactions will take place with our collaborators in France (IEMN, AMU) and in UoToronto. Our research group is composed of about twenty students working in teams on the nanofabrication of memristors on silicon, their complete characterization and the hardware implementation of artificial neural networks. The master's degree will be carried out mainly at the Interdisciplinary Institute for Technological Innovation (3IT) of the UdeS, which is a unique institute in Canada dedicated to the research and development of innovative technologies in the fields of energy, electronics, robotics and health. The candidate will thus benefit from an exceptional international research environment where students, engineers, professors and industrialists work hand in hand to develop the technologies of the future.

Desired profile:
• University degree in electrical or computer engineering
• Strong adaptability, initiative and teamwork skills
• Strong taste for programming, clean room nanofabrication and device characterization
• Assets: Skills in micro-nanotechnologies, artificial neural networks, electrical characterizations, programming (Python, C++, Arduino, LabVIEW)
Additional information:
• Starting date: as soon as possible
• Send CV, cover letter and transcripts for the last 2 years to: yann.beilliard@usherbrooke.ca

Discipline(s) by sector

Natural Sciences and Engineering

Electrical Engineering and Electronic Engineering

Funding offered

Yes