Topic for a

Master thesis / Diplomarbeit

Hardware-aware offline training of a spiking neural network based on memcapacitive neuro-crossbars

At the Chair of Fundamentals of Electrical Engineering novel memristive/memcapacitive memory elements are investigated to enable non-conventional and low-power analog computing systems [1]. Memristive/memcapacitive devices have internal memory functions like a RAM and can be used in crossbar structures for highly parallel computations, especially for matrix multiplications, as they are massively used in artificial neural networks (ANN) [2]. In a current project, a split-gate neuro-transistor with memcapacitive crosspoint array (neuro-crossbar) is designed and fabricated together with NaMLab gGmbH Dresden that aims to emulate spiking neural networks [3]. In this context, an open research topic is the training of this kind of the spiking neural network that uses the memcapacitive neuro-crossbar hardware. In particular, the existing crossbar simulation framework needs to be extended to the memcapacitive operating principle, where the resulting charges open a transistor gate and lead to a corresponding output spike. The neuro-crossbar weights are trained to detect words in spoken digit recordings or speech commands using coding techniques like rate coding or phase coding.

Within the scope of a scientific work, a Python-based simulation framework of the memcapacitive neuro-crossbar hardware is implemented and evaluated for its training detecting time series datasets.

The student thesis should include, but not be limited to, the following:

- Literature research on training of spiking neural networks, using the SNNTorch framework

- Implementation of a spiking neural network simulation for memcapacitive neuro-crossbar structures

- Verification and training of exemplary networks to detect spoken digit recordings or speech commands

- Optimization of the training algorithm considering the hardware constraints of neuro-crossbar structures

- Documentation of the results

For this thesis a very good knowledge of the basics of electrical engineering and Python programming is required. In-depth knowledge of memristive crossbars and memcapacitive neuro-crossbar structures can be acquired in the course of the student thesis work.

References:
[1] Tetzlaff, Ronald. *Memristors and Memristive Systems*. Springer, 2014
[2] R. Schroedter, A.S. Demirkol, A. Ascoli, R. Tetzlaff, E. Mgeladze, M. Herzig, S. Slesazeck, T. Mikolajick, "SPICE Compact Model for an Analog Switching Niobium Oxide Memristor", IEEE International Conference on Modern Circuits and Systems Technologies (MOCAST), pp. 1–4, 2022
[3] Website of NeuroMCross research project, https://memristec.de/projekte/neuromcross/

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