Topic for a

Master thesis / Diplomarbeit

Simulation of a memristive spiking neural network with synaptic crossbar with locally active neuristor cells

At the Chair of Fundamentals of Electrical Engineering novel memristive memory elements with locally active regions are investigated to enable non-conventional and low-power analog computing systems [1]. An electrical neuristor cell can be built that behaves similarly to biological neurons by combining a locally active memristor with a capacitive element and a suitable biasing [2]. Moreover, by placing a non-volatile memristor acting as a synapse between two neuron-like neuristor cells, different learning mechanisms can be emulated exploiting its spike timing [3]. Nevertheless, a current challenge is the proper design that enables efficient learning and propagation of spike signals through a network of memristive synaptic crossbars and neuristor cells.
Within the scope of a scientific work, the memristive spiking neural network of non-volatile crossbars surrounded by locally active neuristor cells is implemented in Python and tested for different learning mechanisms and proper spike propagation.

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

- Literature research on the locally active neuristor cells and their application in spiking neural networks, i.e. to enabling learning mechanisms such as STDP
- Implementation of a Python–based simulation framework of a memristive spiking neural network connecting multiple synaptic non-volatile crossbars with neuristor cells
- Verification of the unsupervised learning and efficient spike propagation through the network to realize inference in a spiking neural network
- Definition and test of suitable digital input/output interface for the analog spiking neural network
- 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 neuristor cells and non-volatile memristive crossbars can be acquired in the course of the student thesis work.

References:
[1] Tetzlaff, Ronald. *Memristors and Memristive Systems*. Springer, 2014
[2] Demirkol, A.S., Messaris, I., Ascoli, A., Tetzlaff, R. (2022). *Pattern Formation in an M-CNN Structure Utilizing a Locally Active NbOx Memristor*. In: Chua, L.O., Tetzlaff, R., Slavova, A. (eds) Memristor Computing Systems. Springer, Cham.
[3] Serrano-Gotarredona, T., Masquelier, T., Prodromakis, T., Indiveri, G., Linares-Barranco, B. (2013). *STDP and STDP variations with memristors for spiking neuromorphic learning systems*. Front. Neurosci. 7.

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