Memristor based Sigma-Delta Modulation Neural Networks

Background & motivation:

Along with the technology advancements a growing rate of analog big data acquisition is increasing, thus there is an essential need for high-precision analog processing elements preserving reliable computation in high accuracy signal processing systems. A sigma-delta modulator is an efficient method for encoding analog signals into digital signals as found on analog to digital converters. It has been used widely in modern integrated circuits because of its cost efficiency and reduced circuit complexity. The quantization process of converting analog voltages to its corresponding digital form keeps high resolution by shaping the noise and oversampling the signal.

The sigma-delta modulation widely used in analog to digital converters, exist at the interface of each domain used for quantization to the digital world, then the bit stream is processed by digital blocks. Memristors are considered a promising technology with very attractive properties, essentially two terminal thin-film devices with non-volatile varying resistance. It describes the relation between the flux and the electrical charge via integral on applied time interval. Therefore, it is equivalent to apply either a specific voltage for longer time or bigger voltage value for less time. This attribute makes the memristor a good candidate to work with encoded pulses completely compatible with sigma-delta modulator.

Biological neurons exchange information by transceiving spikes or pulse trains with other neurons. Thus the information is not encoded by the shape of the pulses but by the arrival time and the correlation of the pulses, this is known by pulse frequency coding.

In the proposed project the students are required to show that sigma-delta modulators can be used to model the information coding process of biological neurons, and implement the sigma-delta neural activation function. While the memristor is used to model the synapse which represents the connection strength between neurons and the firing rate between them (frequency).

Project flow:

- Comprehension of: memristors, conventional sigma-delta modulators, artificial neurons models, synapses …
- Simulation of each component using automation design tools: Virtuoso, Matlab …
- Schematic implementation of memristor based sigma-delta modulator and performance analysis of signal to noise ratio, sampling rate, quantization error …
- Evaluation and comparison to other neural activation function like sigmoid and signum.
- The option to implement a specific application using the integrated artificial neural network.

Perquisites: linear electric circuits
Recommended: Introduction to biological signals & systems.
Supervisor: Loai Danial, sloaidan@tx