Spiking Neural Networks with Unsupervised Learning Based on STDP Using Resistive Synaptic Devices and Analog CMOS Neuron Circuit

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Abstract

Artificial Neural Networks (ANNs), inspired by the function of biological neural network, have been reserched as powerful tools for pattern recognition and classification. One of the ANNs, spiking neurons are considered as the third generation of artificial neural networks [1]. The basic computational unit in spiking neural networks (SNNs) is a neuron circuit that behaves similarly to real neurons in the human brain. We designed the CMOS analog integrate and fire neuron circut can drive resistive synaptic device. The neuron circuit consists of a current mirror for spatial integration, a capacitor for temporal integration, output pulse generation part, a refractory part, and a back-propagation pulse generation part. The synaptic device with HfO_2 switching layer was fabricated using atomic layer deposition (ALD). The synpatic weight, conductance of the RRAM, is adjusted by spike-timing-dependent-plasticity (STDP) learning rule. We have developed an unsupervised SNNs for pattern recognition and classification using the neuron circuit and synaptic devices. In the simulation, input neurons in the 1^{st} layer are connected with output neurons in the 2^{nd} layer through resistive synapic devices. As input patterns are applied to 1^{st} layer neurons, one of the ouput neurons generates action potential, and the weight of the synaptic devices are modified according to the timing deffernce between pre and post synaptic pulses. Without the aid of software calculations, the hardware-based SNNs can autonomously and efficiently control the weight updates between neurons.

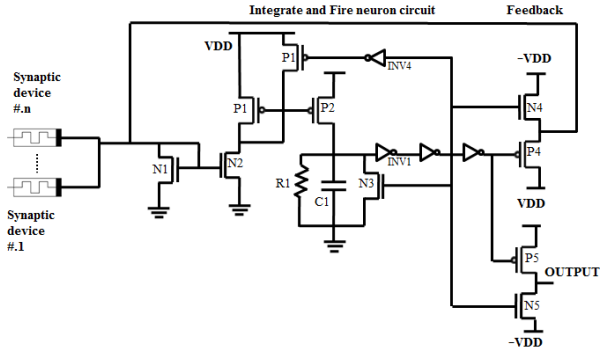

Fig. 1. I&F neuron circuit and synaptic devices.

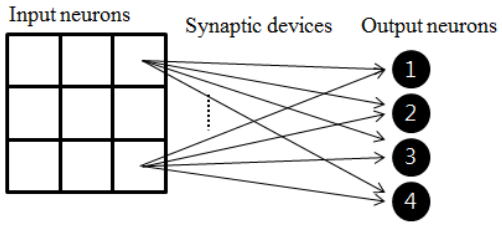

Fig. 2. Schematic diagram of spiking neural networks.

[1] Maass, Wolfgang. "Networks of spiking neurons: the third generation of neural network models." Neural networks 10.9 (1997): 1659-1671.