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Author(s):
Indiveri, Giacomo; Horiuchi, Timothy

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A Neuromorphic VLSI Competitive Network of Integrate and Fire Neurons

Giacomo Indiveri
Institute of Neuroinformatics
University of Zurich and ETH Zurich

Timothy Horiuchi
Computational Sensorimotor Systems Laboratory
University of Maryland, College Park

Competitive networks of I&F neurons

Competitive networks of neurons have been shown to exhibit a broad range of computational properties and can account for many response properties of cortical circuits. Models of competitive networks based on spiking neurons have complex dynamics that require CPU intensive processes and long simulation times.

VLSI implementations of networks of spiking neurons allow us to study in real-time their dynamic properties, to investigate the effect of spike timing and synchrony on the network’s computational properties and to use them for processing sensory signals in multi-chip neuromorphic sensory-motor systems.

The network architecture

We designed a VLSI architecture that contains an array of 33 integrate and fire neurons arranged as depicted above. 32 excitatory neurons (empty circles) project their output to one global inhibitory neuron (filled circle) that projects back its output to the excitatory neurons via inhibitory synapses. Excitatory neurons have also synaptic connections with their nearest neighbors and are arranged in a circle (closed boundary conditions).

Excitatory and inhibitory cells are implemented with leaky integrate and fire neuron circuits. Synapses are implemented with current-mirror integrator circuits.

The leaky I&F neuron

Schematic diagram of the I&F neuron (right box) connected to an excitatory synapse (left box).

Network response properties

By using different bias settings that control the neuron’s and synapses’ response properties we can bias the network to exhibit a wide range of behaviors, ranging from selective amplification to hard winner-take-all.

Firing rates (winner-take-all behavior)

Single neuron response to a 100Hz input spike train, integrated by an excitatory synapse

Spike cross-correlations (increasing synchrony)

We stimulated three neighboring neurons with synchronous inputs and measured cross correlations of their output spike trains for three different network configurations.

Application example: stereo depth perception

By using different bias settings that control the neuron’s and synapses’ response properties we can bias the network to exhibit a wide range of behaviors, ranging from selective amplification to hard winner-take-all.

We interfaced two silicon retinas that generate spikes in response to moving features to the competitive network and biased it to enhance its coincidence-detection capabilities. The arrangement of the sensors and the network connectivity was chosen such that the position of the winning cell in the competitive network encodes stimulus depth.

Response of the network to a bar swinging back and forth in the field of view of the two retinas.

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