The BioRC Biomimetic Real-Time Cortex

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Abstract:

The goal of the BioRC project is to investigate the challenges facing whole brain emulation in the coming decades, and to pose solutions to the challenges that might be instrumental in producing a brain emulation that demonstrates intelligence and problem-solving capability. A number of neuromorphic circuits have been constructed, including those implementing spike-timing-dependent plasticity, structural plasticity and dendritic plastic. This poster demonstrates additional neuromorphic circuits that exhibit some important mechanisms that have not been demonstrated by others. These mechanisms include astrocyte-neuron communications, gap junctions and their role in neural synchronization, neurons with noisy ion channels and synapses, and non-linear dendritic computations that vary depending on the magnitudes of dendritic potentials. Four doctoral students have been involved in this research along with numerous masters students and some undergraduate researchers.

The astrocyte-neuron communication shows a CMOS neuromorphic circuit with two main features. First, we emulate the uptake of neurotransmitters by astrocytes, a type of glial cell, that plays an active role in the coordination of information between neurons. Second, we propose a synapse inactivation mechanism, that prevents the saturation of postsynaptic neurons in the absence of an astrocytic process. We show in a small network of neurons interacting with an astrocyte the influence of both mechanisms on the firing of neurons. In this network, we also incorporate the release of gliotransmitters by the astrocytic microdomain according to the activity of neighbor synapses. This work contribute to better understanding the importance of astrocytes in neuro-glial interactions.

This poster also presents a neuromorphic cortical neuron circuit with ion-channel variability, and synaptic variability. This neuron circuit has been designed and simulated using carbon nanotube transistors, one of several nanotechnologies under consideration to meet the challenges of scale presented by the cortex. Research results suggest that some instances of variability are stochastic, while other studies indicate that some instances of variability are chaotic. In this paper, both possible sources of variability are considered by embedding either Gaussian noise or a chaotic signal into the neuromorphic circuit and observing the results. In simulation experiments, spontaneous firing of neurons due to ion-channel variability was demonstrated.

The poster also shows a gap junction circuit where the channels are open when potentials in both neurons are close and closed when there is a large potential difference, as reported for biological neurons. Finally a circuit is shown that performs non-linear additions of membrane potentials, where the addition varies depending on the magnitude of the potentials.