Learning in Neural Networks of Excitatory and Inhibitory Neurons

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Abstract

Neural networks of spiking neurons (SNs) are used for computer modeling and simulations of biological neural systems as they allow observation of interactions between neurons. There are two major types of biologically inspired artificial neuron models: conductance based models (Hodgkin–Huxley) and the integrate-and-fire models, such as the MacGregor model.

Conductance based models allow for detailed dynamics of a neuron’s membrane potential and spike generation. They imitate the biological neurons’ response by modeling several ion channels, like sodium, potassium, calcium, etc. Advantages of conductance models are the possibility of modeling post-inhibitory rebounds, bursting, and the multiple-compartmental structure of a single neuron. In many applications, such as modeling of learning processes, modeling of spike generation can be simplified but this simplification decreases degree of biological similarity.

The family of integrate-and-fire neuron models has a simplified spike generation mechanism while providing an accurate approximation of the membrane potential and other neuron properties like refractory properties and adaptation to stimuli. Simplification of spike generation allows for improved computation speed as compared with conductance based models.

In this research we investigate the importance of inhibition and inhibitory learning in the network. Our experiments showed that the lack of inhibition almost completely eliminates the ability of the network to learn. For our simulations we use the integrate-and-fire neuron model, which is based on the MacGregor model. It models the biological neuron behavior closely in terms of subthreshold membrane potential, potassium channel response, refractory properties, the neuron’s excitation and inhibition, and adaptation to stimuli.