Spiking neural network model of visual pattern recognition and decision-making using a stochastic STDP learning rule

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The human visual system can efficiently discriminate between different object types in a variety of viewing conditions. Neural networks using the neurobiologically plausible Spike-Timing-Dependent Plasticity (STDP) as a learning rule have been shown to categorize objects on a par with machine learning methods. Studying these neural models may not only lead to efficient hardware and software implementations, but may also lend insight into how objects are represented in the brain. We study the dynamics of a synaptic plasticity rule that was shown to correctly classify highly correlated stimuli. The learning rule was characterized by bistable synapses, which were modulated by presynaptic activity, and stochastic synaptic transitions. We modified the original model to be more biologically plausible by implementing a Spiking Neural Network (SNN) using Izhikevich neurons and conductance-based synapses. A single layer of classifier neurons was trained on spiking responses from simulated neurons with V2/4-like orientation selectivity. Input features were generated from the MNIST database of handwritten digits. During training, an additional excitatory teacher signal drove the classifier neurons toward a desired firing rate. For classification, we used a decision criterion based on a race model. The network achieved 92% correct classifications on MNIST in 100 rounds of random sub-sampling cross-validation. Moreover, the network correctly predicted the shape of behavioral reaction time distributions from psychophysical experiments. Reaction times did not decrease when the target stimulus had become familiar, and when the network made an error, its mean reaction time was significantly slower than when making a correct class prediction.