Stabilizing STDP in Spiking Neural Networks with Homeostatic Synaptic Scaling

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Abstract

Spiking neural network (SNN) simulations with spike-timing dependent plasticity (STDP) often experience runaway synaptic dynamics and require some sort of regulatory mechanism to stay within a stable operating regime. Previous homeostatic models have used L1 or L2 normalization to scale the synaptic weights but the biophysical mechanisms underlying these processes remain undiscovered. We propose a model for homeostatic synaptic scaling that modifies synaptic weights in a multiplicative manner based on the average postsynaptic firing rate as observed in experiments. The homeostatic mechanism was implemented with STDP in conductance-based SNNs with Izhikevich-type neurons. In the first set of simulations, homeostatic synaptic scaling stabilized weight changes in STDP and prevented runaway dynamics in simple SNNs. During the second set of simulations, homeostatic synaptic scaling was found to be necessary for the unsupervised learning of V1 simple cell receptive fields in response to patterned inputs. STDP, in combination with homeostatic synaptic scaling, was shown to be mathematically equivalent to non-negative matrix factorization (NNMF) and the stability of the homeostatic update rule was proven. The homeostatic model presented here is novel, biologically plausible, and capable of unsupervised learning of patterned inputs, which has been a significant challenge for SNNs with STDP.