Competitive Hebbian learning through spike-timing-dependent synaptic plasticity - A summary [SMA00]

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Overview

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Motivation

Hebbian learning:

- Synapse connecting neurons that are repeatedly active at the same time becomes stronger
- Different synapses compete with each other: The strengthening of one leads to the weakening of another

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Song et. al: Spike-timing dependent plasticity (STDP) naturally leads to a stationary distribution of synaptic conductances that enables competition among synapses

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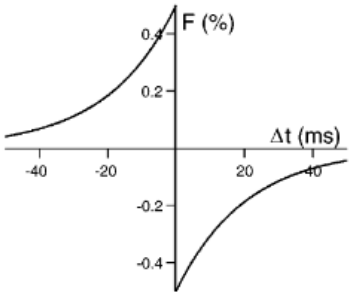
STDP

Function describing change in synaptic conductances

$$F(\Delta t) = \begin{cases} A_+ \exp(\Delta t/\tau_+), & \text{if } \Delta t < 0 \\ -A_- \exp(-\Delta t/\tau_-), & \text{if } \Delta t \geq 0 \end{cases}$$

Presynaptic spikes / Postsynaptic action potential: Strengthening
Postsynaptic action potential / Presynaptic spikes: Weakening



Dependence of synaptic conductances on Δt [SMA00]

The simulation

- Integrate-and-fire model neuron with 1000 excitatory synapses and 200 inhibitory synapses

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- Inhibitory synapses are kept fixed with input frequency of 10 Hz.
- Excitatory synapses initialised with maximum values $g_{\max}$; adapted according to STDP with input frequencies of 10Hz and 40Hz

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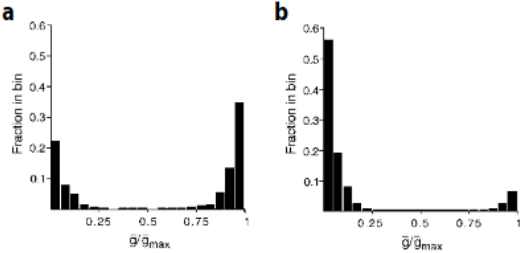
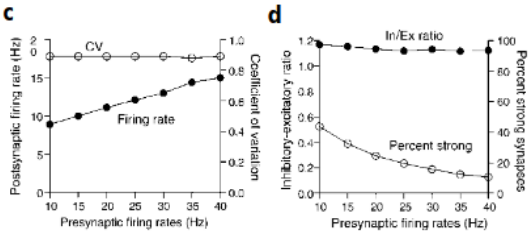


Stationary distribution of synaptic conductances [SMA00]

Stationary distribution II

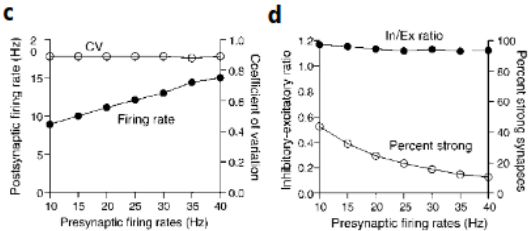
- Regulatory effect on postsynaptic firing rate



Stationary distribution of synaptic conductances [SMA00]

Stationary distribution II

- Regulatory effect on postsynaptic firing rate
- For all input frequencies: Same ratio of inhibitory and excitatory conductances



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Disadvantages:

- Requires a few assumptions to reach equilibrium distribution like nonlinear spike-generation process
- Postsynaptic firing rate is sole source for synaptic adaptiation! What if excitatory synapses aren't strong enough to begin with?

References


Sen Song, Kenneth Miller, and L.F. Abbott.
Competitive hebbian learning through spike timing-dependent plasticity.
Nature neuroscience, 3:919–26, 10 2000.