Synaptic regulation on suppressing STDP rules

Yutaka Sakai **Kaoru Nakano** **Shuji Yoshizawa**

Department of Information and Computer Science,
Faculty of Engineering, Saitama University, Saitama 338-8570, Japan
{*sakai,yoshi*}*@bios.ics.saitama-u.ac.jp*

Activity regulation is an inevitable function for development of networks. On the normal Hebbian rule, synaptic efficacy is potentiated more for higher postsynaptic activity. The synaptic potentiation raises the postsynaptic activity. Thus the normal Hebbian rule causes divergence of activity. More detail synaptic plasticity is known as spike-timing-dependent plasticity (STDP), where synaptic plasticity depends on the relative timings of postsynaptic spikes to presynaptic ones. Song et al.(2000) described the STDP rule as simple exponential functions under the assumption of linearly additive updating rule. They demonstrated that the linearly additive STDP rule automatically achieves regulation and competition among received synapses. Synaptic balance shifts to cancel the changes of presynaptic activities, and the postsynaptic activity has little relativity on presynaptic activities. They assumed hard upper and lower boundaries for synaptic efficacy, which prevents the synapses from divergence. The result, however, implies that the mechanism of activity regulation lies in the STDP rule intrinsically.

The assumption of the hard boundary is not feasible from a physiological view point. van Rossum et al.(2000) introduced a multiplicative updating rule for only LTD to provide a soft lower boundary and an open upper bound. They showed that this multiplicative updating rule can achieve neither synaptic competition nor regulation. Rubin et al.(2002) introduced multiplicative updating rules for both of LTP and LTD to provide soft lower and upper boundaries. They also showed that this multiplicative updating rule can achieve neither synaptic competition nor regulation.

The essential causes for extinction of synaptic competition lie not in the difference between additive and multiplicative rules, but in asymmetry between LTP and LTD in the dependence of the efficacy. The asymmetry cancels the competitive nature in the LTP rule. It is, however, unclear why the multiplicative rules do not exhibit synaptic regulation. The synaptic competition and regulation are expected to be related to each other, but they are identical phenomena.

These models are all constructed under the assumption that STDP effects are constant for any pairs of presynaptic and postsynaptic spikes. Recently, an evidence against the assumption was found by Froemke and Dan (2002). They showed that successive spikes suppresses the STDP effect on the latter spike. The suppressing effect is observed for presynaptic successive spikes, as well as for postsynaptic ones.

Here we attempt to examine the suppressing effects on synaptic competition and regulation, for the additive STDP rule and various types of the multiplicative STDP rules. We simulate various combinations of updating rules and suppressing effects in the same way as Song et al.(2000). As a result, it is found that the suppressing effect has little effect on the synapse distributions. We also find that the suppressing effect enhances the synaptic regulation in the additive updating rule. We will discuss the mechanism of the enhancement by using the Fokker-Plank method.