Unimodal or Bimodal Distribution of Synaptic Weights?

– Both can be Stable at the Same Time (with activity depending switching)!

Wulfram Gerstner[1], Taro Toyoizumi[2],[1], and Jean-Pascal Pfister[1]

[1]EPFL, Lausanne [2] Columbia University, New York

Most Hebbian learning rules or BCM rules used to describe receptive field development exhibit a spontaneous separation of synaptic weights into two groups, i.e., strong and weak synapses, so that the distribution of synaptic weights is bimodal. This implies that even rather 'weak', non-significant correlations lead to changes in synaptic weights, so that the neuron may specialise to 'noise' rather than to features of the outside world. Moreover, such a bimodal distribution seems to be difficult to reconcile with experiments in young rats where a unimodal distribution was found [1].

Other plasticity models, however, that exhibit always [2] or for certain inputs [3] a unimodal distribution of synaptic weights have the problem that they do not lead to long-term stability of the weights. In particular, if, after learing, the input pattern changes back to 'weak' correlations, the neuron 'forgets' its synapse pattern as rapidly as it was learned. Thus, those plasiticity models are not useful for long-term memory.

We have developed a model of synaptic plasticity that shares features with spike-timing dependent plasticity; is sensitive to correlations in the input; and is useful for synaptic memory. Interestingly, input selectivity (sharply tuned receptive fields) based on a bimodal synapse distribution develops only if stimuli with *strong* features are presented. For input with 'weak' correlations, sharply tuned neurons with a bimodal synapse distribution can co-exist with unselective ones with a unimodal distribution.

We hypothesize that, during development, neurons initially start off with a unimodal distribution that remains stable as long as correlations in the input are weak, consistent with the unimodal distribution found in young rats [1]. For strongly correlated input, the neuron becomes selective and a bimodal distribution develops. This bimodal distribution remains stable (and the neuron remains selective) even if the correlations in the input are again reduced to the previous 'weak' level. Thus the model exhibits long-term memory. Only if new and even stronger correlations appeared in the input the neuron would readapt.

Hence our model reconciles theoretical demands of sensitivity to new inputs with long-term stability and achieves this without an 'ad hoc' change of the global learning rate. Our model is derived from only three basic principles: (A) Synapses adapt their weights so that neurons can effectively transmit information; (B) homeostatic processes stabilize the mean firing rate of the postsynaptic neuron; and (C) weak synapses adapt more slowly than strong ones, while maintenance of strong synapses is costly.

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References

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