Learning input correlations through nonlinear temporally asymmetric Hebbian plasticity

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Abstract:

Triggered by recent experimental results, temporally asymmetric Hebbian \(\{\text{TAH}\}\) plasticity is considered as a candidate model for the biological implementation of competitive synaptic learning, a key concept for the experience-based development of cortical circuitry. However, because of the well known positive feedback instability of correlation-based plasticity, the stability of the resulting learning process has remained a central problem. Plagued by either a runaway of the synaptic efficacies or a greatly reduced sensitivity to input correlations, the learning performance of current models is limited. Here we introduce a novel generalized nonlinear \(\{\text{TAH}\}\) learning rule that allows a balance between stability and sensitivity of learning. Using this rule, we study the capacity of the system to learn patterns of correlations between afferent spike trains. Specifically, we address the question of under which conditions learning induces spontaneous symmetry breaking and leads to inhomogeneous synaptic distributions that capture the structure of the input correlations. To study the efficiency of learning temporal relationships between afferent spike trains through \(\{\text{TAH}\}\) plasticity, we introduce a novel sensitivity measure that quantifies the amount of information about the correlation structure in the input, a learning rule capable of storing in the synaptic weights. We demonstrate that by adjusting the weight dependence of the synaptic changes in \(\{\text{TAH}\}\) plasticity, it is possible to enhance the synaptic representation of temporal input correlations while maintaining the system in a stable learning regime. Indeed, for a given distribution of inputs, the learning efficiency can be optimized.

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