BMC Neuroscience

BioMed Central

Poster presentation

Open Access

The learning dynamics of spike-timing-dependent plasticity in recurrently connected networks

Matthieu Gilson*[1,2], Anthony N Burkitt[1,2,3] and J Leo van Hemmen[4]

Address: [1]Dept Electrical & Electronic Engineering, The University of Melbourne, Melbourne, VIC 3010, Australia, [2]The Bionic Ear Institute, 384-388 Albert St, East Melbourne, VIC 3002, Australia, [3]Dept Otolaryngology, The University of Melbourne, Melbourne, VIC 3010, Australia and [4]Physik Dept, Technischen Universität München, 85747 Garching bei München, Germany

Email: Matthieu Gilson* - mgilson@pgrad.unimelb.edu.au

* Corresponding author

from Sixteenth Annual Computational Neuroscience Meeting: CNS*2007
Toronto, Canada. 7–12 July 2007

Published: 6 July 2007

BMC Neuroscience 2007, **8**(Suppl 2):P190 doi:10.1186/1471-2202-8-S2-P190

Background

Functional organization in neural networks is believed to arise from synaptic plasticity. Spike-Timing-Dependent Plasticity (STDP) is a candidate for such plasticity which has received considerable experimental support and been the subject of considerable theoretical investigation. Our work extends the framework developed in [1] for analyzing the learning dynamics of STDP in feed-forward network architecture to the case of recurrently connected networks.

Methods

We investigate the dynamics of a network consisting of Poisson neurons recurrently connected with alpha-synapses, where the synaptic weights are modified by a version of STDP incorporating both rate-based and pairwise-correlation-based changes [1]. The network activity is evaluated in terms of the steady-state fixed points of its dynamic variables (firing rates, correlations and weights, all averaged over time). The framework has general applicability and can be applied to any network architecture. The focus of this paper is on a fully connected network with no external synaptic input, in which the neurons are driven only by their spontaneous spiking-rates. This case is not only the most accessible, but it also illustrates the impact of recurrent connectivity upon the learning dynamics.

Results

A dynamical system involving the neuronal variables is derived to describe the network spiking dynamics, which involves only fairly general and well-founded assumptions on the parameter values. For a fully recurrently connected network with no external input, the conditions for the existence of a stable homeostatic equilibrium of the weight dynamics are found. The respective fixed points for both the firing rates and the correlations are uniquely determined. A continuous manifold of fixed points for the weights exists. Numerical simulations confirm the stability of the predicted homeostatic equilibrium and the equilibrium values of the spiking-rates and the average weight. While individual spiking-rates and correlations remain stable (i.e., the time evolution of their variance is stable and relatively small), individual weights diverge on the manifold of the fixed points due to stochastic noise in the network. The evolution of the variance is approximately linear for identical initial weights at the homogeneous fixed point, similar to the case with feed-forward network structure [1].

Conclusion

The results obtained here for a recurrently connected network with no external input are qualitatively similar to the results obtained for feed-forward networks with correlated inputs [1], although in the case investigated here the correlations are intrinsic to the recurrent network. The equilibrium values of the parameters are obtained and, although the mechanisms are similar to the feed-forward case [1], the quantitative values differ. The analysis of the stability of the whole manifold of fixed points (using matrix notation) is currently in progress. Future work involves the cases of fully connected networks with (i) uncorrelated and (ii) correlated external synaptic inputs, which are more relevant from a biological point of view.

References

1. Kempter R, Gerstner W, van Hemmen JL: **Hebbian learning and spiking neurons.** *Phys Rev E* 1999, **59:**4498-4514.