Learning lateral inhibition with inhibitory spike-timing dependent plasticity to improve stimulus discrimination in a model of the antennal lobe

Bahadir Kasap[1,2] and Michael Schmuker[1,3]

1: Neuroinformatics & Theoretical Neuroscience, Dept. of Biology Chemistry Pharmacy, Freie Universität Berlin, Berlin, Germany
2: Institute for Computational Mathematics, Carl-Friedrich-Gauss-Dept., Technische Universität Braunschweig, Braunschweig, Germany
3: Bernstein Center for Computational Neuroscience Berlin, Berlin, Germany

The insect olfactory system is capable of classifying odorants by encoding and processing the neural representations of chemical stimuli. Odors are transformed into a neuronal representation by a number of receptor classes, each of which encodes a certain combination of chemical features. Those representations resemble a multivariate representation of the stimulus space (). The insect olfactory system thus provides an efficient basis for bio-inspired computational methods to process and classify multivariate data. In previous work, we demonstrated how a network inspired by the insect olfactory system improves classification of multivariate data by lateral inhibition (Schmuker and Schneider, 2007). In that study, the connectivity of lateral inhibition was chosen such that glomeruli with similar response profiles shared strong mutual inhibition, increasing their contrast and thus improving stimulus separability.

Here, we propose an approach to learn the connectivity of lateral inhibition through unsupervised learning of rate correlations in the input by inhibitory spike-timing dependent plasticity (iSTDP, Vogels *et al.*, 2011). To this end, we implemented a spiking network model of the insect antennal lobe with lateral inhibitory connections that support iSTDP. We exposed the network to stimulus patterns with structured firing rate correlation between input channels, similar to input patterns generated by olfactory receptors with partially overlapping receptive fields. As a consequence of iSTDP, the network's inhibitory connectivity converged towards an accurate reflection of the correlation structure in the input data. Moreover, the network efficiently reduced firing rate correlation at the output, potentially improving the separability of stimuli for improved discrimination. Thus, iSTDP in our network model asserts decorrelation of the input data without *a priori* information on the input. Our results indicate that iSTDP is a suitable mechanism to improve stimulus separability in the insect antennal lobe. Moreover, our network model is suited as a building block for bio-inspired data analysis frameworks, for example on a neuromorphic hardware system supporting spiking neural network models (Brüderle *et al.*, 2010).

This was partially funded by the German Ministry for Education and Research (BCCN Berlin, 01GQ1001D) and Deutsche Forschungsgemeinschaft (SCHM 2474/1-1).

References

Huerta R & Nowotny T (2009). Fast and Robust Learning by Reinforcement Signals: Explorations in the Insect Brain. *Neural Comput.* 21:2123–2151.

Schmuker M & Schneider G (2007). Processing and classification of chemical data inspired by insect olfaction. PNAS 104:20285–20289.

Vogels TP, Sprekeler H, Zenke F, Clopath C & Gerstner W (2011). Inhibitory plasticity balances excitation and inhibition in sensory pathways and memory networks. Science 334: 1569–1573.

Brüderle D, Bill J, Kaplan B, Kremkow J, Meier K, Müller E & Schemmel J (2010). Simulator-like exploration of cortical network architectures with a mixed-signal VLSI system. In Proc. ISCAS 2010, 2784–8787.