Abstract for ESF-EMBO symposium: Functional Neurobiology in Minibrains, Hotel Eden Roc, Oct 17-22 2010, Sant Feliu de Guíxols, Spain.

Insect olfactory microcircuits for better neuromorphic classification devices

Michael Schmuker[1,2], Chris Häusler[1,2], and Martin P Nawrot[1,2]

1: Neuroinformatics & Theoretical Neuroscience, Institute of Biology, Freie Universität Berlin, Berlin, Germany
2: Bernstein Center for Computational Neuroscience Berlin, Berlin, Germany

A large body of behavioral discrimination experiments demonstrates that the honeybee can quickly and reliably identify odorant stimuli [1]. The neuronal circuits involved in odor discrimination are well described on the structural level. Here, we decompose the insect olfactory pathway into local circuits that represent successive processing stages. We infer their specific functional role in odor discrimination using spiking neuronal network models, measuring their contribution to the performance of a neuronal implementation of a probabilistic classifier, which we train in a supervised manner [2,3].

In the insect olfactory system, primary receptor neurons project to the antennal lobe (AL). The AL is organized in compartments called glomeruli. Each glomerulus receives input only from one type of receptor neurons. Each odorant activates many different receptor types, inducing a spatial pattern across the AL. Strong lateral inhibitory interactions between glomeruli make an impact on information processing [4]. We illustrate how lateral inhibition enhances linear separability of stimulus patterns by increasing contrast between input dimensions.

From the glomeruli, uniglomerular projection neurons (PNs) send their axons to Kenyon cells (KCs) in the mushroom body, a central brain structure where stimulus associations are being formed from multimodal input [5]. Connections between PNs and KCs are realized within small local microcircuits, where PNs and KCs interact with an inhibitory cell population [6]. We show how these microcircuits can create non-linear transformations of the input patterns. Moreover, this stage is anatomically characterized by a massive 'fan-out' of connections: In the honeybee, about 950 PNs synapse onto about 100.000 KCs. Taken together, this organization resembles the working principle of a support vector machine, transforming data which is not linearly separable into a higher-dimensional representation, in which linear separation is possible.

At each stage of the model, we use a two-dimensional toy data set to illustrate the classification problem and the processing principle.

Currently, we test the performance of the neuronal classifier on benchmark data sets and a real-world odorant data set [7]. In addition, we test implementations of our models on neuromorphic hardware. This is a first step towards implementations of fast and powerful neuromorphic classification devices, applicable to a wide range of sensor data.

References:

[1] Giurfa (2007) *J Comp Physiol A* **193**:801-24.

[2] Fusi, Asaad, Miller and Wang (2007) *Neuron* **54**:319-333.

[3] Soltani and Wang (2010) *Nat Neurosci* **13**:112-9.

[4] Wilson and Mainen (2006) *Annu Rev Neurosci* **29**:163-201.

[5] Heisenberg (1998) *Learn Mem* **5**:1-10.

[6] Ganeshina and Menzel (2001) *J Comp Neurol* **437**:335-349.

[7] Schmuker and Schneider (2007) *PNAS* **104**:20285-20289.