HUMBOLDT-UNIVERSITÄT ZU BERLIN

BERNSTEIN CENTER FOR

COMPUTATIONAL NEUROSCIENCE

Humboldt-Universität zu Berlin
Philippstr. 13 House 6

Phone: 030/2093-9110
Fax: 030/2093-6771
webpage: http://www.bccn-berlin.de/

Models of Neural Systems, WS 2018/19
Project 4: Balancing an Inhomogeneous Neural Network
Report submission: February 11th. Project presentation: February 12th.

Background

Neural networks consist of excitatory and inhibitory neurons. Recordings from various brain areas reveal that cortical neurons receive balanced excitatory and inhibitory currents. On the one hand, this balance leads to highly irregular firing properties of the neurons (asynchronous irregular (AI) state, see Brunel, 2000), and, on the other hand, it is considered to be critical for maintaining the stability of the whole network. For long, a systematic approach of balancing recurrent networks was causing difficulties in Computational Neuroscience. The open question was how one should adjust the weights in a model so that the network 'behaves' properly (i.e. AI state). Vogels et. al., 2011 present a simple idea for such balance, proposing that the desired output of a single excitatory neuron is achieved by adjusting the synaptic strength of the input inhibitory connections. The rule can be summarized as:

$$\Delta w = \eta(pre \times post - \rho_0 \times pre),$$

where Δw is the change of inhibitory-to-excitatory synaptic efficacy, *pre* and *post* are the inhibitory and excitatory activities, respectively, and ρ_0 is the target firing rate of the postsynaptic neuron.

Problems

1. Using Brian (www.briansimulator.org), implement an inhomogeneous network of 10000 neurons (8000 excitatory and 2000 inhibitory ones) with 2% random connectivity between them. For various parameter values (e.g. time constants, conductances, etc.), you can refer to Vogels et. al. 2011. What kind of network states do you observe? In order to measure the synchrony and the regularity of firing, what measures would you apply?

2. Implement a spike-timing-dependent plasticity rule on the inhibitory-to-excitatory synapses as in Vogels et. al., 2011. (Hint: For the implementation details, use the Supplementary material). What is the equilibrium state of network in terms of your previous measures?

3. Measure the input currents (excitatory and inhibitory) of one neuron, and plot them. Do you see any correlation between them? What is the delay between both currents?

4. In the already balanced network, pick randomly a group of excitatory neurons (e.g., 500 neurons) and connect them with probability p_{rc}. Do you need to balance the network once again after that? Vary p_{rc} and observe how the assembly activity changes.

Create labelled figures for all your main findings and summarize your results.

Literature

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

(optional) N. Brunel (2000). Dynamics of sparsely connected networks of excitatory and inhibitory spiking neurons, J. Comp. Neurosci., 8:183-208.

Supervisor: Greg Knoll Phone: 2093-6299 Email: gregory(at)bccn-berlin.de