Cortical microcircuit with adapting synapses

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A basic building block of mammalian neocortex consists of the circuit with the pyramidal excitatory cells connected to the inhibitory interneurons. We modeled a neuronal network of these elements. We used one point neurons with the Hodgkin-Huxley equations adapted for neocortical neurons. The f-I curve of these equations is close to the linear function. It is linearized by the presence of the K^+ AHP current. The Na^+, K^+, and Ca^{++} currents are chosen with the aim to reach the compromise between the biological complexity and numerical tractability of the network. Cells are randomly connected. We study, what is the effect of replacing the static, conventional synapses by dynamic, adaptive synapses, described by Markram and others. Differential equations for both neurons and synapses are solved by a custom written Runge-Kutta method differential equation solver. One property which cannot be modeled solely by differential equations are delays. Therefore we also implemented delays as one of the features toward modeling more realistic network. As output variables we observe: mean firing rate in the network, synchronous firing of groups of neurons and the degree of their synchronization and also the development of state variables in dynamic synapses. The aim of the simulation is to keep local and global parameters of the network close to the experimentally reported values.

We ask, how do networks with static and dynamic synapses differ. We found that dynamic synapses keep network firing with plausible outputs for larger range of sensory-like inputs in comparison to static synapses. We found that bursting is a network property, not dependent on the type of synapse.

In the current state of the project we investigate following questions:
1) Dynamical synapse can reproduce the LTP/LTD, shown originally in slices. We also demonstrate the LTP/LTD in one neuron. We go beyond the slices experiment and show, what parameters of dynamic synapses are important for inducing the LTP/LTD. We also show, what is a typical distribution of potentiated and depressed synapses during the network activity close to the *in vivo* situation.
2) Nonlinear synapses and delays enable more storage capacity than classical synapses and no delays in network. We again compare setups with and without these properties. We show, how selected parameters of the network, which represent biophysical quantities, can be tracked back into fewer parameters describing the memory capacity in the network.