Presentation Abstract

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Presentation Title: Investigating functional connectivity maps through simulation of cortical networks

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Abstract: The response of a neuron is well known to be stimulus-dependent (selective), but the surrounding cells also contribute strongly to shape that response. In fact, neurons closely interact together via synaptic couplings to frame complex networks. While computer models are not extensively used in biology/neuroscience, they can provide insights about such complex interactions at multiple scales: from synaptic dynamics, to single neuron responses and large-scale network behaviours. To this aim, a generic simulation scheme is described and applied to a sample task. The goal is to reproduce network selectivity effects in a virtual assembly of visual neurons, phenomena observed in recordings of cat V1 neurons in response to different orientations (sine wave drifting gratings).

While the bio-plausibility of the model helps to reproduce specific details of the in-vivo neuronal activity, the complexity of the simulation always depends on the task. It is thus shown that many parameters of the simulated neurons can be derived from single electrode recordings: cell types (pyramidal cells, interneurons) and their stimulus selectivity (tuning curves), axonal conductance delays, putative synaptic connections, neural refractory periods and spontaneous activity levels. Moreover, the number of simulated neurons is fully scalable and can range from a few tens to several thousands. Spike trains extracted from the simulation can be conveniently analysed in the same way as those of the recordings. In both cases, the functional connectivity matrix to each orientation is derived from the
crosscorrelograms of the spike trains. The simulated neurons follow the Hodgkin-Huxley equations, a biophysical conductance-based model of the cell membrane potential. As an illustration, a network of excitatory neurons is initialized with random tuning curves and synaptic connectivity (including synaptic efficiencies and delays). The different input stimuli generated for the network have the effect of producing distinct levels of activity across the neurons, thus eliciting distinct neural trajectories. It is observed that the intensity and topology of functional connections vary across simulated input conditions (orientations), similar to the in-vivo recordings. The simulation parameters have only little influence on the observations, showing that this particular effect only requires a coarse model. The presented simulation scheme is then useful in building empirical models to investigate network-scale behaviours. Additionally, its flexibility would allow to integrate fine-scale phenomena such as neuronal adaptation.

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