Mean-field models for finite-size populations of spiking neurons with short-term synaptic plasticity

Tilo Schwalger   Bastian Pietras   Valentin Schmutz

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Firing-rate (FR) or neural-mass models are widely used for studying computations performed by neural populations. Despite their success, classical firing-rate models do not capture spike timing effects on the microscopic level such as spike synchronization and are difficult to link to spiking data in experimental recordings. For large neuronal populations, the gap between the spiking neuron dynamics on the microscopic level and coarse-grained FR models on the population level can be bridged by mean-field theory for infinitely many neurons. It remains however challenging to extend mean-field theories to finite-size populations with biologically realistic neuron numbers per cell type (mesoscopic scale). In this talk, I present a mathematical framework for mesoscopic populations of generalized integrate-and-fire neuron models that accounts for fluctuations of the population activity caused by the finite number of neurons [1]. To this end, I will introduce the refractory density method for quasi-renewal processes and show how this method can be generalized to finite-size populations [2]. To demonstrate the flexibility of this approach, I will show how synaptic short-term plasticity can be incorporated in the mesoscopic mean-field framework [3]. On the other hand, the framework permits a systematic reduction to low-dimensional FR equations using the eigenfunction method [4]. Our modeling framework enables a re-examination of classical FR models in computational neuroscience under biophysically more realistic conditions.

References

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