Dynamics and spike trains statistics in conductance-based Integrate-and-Fire neural networks with chemical and electric synapses

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ROLE OF ELECTRIC SYNAPSES IN SPIKE TRAINS STATISTICS OF LINEAR INTEGRATE AND FIRE NEURAL NETWORKS

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Communication between neurons involves chemical synapses as well as electric synapses. On theoretical grounds, the role of gap junctions in encoding and shaping collective dynamics as well as spike train statistics is quite less understood than the role of chemical synapses. In previous work [1] the collective spike train statistics in conductance-based Integrate and Fire neural networks was studied rigorously. It was especially shown that this statistics is characterized by a Gibbs distribution whose potential can be explicitly computed. This provides moreover a firm theoretical ground for recent studies attempting to describe experimental rasters in the retina [4] as well as in the parietal cat cortex [2] by Gibbs distributions and maximal entropy principle. The work presented at AREADNE will extend the mathematical analysis of previous work [1] to conductance-based Integrate and Fire neural networks with chemical synapses as well as electric synapses, in the presence of noise. In opposition to previous paper dealing with this subject [3] we do not consider mean field approximations and the analysis is not limited to pulse type chemical synapses.

The core of the analysis is to show how multiple single neurons interact in the presence of gap junctions. In conductance based models coupled with gap junctions, the sub-threshold dynamics is ruled by a coupled set of linear, non-autonomous and non-homogeneous stochastic differential equations of Ornstein-Uhlenbeck type, where conductances depends upon the spike-history of the network. We compute explicitly the evolution operator and show that given the spike-history of the network and the membrane potentials at a given time, the further dynamical evolution can be explicitly written in a closed form. Under a moderate assumption on the evolution operator the system has a unique strong solution. From this we obtain a family of transition probabilities for spike dynamics, corresponding to a Gibbs distribution. This results emphasizes the role of gap junctions on spike statistics with strong effects on space time correlations and memory. This work suggest that electric synapses could have a strong influence in spike train statistics of biological neural systems, especially the retina where gap junctions connections between several cells-type (e.g. amacrine and ganglion cells or amacrine-bipolar) are ubiquitous.

References

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