BMC Neuroscience

BioMed Central

Poster presentation

Open Access

Response of integrate-and-fire neurons to noisy inputs filtered by synapses with arbitrary timescales: firing rate and correlations

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from Eighteenth Annual Computational Neuroscience Meeting: CNS*2009
Berlin, Germany. 18–23 July 2009

Published: 13 July 2009

BMC Neuroscience 2009, **10**(Suppl 1):P237 doi:10.1186/1471-2202-10-S1-P237

This abstract is available from: http://www.biomedcentral.com/1471-2202/10/S1/P237

Introduction

Delivery of neurotransmitter produces on a synapse a current that flows through the membrane and gets transmitted into the soma of the neuron, where it is integrated. The decay time of the current depends on the synaptic receptor's type, and ranges from a few (e.g. AMPA receptors) to a few hundred milliseconds (e.g. NMDA receptors). The role of the variety of synaptic timescales, several of them coexisting in the same neuron, is at present not understood. A prime question to answer is which is the effect of temporal filtering at different timescales of the incoming spike trains on the neuron's response.

Results

Here, based on our previous work on linear synaptic filtering [1-3], we build a general theory for the stationary firing response of integrate-and-fire (IF) neurons receiving stochastic inputs filtered by one, two or multiple synaptic channels each characterized by an arbitrary timescale. The formalism applies to arbitrary IF model neurons, and to arbitrary forms of input noise (i.e., not required to be Gaussian or to have small amplitude), as well as to any form of synaptic filtering (linear or non-linear). The theory determines with exact analytical expressions the firing rate of an IF neuron for long synaptic time constants using the adiabatic approach. The correlated spiking (cross-correlations function) of two neurons receiving common as well as independent sources of noise is also described (see figure 1). The theory is exemplified using leaky, quadratic and noise thresholded IF neurons (LIF, QIF, NTIF). Although the adiabatic approach is exact when at least one of the synaptic timescales is long, it provides an excellent prediction of the firing rate even when the timescales of the synapses are comparable to that of the leak of the neuron; it is not required that the synaptic time constants are longer than the mean inter-spike-intervals. The distribution of the potentials for general IF neurons is also characterized.

Conclusion

Our results provide very powerful analytical tools that can allow a quantitative description of the dynamics of neuronal networks with realistic synaptic dynamics.

References

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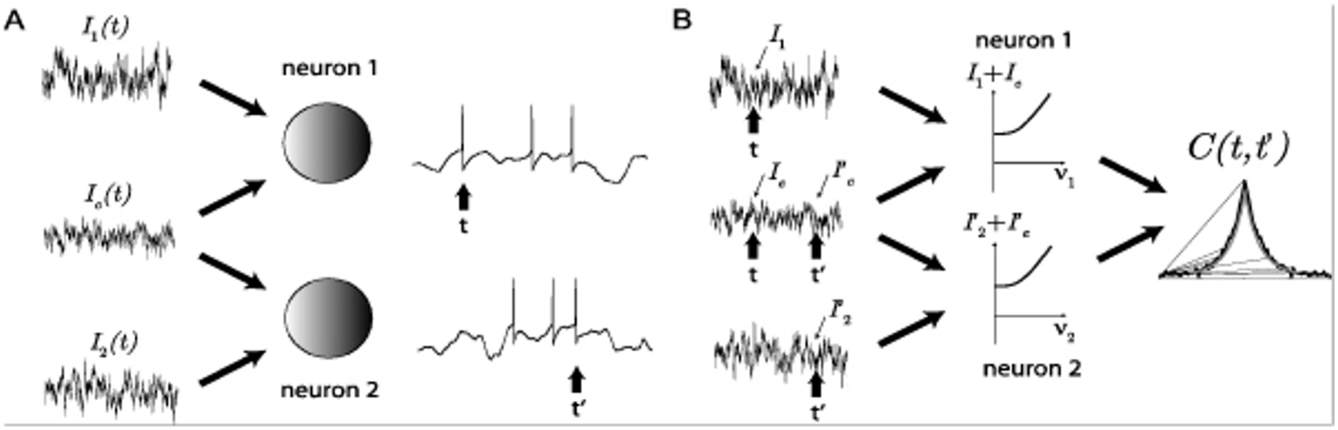

Figure 1
A. Two spiking neurons receiving correlated/common inputs fire in a correlated manner. B: The cross-correlated output spike trains of the two neurons are analytically described.