Parametric estimation of spike train statistics

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BMC Neuroscience

Poster presentation

Open Access

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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):P165 doi:10.1186/1471-2202-10-S1-P165

This abstract is available from: http://www.biomedcentral.com/1471-2202/10/S1/P165

Introduction

We consider the evolution of a network of neurons, focusing on the asymptotic behavior of spikes dynamics instead of membrane potential dynamics. The spike response is not sought as a deterministic response in this context, but as a conditional probability: "Reading the code" consists in inferring this probability [1]. Since one has experimentally only access to finite time raster plots and since the convergence of the empirical statistics to their average can be quite slow, we use a parametric statistical model using a thermodynamic formalism. The natural candidate for spike train statistics is a Gibbs measure [2]. Our work generalizes this seminal and profound work of Bialek and collaborators. This model allows us to predict the conditional probability of rank *R* Markovian spike patterns and is strongly linked with the thermodynamic formalism [3]. It generalizes most spike patterns statistical models (e.g. Poisson, correlated Poisson, etc.).

Methods

A minimal instantiation of the formalism is reviewed, following [3,4], while a general algorithmic estimation method is proposed, minimizing the relative entropy, yielding fast convergent implementations. It is also made explicit how several spike observables (entropy, rate, synchronizations, correlations) are given in closed-form from the parametric estimation. This paradigm not only allows us to estimate the spike statistics, given a design choice, but also to compare different models, thus answering comparative questions about the neural code such as are correlations or time synchrony or a given set of spike patterns significant with respect to rate coding?

Results

A numerical validation of the method is proposed, in order to analyze the statistics of small groups (up to 8/12) of neurons, while the state of the art considers pairs only. The parametric statistical potential of Markov processes up to rank 16/20 is calculable, thus considering up to 2^{20} states for the process. The method has been carefully calibrated with respect to standard processes such as Bernouilli processes. The implementation considers several well-established numerical methods, in order to be applicable to a large set of possible data. It is available as an open-source module in the http://enas.gforge.inria.fr middle-ware set. EnaS is a set of classes allowing to simulate and analyze so called "event neural assemblies." It is designed mainly as existing simulator plug-in (e.g. MVASpike or other simulators via the NeuralEnsemble meta-simulation platform) or as an add-on for computations with neural unit assembly on standard platforms. It is usable in C/C++, Java and Python.

Acknowledgements

Partially supported by the ANR MAPS & the MACCAC ARC projects.

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