BMC Neuroscience

BioMed Central

Poster presentation

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Dynamics of self-sustained microcircuits examined with regular-spiking readouts

Raul C Mureşan[1,2]

Address: [1]Experimental and Theoretical Neuroscience, Center for Cognitive and Neural Studies, Cluj-Napoca, Romania and [2]Neurophysiology, Max Planck Institute for Brain Research, Frankfurt am Main, Germany

Email: Raul C Mureşan - muresan@coneural.org

from Seventeenth Annual Computational Neuroscience Meeting: CNS*2008
Portland, OR, USA. 19–24 July 2008

Published: 11 July 2008

BMC Neuroscience 2008, **9**(Suppl 1):P37 doi:10.1186/1471-2202-9-S1-P37

This abstract is available from: http://www.biomedcentral.com/1471-2202/9/S1/P37

Analyzing the dynamics of large populations of neurons is a still a formidable challenge at present [1]. Even more so, beyond classical analysis techniques (correlation analysis, etc), characterizing the spatio-temporal trajectory of a neural system is very difficult. It has been suggested that such an endeavor can be made possible by describing the dynamics of the neuronal system through a state-space [2]. Such approaches have proven useful for odor decoding in honeybees [3], or the description of neuronal activity from monkey frontal areas [4]. There is however a fundamental problem for large neuronal systems: Finding of a relevant subset of variables that define a state, such that the subset preserves a reasonable amount of information about the whole system. Relevance is to be defined according to the observer of the neuronal population, which, in the real brain, consists of other neurons. Perhaps a good way to characterize a neuronal circuit is to use neuronal observers, and here, we show that a subset of neurons can be used to extract and compress information about the dynamics of a large self-sustained microcircuit. We used a population of 10 regular-spiking neurons as readouts, connected to all neurons of a self-sustained microcircuit containing ~600 Izhikevich type resonator neurons [5]. Synapses of each readout are excitatory, with long NMDA-like exponential decay of the synaptic conductance (30 ms). Synaptic strength for each individual synapse is computed as a sum of a fixed baseline (e.g. 0.7) and a smaller random fluctuation (e.g. between 0 and 0.2) drawn from a uniform distribution. The synaptic trees of the readouts are balanced: The total synaptic strengths are similar for each readout neuron. As a result, readouts fire with very similar rates, engaging into repeated temporal firing patterns, such that information can be recovered in the relative phase of their spike times (Fig 1). For each firing pattern, a phase vector is computed by calculating, for each readout, the time difference between its firing and

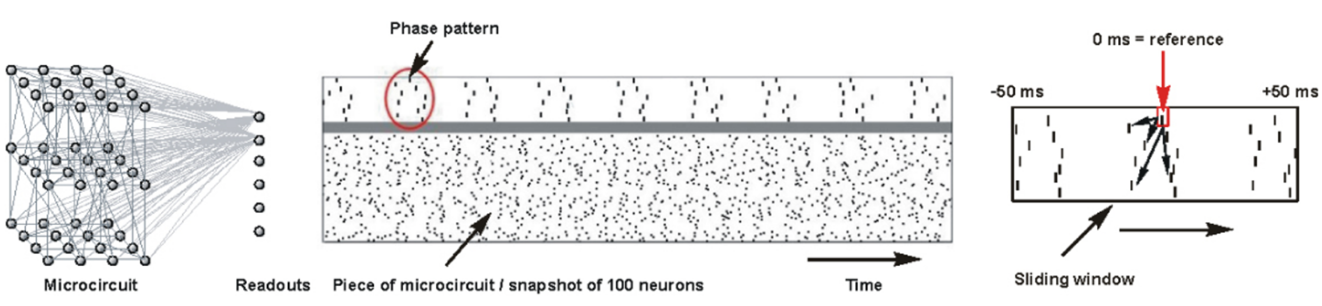

Figure 1
Readouts from a microcircuit.

that of the first readout (Fig. 1). As a result, a 10 dimensional vector of relative phases is computed, for each moment in time where a phase pattern occurs in the readout population. We show that the succession of these phase patterns can be used to characterize, in a compressed fashion, the dynamics of the whole microcircuit, including limit cycles.

Acknowledgements

Research was supported by two grants of the Romanian Government: RP-5/2007, Contract 1/1.10.2007 and ID_48/2007, Contract Nr. 204/1.10.2007 financed by MECT/UEFISCSU and a Max Planck-Coneural Partner Group.

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