BMC Neuroscience

BioMed Central

Poster presentation

Open Access

Self-sustaining non-repetitive activity in a large scale neuronal-level model of the hippocampal circuit

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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):P62 doi:10.1186/1471-2202-9-S1-P62

This abstract is available from: http://www.biomedcentral.com/1471-2202/9/S1/P62

Introduction

The mammalian hippocampus is involved in spatial representation and memory storage and retrieval, and much research is ongoing to elucidate the cellular and system-level mechanisms underlying these cognitive tasks. Modeling may be useful to link network-level activity patterns to the relevant features of hippocampal anatomy and electrophysiology. Investigating the effects of circuit connectivity requires simulations of a number of neurons close to real scale.

Methods

Here, we construct a model of the hippocampus with 16 distinct neuronal classes [1,2] (including both local and projection cells) and 200,000 individual McCulloch-Pitts neurons[3]. The number of neurons in each class and their interconnectivity are drawn from rat anatomy [1].

Results and Discussion

When the model is run with a simple variation of the McCulloch-Pitts formalism, self-sustaining non-repetitive activity patterns consistently emerge (see Fig 1). Specific firing threshold values are narrowly constrained for each cell class upon multiple runs with different stochastic wiring and initial conditions, yet these values do not directly affect network stability. Analysis of the model at different network sizes demonstrates that a scale reduction of one order of magnitude drastically alters network dynamics, including the variability of the output range, the distribution of firing frequencies, and the duration of self-sustained activity. Moreover, comparing the model to a control condition with an equivalent number of (excitatory/inhibitory balanced) synapses, but removing all class-specific information (i.e. collapsing the network to homogeneous random connectivity) has surprisingly sim-

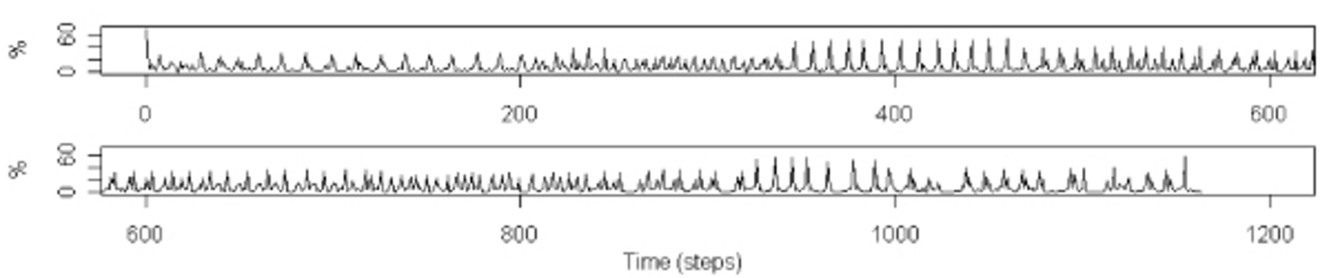

Figure 1
Sample total activity in % of total neurons for 200 k neuron network with realistic connectivity. Network receives input only at t = 0 when 70% of its neurons are randomly activated.

ilar effects to downsizing the total number of neurons. The reduced-scale model is also compared directly with integrate-and-fire simulations, which capture considerably more physiological detail at the single-cell level, but still fail to reproduce the full behavioral complexity of the large-scale model. Thus network size, cell class diversity, and connectivity details may all be critical to generate self-sustained non-repetitive activity patterns.

Acknowledgements

This work was supported by NIH grants NS39600, AG025633 and NSF grant SGER 0747864.

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