BMC Neuroscience

BioMed Central

Poster presentation

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A fast-computational spiking neuron model adaptable to any cortical neuron

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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):P22 doi:10.1186/1471-2202-10-S1-P22

This abstract is available from: http://www.biomedcentral.com/1471-2202/10/S1/P22

There has been a growing need for simulating a massively connected network of neurons, to an extent of a column, a cortical area and ultimately the entire brain. The information coding in the brain is critically attributed to the manner in which individual neurons integrate incoming signals and fire the action potentials called spikes to send signal to others. A neuronal model should be able to accurately reproduce a variety of responses of cortical neurons. The Hodgkin-Huxley model has been the standard, and continually revised by including ionic channels to account for some typical neuronal firing phenomena qualitatively and it became possible to use simulation platforms, such as NEURON and GENESIS. However, it turned out that these models are weak in quantitative reproduction as well as prediction of new phenomena. In addition, they require the high computational cost, which hinders performing the simulation of a massively interconnected network.

Here we propose a fast-computational spiking neuron model that is capable of accurately predicting a rich variety of spike responses to not only the fluctuating current inputs, but also the conductance inputs, for which the previous models fail to predict. The key features of this new model are a non-resetting leaky integrator and an adaptive threshold equipped with fast (10 ms) and slow (200 ms) time constants. The model can easily be tailored to any cortical neuron, including regular spiking (RS), intrinsic bursting (IB), and fast spiking (FS) neurons, by simply adjusting three parameters. It is notable that the model can express in the three dimensional parameter space a continuous variety of firing characteristics of biological neurons rather than just those identified in the conventional discrete categorization. Both the high flexibility and the low computational cost would help to model the real brain faithfully and examine how network properties may be influenced by the distributed characteristics of component neurons.

Acknowledgements

This study is supported in part by Grants-in-Aid for Scientific Research to SS (No.20300083, 20020012), and to YT (No.20700280) from the MEXT Japan. RK is supported by the Research Fellowship of the Japan Society for the Promotion of Science for Young Scientists. We are very grateful to T. Fukai for helpful comments.