BMC Neuroscience

BioMed Central

Poster presentation

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Comparison of methods to calculate exact spike times in integrate-and-fire neurons with exponential currents

Alexander Hanuschkin*[1], Susanne Kunkel*[1], Moritz Helias[1], Abigail Morrison[2] and Markus Diesmann[1,2]

Address: [1]Bernstein Center for Computational Neuroscience, Albert-Ludwigs-University, 79104 Freiburg, Germany and [2]Computational Neuroscience Group, RIKEN Brain Science Institute, Wako City, Saitama 351-0198, Japan

Email: Alexander Hanuschkin* - hanuschkin@bccn.uni-freiburg.de; Susanne Kunkel* - kunkel@bccn.uni-freiburg.de

* Corresponding authors

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):P131 doi:10.1186/1471-2202-9-S1-P131

This abstract is available from: http://www.biomedcentral.com/1471-2202/9/S1/P131

Discrete-time neuronal network simulation strategies typically constrain spike times to a grid determined by the computational step size. This approach can have the effect of introducing artificial synchrony [1]. However, time-continuous approaches can be computationally demanding, both with respect to calculating future spike times and to event management, particularly for large network sizes. To address this problem, Morrison et al. [2] presented a general method of handling off-grid spiking in combination with exact subthreshold integration in discrete time driven simulations [3,4]. Within each time step an event-driven environment is emulated to process incoming spikes, whereas the timing of outgoing spikes is based on interpolation. Therefore, the computation step size is a decisive factor for both integration error and simulation time.

An alternative approach for calculating the exact spike times of integrate-and-fire neurons with exponential currents was recently published by Brette [5]. The problem of accurate detection of the first threshold crossing of the membrane potential is converted into finding the largest root of a polynomial. Common numerical means like Descartes' rule and Sturm's theorem are applicable. Although this approach was developed in the context of event-driven simulations, we take advantage of its ability to predict future threshold crossings in the time-driven environment of NEST [3]. We compare the accuracy of the two approaches in single-neuron simulations and the efficiency in a balanced random network of 10,000 neurons [6]. We show that the network simulation time when using the polynomial method depends only weakly on the computational step size, and the single neuron integration error is independent of it. Although the polynomial method attains the maximum precision expected from double numerics for all input rates and computation step sizes, the interpolation method is more efficient for input rates above a critical value. For applications where a lesser degree of precision is acceptable, the interpolation method is more efficient for all input rates.

Acknowledgements

Partially funded by DIP F1.2, BMBF Grant 01GQ0420 to the Bernstein Center for Computational Neuroscience Freiburg, and EU Grant 15879 (FACETS).

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