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14. ABSTRACT
A new promising way to significantly improve computational efficiency of neurobiological network simulations is to design a neuronal model in the form of difference equations that generates neuronal states in discrete moments of time. In this approach, time step can be made comparable with the duration of action potential (a spike) and capture correctly dynamics of the intrinsic and input-responsive firing patterns. We propose to use modern DSP ideas to develop new efficient approaches to the design of such discrete-time models for studies of large-scale neuronal network activity.

15. SUBJECT TERMS
Map-based neuronal model, Discrete time spiking dynamics, Synapses, Neurons, Neurobiological Networks

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Performance/Technical Monthly Report

Nonlinear Maps for Design of Discrete-Time Models of Neuronal Network Dynamics

March 31, 2016

Sponsored by

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Award No. N00014-16-1-2252

Awarded to: UCSD
Principal Investigator: Dr. Nikolai Rulkov
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Performance/Technical Monthly Report

During this one-month period, PI continued search for a postdoc candidate and work on the Task 1 of the research plan.

Postdoc. The research plan assumes part-time involvement (50%) of a postdoc, which have experience with neuronal network simulations using standard conductance-based models and analysis of nonlinear dynamics so he/she can clearly understand requirements for the map-based model design. The research of network dynamics utilizing the conductance-based models will be done in collaboration Dr. M. Bazhenov who will support the remaining 50% of postdoc time. Our project will be focused on the design of corresponding map-based models. We have received six applications and work on formation of short list and requests of recommendation letters.

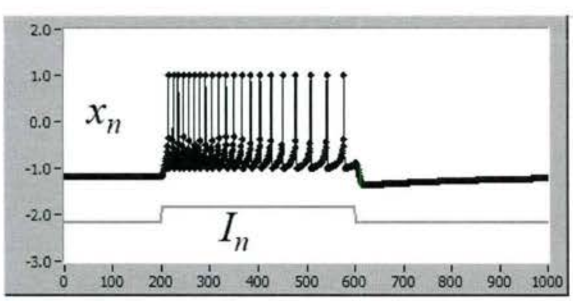
Task 1. Continued analysis of potential improvements of computational efficiency and usability of equation for x_n capturing fast dynamics of Na+ and K+ pumps responsible for generation of action potential (spike). The 2-D map is of the form

$$x_{n+1} = f_\alpha(x_n, y_n + \beta_n),$$
$$y_{n+1} = y_n - \mu(x_n + 1) + \mu\sigma_n$$

where x_n is a dynamical variable and function $f_\alpha(..)$ is a piecewise nonlinear function written a new form as

$$f_\alpha(x_n, y_n) = \begin{cases} \dfrac{\alpha}{1 - x_n} + y_n, & x_n \le -0.5, \\ 1, & -0.5 < x_n < 1, \\ -1, & x_n \ge 1\,. \end{cases}$$

The analysis of two-dimensional map capturing slow variable y_n (modeling slow adaptation current) have shown that the proposed change of nonlinearity shape did not affect qualitative dynamics of the system and has a minor effect on the parameter shift for input current. It also provides a consistent shape of individual spikes. See Figs. 1 and 2.



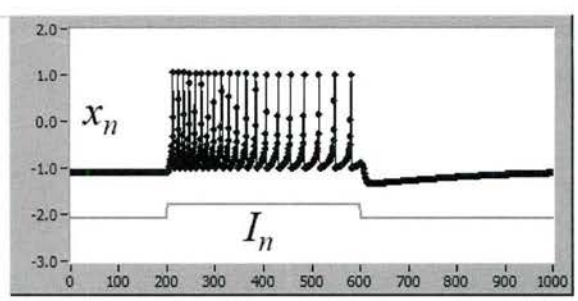


Figure 1 Waveforms of decelerated spiking activity in response to the rectangular depolarizing pulse I_n. The case of new nonlinear function (left panel) and the original one (right panel). Note that amplitude of the input current has to be increased to match the spiking rate in the both cases.

The consistency of models from the viewpoint of qualitative behavior is illustrated in the phase portraits plotted for the corresponding waveforms shown in Fig. 1. The iteration samples of the map in waveforms and phase portraits are shown with the black filled circles.

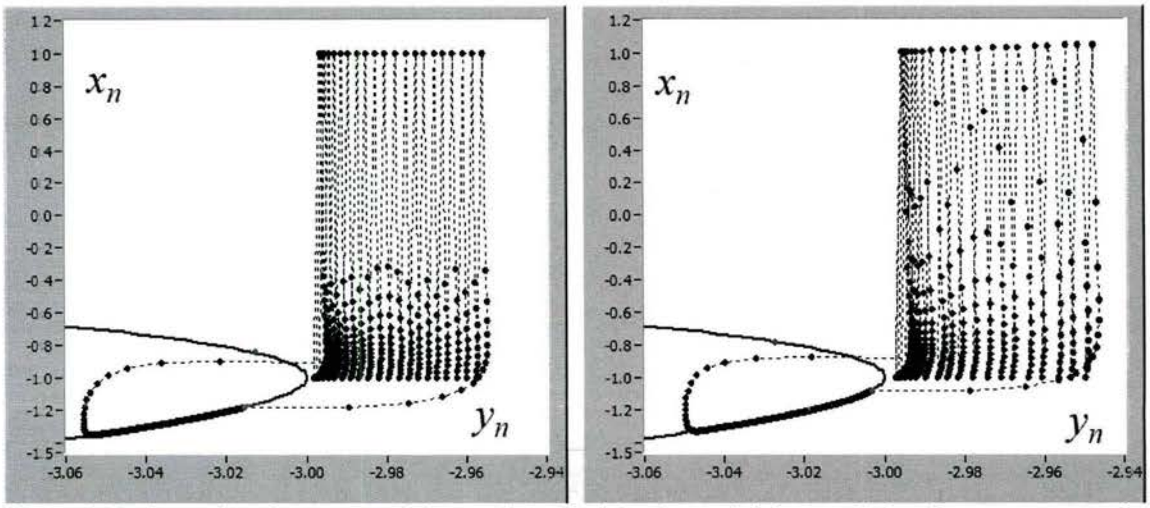


Figure 2 Trajectories of new map (left panel) and original map (right panel) for the responses to the rectangular pulse of current.