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Nikolai F. Rulkov received the M.S. and Ph.D. degrees, both in physics and mathematics, from the University of Nizhny Novgorod, Nizhny Novgorod, Russia, in 1983 and 1991, respectively. In 1983, he joined the Radio Physics Department of the University of Nizhny Novgorod, where he worked as a Researcher until 1993. He has been with the Institute for Nonlinear Science, University of California, San Diego, from 1993 through the present. His research interests are in the areas of bifurcation theory, nonlinear phenomena, theory of synchronization, chaos and applications of nonlinear dynamics in science and engineering. Starting form 2004 he is with the Information Systems Labs, San Diego, where he works on a wide spectrum of nonlinear problems in the areas of signal processing, biologically inspired control systems, biomimetic robotics and modeling of neurobiological networks.

Keynote: Modeling of oscillations and synchronization phenomena in large-scale neuronal networks

Intrinsic neuronal and synaptic properties control the responses of networks of thousands of neurons by creating spatio-temporal patterns of activities, which are used for muscle control, sensory processing, memory formation and other cognitive tasks. The modeling of such systems requires single neuron models capable of displaying both realistic response properties and computational efficiency.

We use difference equations (map-based models) to simulate the individual dynamics of neurons and synapses. Such phenomenological models can be designed to capture the main intrinsic dynamical properties of specific type of neurons. This approach allows fast simulation and efficient parametric analysis of networks containing hundreds of thousands of neurons of different cell types using a conventional workstation.

This paper presents results of the modeling of spatio-temporal behavior of large-scale models of a cortical network, formation and synchronization of fast oscillations and restructuring of synchronization patterns as a function of parameters of synaptic interconnections and the intrinsic states of the neurons. The paper also discusses the application of map-based models in the design of a real-time CPG network model that controls undulatory locomotion of a biomimetic lamprey-based robot.