Conductance-Based Refractory Density Approach and Its Application to Biophysically Detailed Modeling of Cortical Neuronal Populations

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The conductance-based refractory density (CBRD) approach has been developed in [1,2] for a population of adaptive and non-adaptive neurons, where population implies an infinite number of similar neurons receiving a common input with an implicit noise term that is distinct for each neuron. Neurons of a single population constitute a 1-d continuum in the phase space of the time elapsed since their last spikes, that parameterizes the Hodgkin-Huxley-like equations. Evolution of the neuronal density determines the population firing rate dynamics. The key element of the CBRD approach is a hazard function of neuronal spiking probability, which has been derived in [1,2] and is universal for a wide range of basic neuron models. Basing on CBRD, a complex model of a cortical network has been constructed. The neuronal populations on each cortical layer constitute a continuum in 2-d cortical space. The model is compared with known experimental intracellular and optical recordings done in primary visual cortex in vivo with visual stimuli and in vitro with electric stimulation. For mathematical analysis of the effects of cortical activity such as orientation selectivity, the model is mapped to a set of reduced models. The reductions include mapping to an orientation ring of Fokker-Planck equation-based populations and arrives to the classical firing-rate ring model. The results demonstrate that the constructed hierarchy of models can serve as a useful instrument for analysis and fitting mathematical models to experimental data.

[1] Chizhov AV, Graham LJ: Efficient evaluation of neuron populations receiving colored-noise current based on a refractory density method. *Phys Rev E* 2008, 77: 011910.
[2] Chizhov AV, Graham LJ: Population model of hippocampal pyramidal neurons, linking a refractory density approach to conductance-based neurons. *Phys Rev E* 2007, 75: 011924.