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COMPUTING MEAN FIRING RATES OF ENSEMBLES OF REALISTIC NEURONS.

A.G. Siapas, E. Todorov and D.C. Somers* MIT, E25-147A, Cambridge, MA 02139

Realistic models of neural circuits typically are too complex to be analyzed exactly and have too many parameters to be fully explored in computer simulations. Thus, methods for characterizing the collective dynamics of such systems are needed. Here, we develop a technique for approximating the mean firing rate of highly interconnected, homogeneous groups of neurons that receive Poisson input. This technique applies to single compartment neurons with realistic synaptic and intrinsic currents. Assuming only that conductances equal their averages, we derive a nonlinear equation relating the mean firing rate to the cellular and network parameters. This approach extends to the analysis of multiple neuronal groups, for which a system of equations is derived.

We compare our analytical results to simulations and observe a close fit for most parameter settings. In a system with 2 excitatory and 2 inhibitory groups with a total of 250 cells, the approximation error is less than 2%. The accuracy of mean firing rate calculations depends on proper estimation of the afterhyperpolarization reset potential. Unlike most related techniques which assume a constant reset potential, our method computes this potential as a function of input. The current form of our analysis is inaccurate only near threshold input levels where conductance variability significantly affects firing rate. We are presently extending the approximation technique to take this variability into account.

Computing the mean firing rate with our technique reduces to solving a system of nonlinear equations, which is much faster than full simulation. In addition to guiding the search for suitable model parameters, our technique also can yield analytical insights not available through simulations. For example, we can estimate the sensitivity of the mean firing rates to changes in model parameters. In addition, the system of equations can be solved directly to find parameter settings that achieve a desired set of mean firing rates.

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