15th INTERNATIONAL CONFERENCE

Dynamical Systems — Theory and Applications

December 2-5, 2019. Lodz, POLAND.

paper id: LIF120

Optimal parameter estimation for single-neuron models

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Abstract: Neurons constitute complex nonlinear systems whose unobserved ion channel dynamics and parameters may be estimated from electrophysiological time series. Precise estimation of these quantities allows for accurate prediction of the response of the neuron to a novel stimulus. Here, we utilize nonlinear interior point optimization to constrain ionic conductance neuron models by assimilating membrane voltage data of rat hippocampal cells. While the desired solution to this inverse problem corresponds to the global minimum of an objective function, the model dynamics can give rise to undesirable solutions in the search space which attract gradient descent methods. We show that the addition of artificial noise to time series can aid convergence to the global minimum by destabilizing these local minima. We further enhance the efficiency of our assimilation approach by implementing an adaptive time-step method which enables irregular sampling of the time series data. This allows for higher frequency sampling during neuron depolarisation, where the ion channel dynamics are most prevalent, optimizing the transfer of information from the biological neuron to our model. We validate the estimation of neuron parameters by successfully predicting the response of the hippocampal cells to a variety of novel current stimuli.

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