Effective Stimuli for Constructing Reliable Neuron Models

By segev
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By segev August 19, 2011


Abstract:

Neurons perform complicated non-linear transformations on their input before producing their output - a train of action potentials. This input-output transformation is shaped by the specific composition of ion channels, out of the many possible types, that are embedded in the neuron's membrane. Experimentally, characterizing this transformation relies on injecting different stimuli to the neuron while recording its output; but which of the many possible stimuli should one apply? This combined experimental and theoretical study provides a general theoretical framework for answering this question, examining how different stimuli constrain the space of faithful conductance-based models of the studied neuron. We show that combinations of intracellular step and ramp currents enable the construction of models that both replicate the cell's response and generalize very well to novel stimuli e.g., to noisy stimuli mimicking synaptic activity. We experimentally verified our theoretical predictions on several cortical neuron types. This work presents a novel method for reliably linking the microscopic membrane ion channels to the macroscopic electrical behavior of neurons. It provides a much-needed rationale for selecting a particular stimulus set for studying the input-output properties of neurons and paves the way for standardization of experimental protocols along with construction of reliable neuron models.

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