State-space methods for inferring synaptic inputs and weights

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Advances in intracellular recording and imaging methods have opened the door to increasingly detailed investigations of synaptic computations *in vitro* and *in vivo*. In this work we introduce several new methods based on "state-space" statistical methods for efficiently extracting meaningful biophysical information from postsynaptic voltage data.

First, we discuss methods for optimally inferring the synaptic inputs to an electrotonically compact neuron, given intracellular voltage-clamp or current-clamp recordings from the postsynaptic cell. These methods are based on sequential Monte Carlo techniques ("particle filtering"). We demonstrate on model data that these methods can accurately recover the time course of excitatory and inhibitory synaptic inputs on a single trial; no averaging over multiple trials is necessary. Once these synaptic input time courses are recovered, it becomes possible to fit (via tractable convex optimization techniques) simple models describing the relationship between the sensory stimulus and the observed synaptic input. We develop an expectation-maximization (EM) algorithm that consists of alternating iterations between these synaptic recovery and model estimation steps. These proposed methods have direct and immediate applications to understanding the balance between excitation and inhibition in sensory processing *in vivo*.

Second, we describe efficient methods for mapping the location and strength of a synaptic input on a dendritic tree, given the presynaptic spike times and (possibly noisy and incomplete) observations of the voltage on the postsynaptic dendrite (available, e.g., via voltage-sensitive imaging techniques). The proposed techniques in this case have the potential to significantly complement recently introduced methods for computational neuroanatomy (c.f. Nikolenko et al, Nature Methods 2007; Briggman and Denk, Curr. Opin. Neurobio. 2007).

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