

# A novel sequential Markov chain Monte Carlo approach to robust synaptic deconvolution

Michael Vidne<sup>1,\*</sup>, Liam Paninski<sup>1</sup>

<sup>1</sup> Columbia University, New York, USA

\* mv333@columbia.edu

Sequential Monte Carlo (“particle filtering”) methods have been proposed to solve a number of different problems in statistical neuroscience, including: decoding of behavioral information from spiking responses in hippocampus or motor cortex; deconvolution of calcium fluorescence data into estimates of underlying spiking activity; inference of presynaptic activity given postsynaptic voltage data; and smoothing of noisy voltage fluorescence observations. The major strength of this method is its flexibility: the approach can be applied in principle in arbitrary nonlinear, non-Gaussian state space models, unlike simpler methods of time series analysis such as the Kalman filter. Thus particle filtering may be considered a key technique in neural data analysis, and will become more prevalent in the future as more large, complex data sets become available.

However, particle filters suffer from a major problem: they are based on importance sampling, which is known to fail in several important cases. For example, particle filters are very non-robust with respect to outliers, incorrect parameter settings, or modeling assumptions, and do not handle high-dimensional or very high-SNR observations properly at all.

Here we develop a more general approach to the state-space filtering problem. Our method solves the same recursive set of Markovian filter equations as does the particle filter, but we replace all importance sampling steps with a more general Markov chain Monte Carlo (MCMC) step. For certain models, this MCMC step can be implemented very efficiently, and in these cases the resulting sequential MCMC filter essentially solves the robustness problems of the particle filter, while still retaining the online, recursive, computationally-efficient nature of the filter.

We demonstrate applications of this new sequential MCMC filter to the problem of estimating presynaptic activity given traces of intracellular postsynaptic voltage data, and discuss the potential for broader applications in the other neural contexts discussed above.

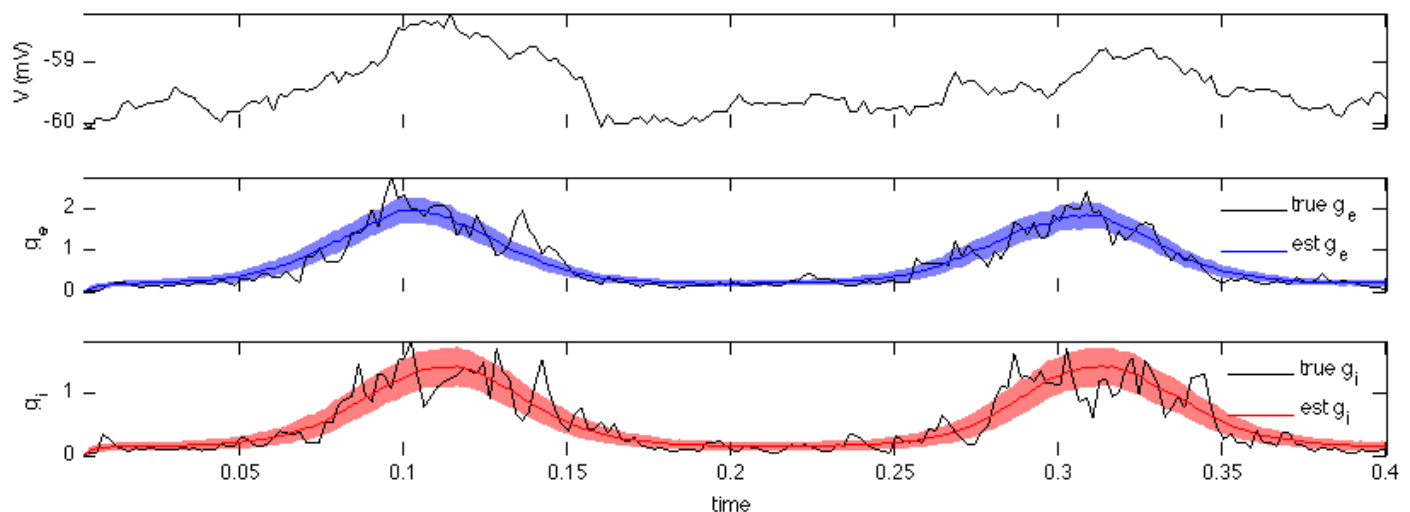


Fig. 1: Estimating synaptic inputs given a single voltage trace. Top: Observed artificial voltage data. Middle: True (black) and inferred (blue) excitatory conductance. Bottom: True (black) and inferred (red) inhibitory conductance.