A state space model for bursting neurons

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Bursting is a complex behavior observed in neural spike dynamics that is characterized by a cluster of rapid successive spikes followed by a longer period of quiescence. It is well known that some classical neuron models such as the FitzHugh-Nagumo model [1] and the Morris-Lecar model [2] among others, cannot produce this behavior [3]. The duality of this behavior requires a model that can account for dual time scales to handle a fast and slow subsystem such as the Izhikevich model, [3]. However, while the Izhikevich model is capable of producing bursting behavior in simulations, it is cumbersome to fit model parameters to observed data. In contrast, a statistical model class such as the Generalized Linear Model (GLM) is capable of capturing the features of a variety of spike train behaviors as shown in [6]. The flexibility of the GLM has been illustrated previously by the broad applications of this model class (see [4, 5]). However, the interpretation of a GLM is not always intuitive and in [6] this was indeed the case for a bursting neuron. Although the model was capable of capturing bursting, evident from the estimated intensity, the model itself had a more complex interpretation. In this paper, we show how the GLM can be extended to a State Space GLM (SSGLM) to explicitly account for the dual behavior observed for a bursting neuron. We demonstrate how the model can be fitted to an observed spike train by utilizing a marginalized particle filter to simultaneously decode the state of the neuron (bursting/resting) and estimate history dependent kernels that modulate the baseline firing rate, dependent on the behavior. This leads to a simple statistical model that captures the bursting behavior very well when evaluated by a goodness-of-fit analysis based on the Kolmogorov-Smirnov statistic as in [6].

References