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A comparison of spike time prediction and receptive field mapping with point process generalized linear models, Wiener-Voltera kernels, and spike-triggered averaging methods

Gordon Pipa*[1,2,3], Sergio Neuenschwander[2], Bruss Lima[2], Zhe Chen[1] and Emery N Brown[1]

Address: [1]Department of Anesthesia, Massachusetts General Hospital & Department of Brain and Cognitive Sciences, MIT, MA, USA, [2]Max-Planck Institute for Brain Research, Frankfurt, Germany and [3]Frankfurt Institute for Advanced Studies, Frankfurt, Germany

Email: Gordon Pipa* - mail@g-pipa.de

* Corresponding author

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Characterizing neuronal encoding is essential for understanding information processing in the brain. Three methods are commonly used to characterize the relationship between neural spiking activity and the features of putative stimuli. These methods include: Wiener-Volterra kernel methods (WVK), the spike-triggered average (STA), and more recently, the point process generalized linear model (GLM). We compared the performance of these three approaches in estimating receptive field properties and orientation tuning of 251 V1 neurons recorded from 2 monkeys during a fixation period in response to a moving bar. The GLM consisted of two formulations of the conditional intensity function for a point process characterization of the spiking activity: one with a stimulus only component and one with the stimulus and spike history. We fit the GLMs by maximum likelihood using GLMfit in Matlab. Goodness-of-fit was assessed using cross-validation with Kolmogorov-Smirnov (KS) tests based on the time-rescaling theorem to evaluate the accuracy with which each model predicts the spiking activity of individual neurons and for each movement direction (4016 models in total, for 251 neurons and 16 different directions).

The GLMs that considered spike history of up to 35 ms, accurately predicted neuronal spiking activity (95% confidence intervals for KS test) with a performance of 97.0% (3895/4016) for the training data, and 96.5% (3876/4016) for the test data. If spike history was not considered, performance dropped to 73,1% in the training and 71.3% in the testing data. In contrast, the WVF and the STA predicted spiking accurately for 24.2% and 44.5% of the test data examples respectively. The receptive field size estimates obtained from the GLM (with and without history), WVF and STA were comparable. Relative to the GLM orientation tuning was underestimated on average by a factor of 0.45 by the WVF and the STA. The main reason for using the STA and WVF approaches is their apparent simplicity. However, our analyses suggest that more accurate spike prediction as well as more credible estimates of receptive field size and orientation tuning can be computed easily using GLMs implemented in Matlab with standard functions such as GLMfit.

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