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Poster presentation

Probabilistic models and inference algorithms for neuronal decoding of UP and DOWN states

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Background

In the neuroscience literature, periods during which populations of neurons are either simultaneously depolarized or hyperpolarized are often classified as "UP" and "DOWN" states, respectively [1]. No particular attention has been devoted to accurately characterize the transition between these two states within a statistical framework [2]. We propose two (semi-) Markov probabilistic models, in both discrete- and continuous-time domains, aiming to infer a discrete two-state (UP vs. DOWN) latent process based on multi-unit spike train observations. The simultaneously recorded spike trains, treated as stochastic point processes, are modulated by the discrete hidden state and the firing history of ensemble neurons. To jointly estimate the hidden state and the unknown parameters of the probabilistic models, we develop statistical inference algorithms within the maximum likelihood estimation framework.

Data

Simultaneous recordings of electroencephalograph (EEG) and multi-unit spike trains are collected from the primary somatosensory cortex and hippocampus of behaving rats during (RUN) behavior and sleep. For the purpose of the UP/DOWN state analysis, only data from slow wave sleep (SWS) sessions are analyzed.

Methods

The UP/DOWN states are treated as a latent two-state Markov or semi-Markov process. The multi-unit spike trains are modeled as state-dependent Markov-modulated Cox processes. Given the observed spike trains, the missing data estimation problem can be tackled efficiently by maximum likelihood estimation. We develop a discrete-time two-state hidden Markov model (HMM) and the associated expectation maximization (EM) algorithm [3] for estimating the UP and DOWN states. Using estimates obtained from this analysis, we further develop a continuous-time semi-Markov model for inferring the sojourn time probability distributions that characterize the transition between the two states. This inference is tackled by a Monte Carlo EM (MCEM) algorithm, including implementation of a reversible jump Markov chain Monte Carlo (RJMCMC) sampling procedure [4].

Discussion

The discrete-time HMM provides a fast and reasonable estimate of the hidden states; however, it is prone to converge to a local solution that is far away from the optimum estimate. The continuous-time semi-Markov model uses the RJMCMC to incrementally estimate where and how many state transitions occur during the inference procedure, which yields more reliable estimation results (as confirmed by analysis of synthetic data). Using different methods, we compared the EEG-triggered average based on the estimated UP-state start and end time.

Results suggested that the EEG-triggered (K-complex) average from the continuous-time model produced a more accurate onset of the UP state.

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