Detection of non-stationary higher-order spike correlation
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Abstract

Classical studies in neurophysiology are based on the idea that stimulus information is encoded in the firing rates of single neurons. Alternatively, precise spike coincidence is discussed as an indication of coordinated network activity and may be expressed by higher-order correlations between the simultaneous spiking activities of neurons. As shown in earlier studies [1-3], correlation between neurons may modulate in time in relation to the behavioral demand. Here, we simultaneously estimate the time-dependent rate and correlation underlying multiple-neuron spiking activities by means of state-space analysis [2,3]. We model discretized parallel spike trains by a conditionally independent multivariate Bernoulli process using a log-linear link function [4-8]. A nonlinear recursive filtering formula is derived from a hierarchical log-linear model to avoid over-fitting. Application of the method to simultaneously recorded neuronal spike sequences is expected to uncover dynamic cooperative activities of neurons in relation to behavior.

Log-linear model

The log-linear model provides a well-defined measure of higher-order correlation based on informed parameterization [18].

State-space Analysis

A state-space framework allows regression of a time-dependent system to spike data. State-space model of parallel spike trains with an optimized covariance matrix and autoregressive parameters.

Model Selection

To validate that the inclusion of the triplet correlation improves the goodness-of-fit, we computed ABIC for the hierarchical state-space models. The Akaike Bayesian Information criterion (ABIC) is computed as

\[ ABIC = -2 \log \hat{L} + p \log n \]

where \( \hat{L} \) is the lower bound of evidence (Q-function). Note that the marginal likelihood takes account of the parameter uncertainty only (approximation is known as BIC).

State-space method applied to a sub-model is useful for large-scale data analysis. Incorporation of the user signals into the model may be useful for detecting tresequences related to behavior.

Introduction

To study cooperative neural network activity, we develop state-space method to estimate the time-dependent rate and correlation underlying multiple-neuron spike trains. Hypothetical Dynamic Cooperative Activity of Neurons

Modeling external signals’ effects

We developed a method for estimating time-varying rate and higher-order correlation structures in parallel spike sequences. To our knowledge, it is the first method that can resolve the time-dependent spike rates and well-defined spike correlation measures simultaneously. The method is thus applicable to simultaneously recorded neuronal spike sequences recorded from an awake behaving animal. Such an application is expected to provide us with new insights into dynamic assembly activities, their compositions, and behavioral relevance.

What is the Higher Order Correlation?

It has been shown that spike correlation can be modulated in time [9] and it occurs at behaviorally relevant instances [10].

What is the Higher Order Correlation?

It has been shown that spike correlation with a precision of 1 is mediated in time and 2 occurs at behaviorally relevant instances [11].

Positive higher order correlation (HOC) indicates excess synchrony that can not be explained by the lower order correlations.

References


