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Bayes factor analysis for detection of time-dependent higher-order spike correlations

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Precise spike coordination in the spiking activities of a neuronal population is discussed as an indication of coordinated network activity in form of a cell assembly relevant for information processing. Supportive evidence was provided by the existence of excess spike synchrony occurring dynamically in relation to behavioral context [1-3]. These findings are based on the measured dependence of multiple neurons against the null-hypothesis of full independence. However, neurons jointly involved in assemblies may express higher-order correlations (HOCs) in their spiking activities [4]. By characterizing the spatio-temporal pattern of parallel spikes with the HOCs, one may elucidate assembly activities and possibly their behavioral relevance. To describe the HOCs in parallel spike trains, the log-linear model is an useful model because it provides a well-defined measure of correlation based on information geometry [5]. Former studies on HOCs performed a regression analysis on parallel spike trains using either a full log-linear model [6] or a log-linear model containing up to pairwise interaction only (maximum entropy model) [7]. The existing approaches, however, assume stationarity, a condition that is typically not fulfilled in neuronal spike data from awake behaving animals. Recently, we established a method for estimating the dynamics of HOCs by means of a state-space analysis [8] with a log-linear observation model to trace active assemblies [Abstracts in SAND4, NIPS08 Workshop, and Cosyne09, [9]]. However, presentation of the smoothed posterior estimates only may mislead neurophysiologists to presume the existence of the HOC at the moment when no or weak evidence is available. Furthermore, the method did not provide a statistic to detect an assembly in which cells are jointly connected through multiple correlations. In this contribution, we investigate the method of the Bayesian hypothesis testing to answer which compositions of parallel spikes exhibit the joint HOCs, and if they do, when those HOCs appear. We computed the Bayes factor [10] of temporally local spike observation to gain evidence of positive joint HOCs of a specific set of parallel spike sequences against negative HOCs by using filter and one-step prediction odds. The proposed method may be useful to detect the dynamic assembly activities, their composition and behavioral relevance when applied to simultaneous recordings of neuronal activity of behaving animal.

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