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TITOLO: Assessment of synchrony propagation in massively parallel spike trains

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Abstract

Synchronization of electrical impulses (spikes) within groups of neurons in the cortex has been suggested as a possible mechanism for information processing in the brain, and is supported by a number of experimental studies (see e.g. Riehle A. et al, 1997). Building on this notion, propagation of synchrony across cell groups has been hypothesized as a possible mechanism of information processing and transmission (Abeles M.,1991). In theoretical studies it was shown that biologically plausible neural networks can indeed exhibit propagation of synchronous activity provided suitable feed-forward convergent and divergent connectivity structure between groups of neurons. This model, termed 'synfire chain' (SFC; Abeles, 1991), was shown to enable stable propagation of synchronous spiking activity within a wide range of parameters such as number of neurons per group involved and temporal spread of the spiking activity (Diesmann et al, 1999).

Experimentally, only indirect evidence of synchrony propagation in the cortex has been shown. In small numbers of simultaneously recorded neurons evidence was found for the occurrence of precise spatio-temporal spike patterns (Prut et al, 1998). However, there is no direct evidence yet. One reason is that simultaneous recordings of the activity of large number of neurons are required to observe such specific activity. Only recent advances in electro-physiological techniques to record from hundreds of neurons

in parallel open this perspective. On the other hand, there is a lack of statistical methods suitable for application to massively parallel experimental spike data for detection of such propagating synchronous activity.

Here we address the latter point by proposing a quantitative approach in the framework of a method that was designed for visual detection of repeated occurrences of propagating synchronous activity (Schrader et al, 2008; Gerstein et al, 2012). The method is based on an intersection matrix, in which repeated propagation of synchronous events is visible as diagonal structures composed of high entries. Building on this idea we introduce a mathematical framework to assess the statistical significance of such diagonal structures under the null hypothesis that zero-delay correlations observed in the data are not temporally ordered. The method relies on analytical and Monte Carlo-based estimates of statistical significance. Upon rejection of the null hypothesis, the diagonal structures are classified as significant given the observed correlations. The neuronal composition underlying each structures is then extracted to identify the neurons involved. The method is calibrated by use of stochastic simulations containing temporal sequences of synchronous events. It enables to correctly identify large portions of the embedded sequences together with their neuronal composition in realistic scenarios in terms of e.g., realistic firing rates and sample sizes, thereby yielding low false positive and false negative levels. We discuss future improvements of the method and first possible applications to electrophysiological data.

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