NeuroXidence: A Quick algorithm for finding spike-pattern with jitter in case of multiple Neurons

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Abstract

The assembly hypothesis postulates [1,2] that information processing in the cortex is mediated by groups of neurons by their coordinated spiking activity. In order to test the hypothesis, occurred spike patterns have to be identified first. Thus, NeuroXidence, a quick algorithm for finding spike-pattern with jitter for multiple neurons has been developed. NeuroXidence needs only one run for finding all spike pattern across multiple neurons and takes jitter or latency into account. NeuroXidence keeps the dependencies of sub-patterns caused by a more complex one and does not confuse the results with thousands of sub-patterns belonging to more complex pattern.

keywords: spike synchronization, spike pattern, joint spike events, algorithm, online analysis, jitter, latency

The assembly hypothesis postulates [1,2] that information processing in the cortex is mediated by groups of neurons by their coordinated spiking activity and is supported by a number of experimental studies (e.g. [2,10]). In order to test the hypothesis (e.g. based on statistical significance [4,7,9]), occurred spike-patterns in neuronal recordings have to be identified first. Thus, NeuroXidence, a quick algorithm for finding spike-patterns with jitter in case of multiple neurons will be presented here. Previous algorithms for finding pattern like the Punch-card algorithm [3] or Multiple-shift [6] method have to be applied to the data for each individual pattern. Because the number of patterns to be analysed explodes with increasing number of recorded neurons and with increasing jitter to be taken into account these approaches become impractical under the above mentioned conditions. Thus the event based algorithms NeuroXidence [8] and Colored-spike [5] have been developed. Both algorithms search for joint-spike events across neurons and take jitter into account. The Colored-spike algorithm is fast but acts asymmetrically in time. Therefore the delectability of patterns is highly dependent on the previous spike sequences. In contrast the NeuroXidence algorithm detects all existing patterns, is not dependent on the structure of the spike-train and is comparable in speed.

The NeuroXidence algorithm detects all existing patterns in single run. NeuroXidence does not list sub-patterns of a more complex mother-pattern. Therefore NeuroXidence keeps the dependencies of sub-patterns and the mother-pattern for each observed pattern and does not confuse the results with thousands of additional sub-patterns which can be represented by the mother-pattern.

The aim of the NeuroXidence algorithm is to make online analysis of spike-pattern possible. Therefore the structure of the complete NeuroXidence algorithm is designed to facilitate the implementation on specialized Logic Devices like FPGAs ('Field Programmable Gate Array'). The algorithm avoids time consuming if/else statements and function calls depending on unpredictable states during runtime.

NeuroXidence is based on four major steps. The first step is used to prepare the data for the analysis. Patterns which are overlapping concerning the allowed jitter are separated. Thus, step one produces a data set consisting of the same pattern as the original data set without overlapping pattern concerning the allowed jitter. Step two introduces a second data set, to detect pattern and to drive their order. The third step determines for each pattern the jitter or latency of the participating spikes. A fourth step determines the frequencies of occurred pattern. Because of the event based architecture of the NeuroXidence algorithm the computational effort is mainly affected by the number of spikes (K), number of sample points (t) and the Number of neurons (N) and not by the number of possible patterns (2^{N*J}) which is exploding with the jitter (J) to be considered, as in case of the Punch-card and Multiple-shift method. For the number of computational steps approximately holds: $N*t+3*K*\ln(K)$.

Therefore NeuroXidence makes use of the sparseness of spike-trains and reduces the computational effort dramatically.

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