Multiple independence tests for point processes by permutation methods: a Unitary Events approach based on delayed coincidence count

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The possible time dependence either between cerebral areas or between neurons, and in particular the synchrony phenomenon, has been vastly investigated as a potential element of the neuronal code [1]. Nowadays, it is possible to record simultaneously the occurrence times of action potentials (spikes) of several neurons. Then, one of the first steps is to understand if two simultaneously recorded spike trains modeled by point processes, corresponding to two different neurons, are independent or not.

Several methods have been used to detect such dependence, or synchrony. Among the most popular ones, the Unitary Event (UE) method, due to Grün and collaborators [2], has been largely applied in the last decade. Indeed, this method gives a precise location in time of the dependence periods, and quantifies the degree of dependence by providing p-values for the independence tests. Moreover, substantial upgrades have been developed from the original method. Firstly, in order to overcome the information loss that the binning data pre-processing may involve in some cases, Grün et al. have introduced the notion of Multiple Shift coincidence in [3]. Secondly, the original UE method assumes the point processes to be Poisson (or Bernoulli). Nevertheless, no general model for spike trains is commonly accepted, and therefore, trial shuffling methods have been introduced (see e.g. [4]) in order to assess p-values using bootstrap paradigm, without making any assumption on the underlying point processes distribution. However, these surrogate data methods are based on binned coincidence count, for computational reasons. Thirdly, a recent work of Tuleau-Malot et al. [5] gives a generalization of the MS coincidence count, namely the delayed coincidence count for point processes, and introduces a multiple testing procedure based on a Gaussian approximation of the Unitary Events (MTGAUE). Notably, this new method corrects the multiple testing procedure by taking into account the multiplicity of the tests, and justifies the plug-in principle used in the p-values computation. Yet, it assumes that the point processes are homogeneous Poisson processes. Our aim is thus to propose a new multiple testing procedure, based on delayed coincidence count, not needing any binning pre-processing of the data, and without assuming any model on the underlying point processes.

To do so, we first introduce a single test of independence between two point processes based on the delayed coincidence count of [5] and a permutation approach, which is close in spirit to trial shuffling. It is proved to exactly achieve the desired level, and to be consistent against any reasonable alternative, as illustrated in our simulation study. Then, we introduce the corresponding multiple testing procedure, which satisfies similar properties as existing UE methods, and this with as few assumptions as possible on the underneath distribution. In particular, we compare this new method to the trial-shuffling [4] and the MTGAUE methods [5] from a practical point of view on simulated data. Finally, an application on real data is also provided.

References

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