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Measuring spike train synchrony between neuronal populations

Thomas Kreuz*[1,2], Daniel Chicharro[3] and Ralph G Andrzejak[3]

Address: [1]Institute for Nonlinear Sciences, University of California, San Diego, CA, USA, [2]Institute for Complex Systems, CNR, Sesto Fiorentino, Italy and [3]Department of Information and Communication Technologies, Universitat Pompeu Fabra, Barcelona, Spain

Email: Thomas Kreuz* - tkreuz@ucsd.edu

* Corresponding author

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With the increasing availability of multi-unit recordings the focus of attention starts to shift from bivariate methods towards methods that provide the possibility to study patterns of activity across many neurons. Measures of multi-neuron spike train synchrony are becoming indispensable tools for addressing issues such as network synchronization, spike timing reliability and neuronal coding. However, many multi-neuron synchrony measures are extensions of bivariate measures. Two of the most prominent bivariate approaches are the spike train metrics by Victor-Purpura and van Rossum [1,2]. The former evaluates the cost needed to transform one spike train into the other using only certain elementary steps [1], while the latter measures the Euclidean distance between the two spike trains after convolution of the spikes with an exponential function [2]. Both methods involve one parameter that sets the time scale. In contrast, a more recent bivariate approach, the ISI-distance [3], is time scale independent and self-adaptive. Another essential difference is that the ISI-distance relies on the relative length of interspike intervals (ISI) and not on the timing of spikes. Finally, this method also allows the visualization of the relative firing pattern in a time-resolved manner.

Recently, the Victor-Purpura and the van Rossum distances have been extended to quantify dissimilarities between multi-unit responses [4,5]. To calculate the multi-unit Victor-Purpura metric, simultaneous spikes are labeled by the neuron that fired them, but this label can be changed at an additional cost which is determined by a second parameter. By varying this population parameter the metric is shifted from a "labeled line" (LL) code metric in which the distance is defined as the sum of the distances of the single neurons, to a "summed population" (SP) code metric in which the spike trains are superimposed before the distance is calculated [4]. In the extended van Rossum metric, the spike trains of each population are located in a space of vector fields (with a different unit vector assigned to each neuron). In this case interpolation between the LL and the SP coding is achieved by varying the angle (a second parameter) between unit vectors [5].

Here we present an analogous extension for the ISI-distance [6] that also interpolates between the LL and the SP codes. This multi-neuron ISI-distance inherits all the basic properties of the bivariate ISI-distance described above; in particular, it is also time scale independent and thus, in contrast to the other two multi-neuron metrics, depends on one population parameter only. In this study we compare all three multi-neuron distances using both controlled simulations and real data. We stress the advantages of our extension with respect to visualization, computational cost and applicability to larger numbers of spike trains with higher numbers of spikes.

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