

Possibilities of state space reconstruction from potentials and spike trains

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Abstract

Telling the connectivity of neurons from spike-trains based on correlations is widely used in neuroscience since extracellular multi-electrode array measurements became available, however correlations fail to capture the nonlinear relationships between the elements of a system.

In the last decade new possibilities emerged on the horizon of multivariate time series analysis namely the Transfer Entropy (TE) and Cross Convergence Mapping (CCM), both capable to detect nonlinear coupling of variables.

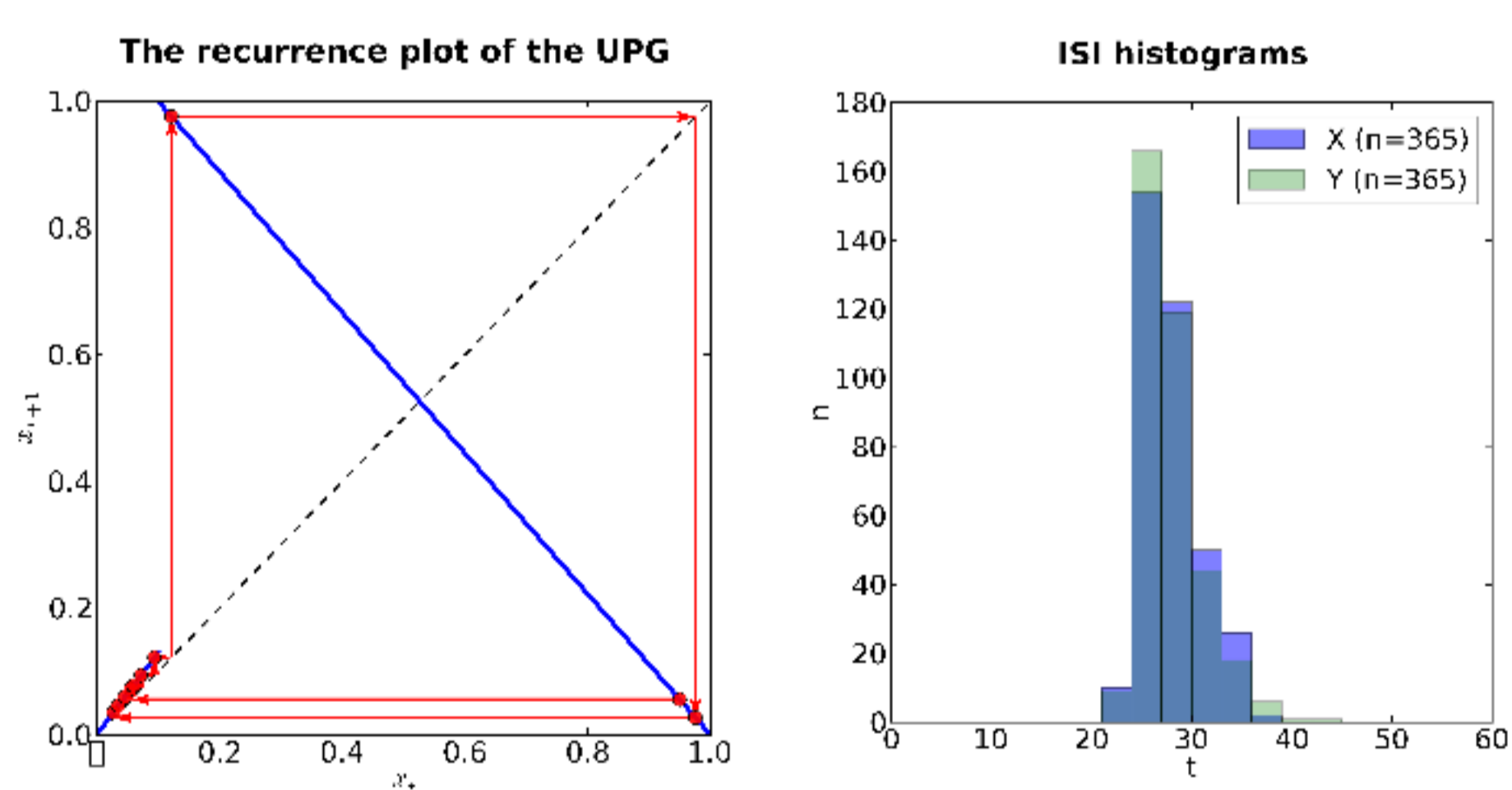
These two methods were successfully used on continuous data, but the application is somewhat missing for point-processes like spike-trains.

A reason for this situation is that a good state-space reconstruction is a vital step in the calculation both of TE and CCM, but the reconstruction of the state-space is not a well defined procedure in the case of spike-trains. In this poster we show the applicability of convergent crossmapping on membranepotentials and sketch up some current attempts of state space reconstruction for spike-trains, to make TE and CCM computable.

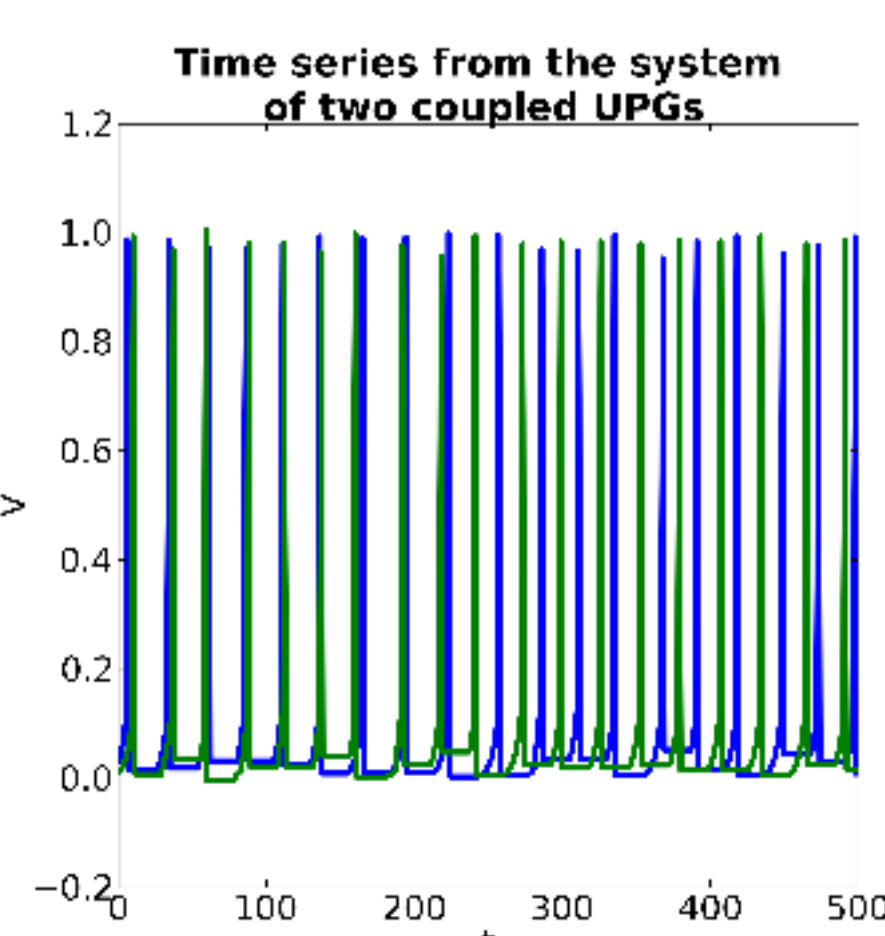
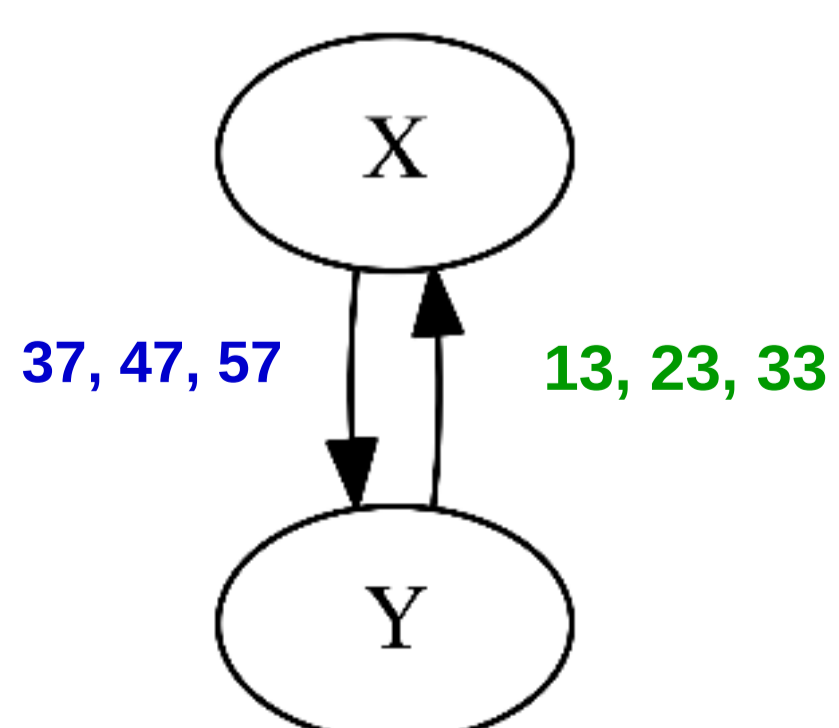
Model system

We used a chaotic oscillator, the Universal Pattern Generator (UPG) to produce time series of two coupled model neurons.

Each time series was generated using a recursive rule, that is the next data point was computed from the previous one according to a simple function. The function (recurrence plot) consists of two linear parts separated by a threshold. At the threshold the function has a discontinuity. A spike is followed by a refractory period.

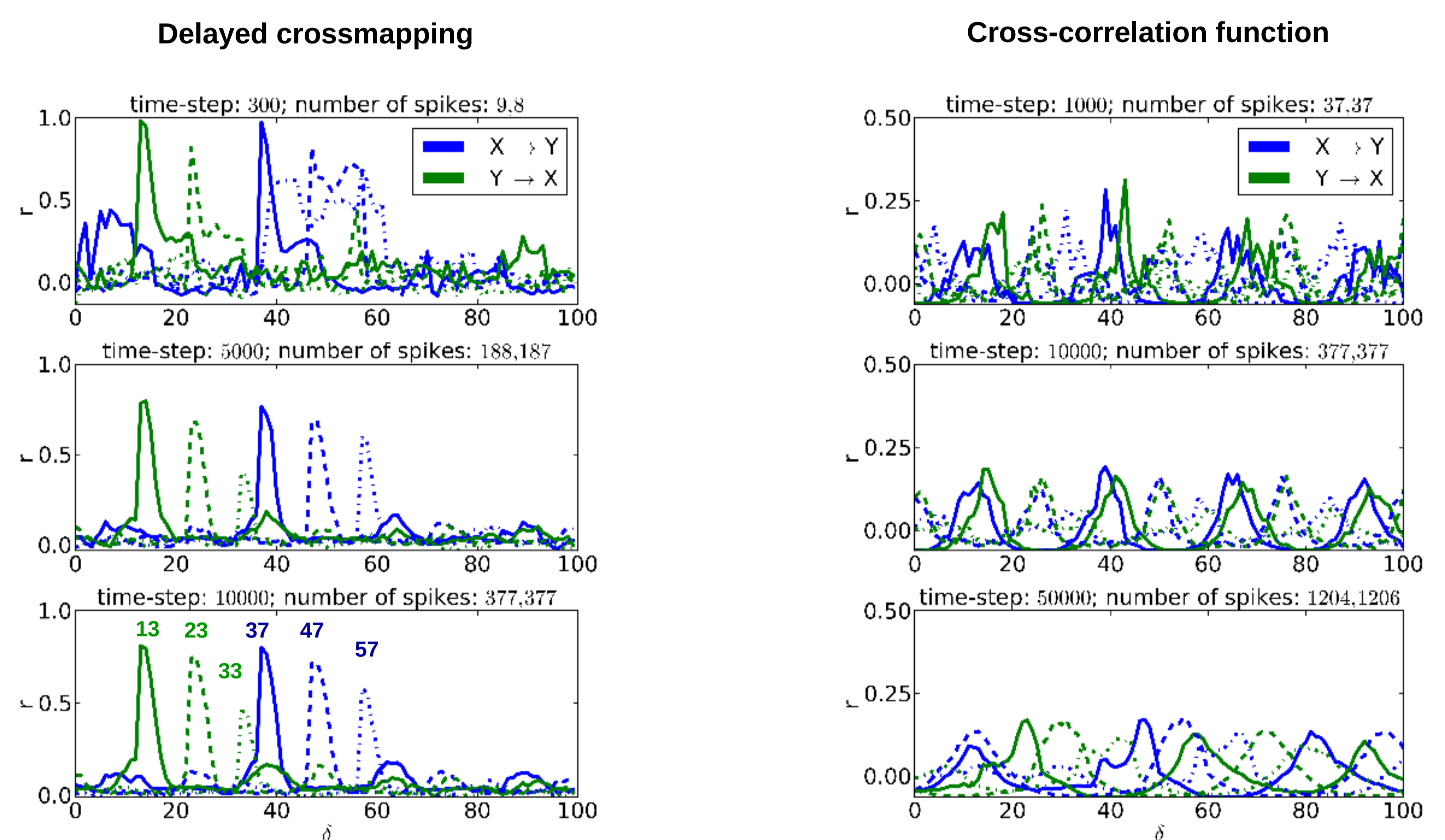


A 'difference of two exponentials'-type kernel was used to model synaptic coupling with different interaction delays. The resulting system produced nice neuronlike spiking activity.



Results - Revealing interaction delays from potentials

We used simple cross-correlation and our modified crossmapping method to reveal interactions and coupling delays between the model neurons. Cross-correlation failed to detect proper interaction delays, crossmapping turned out to be more data efficient and accurate.



Interaction delays from spike trains

We transformed the spike trains into continuous time series using exponential, double-exponential and gaussian kernels. By this process we tried to estimate the state of a neuron from its local spiking pattern. This naive application of kernel method failed to restore the state of the system, therefore crossmapping did not show significant peaks. Cross-correlation worked well with massive amount of data on the simulations and hippocampal cell pairs too. Further investigation needed if convergent crossmapping has applicability in spike train analysis.

