

Visualisation of multi-dimensional Spike Trains

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1. Introduction

Temporal coding has an important role in the debate on information encoding by spike trains. It establishes that information is encoded in the seemingly random patterns of spikes, even in the exact temporal arrangement of inter-spike intervals. Subsequently, one of basic principles that underlie information processing in the brain is the principle of synchronisation of neural activity [1] [2]. Vast quantities of experimental data and mathematical models indicate that the synchronisation principle may be useful in devising various systems of information processing.

The experimental evidence that is currently available requires analysis in order to extract inherent information. Analysis of multidimensional spike trains using standard tools such as cross-correlograms is increasingly complex due to the quantity of data involved. Hence, new methods of dealing with this data are needed. In 1985, one such analysis tool called the “Gravity Transformation” [3][4] was developed at the Multiple Unit Laboratory at Department of Neuroscience in the University of Pennsylvania [5].

It is based on the principle of gravitational interaction of particles where each neuron is represented by a particle and the movement of that particle is described in an n -dimensional space, where n is the number of neurons under investigation. All particles start equidistant from one another and the gravitational force (or charge) exerted by a particle is proportional to the spike train of the corresponding neuron. Each spike contributes charge and this charge decays exponentially over time. Thus, should two or more neurons spike coincidentally, their corresponding particles will have an attractive force that causes the particle to move closer together. Let us suppose that two neurons have an above average synchrony of firing. Over time this would result in a strong attractive force between their corresponding particles. This would result in aggregation in n -dimensional space. Since, significant synchrony can indicate synaptic coupling [6] the aggregation of the particles can show the assemblies represented by the spike train data.

The gravity transformation has made a significant contribution to the field however there are some difficulties with the display of output data for large numbers of particles.

2. Parallel Coordinates

The use of parallel coordinates, originally pioneered in the 1980's, is a technique used to represent diverse sets of multidimensional data. In 1990, Inselberg [7] [8] renewed the use of parallel coordinates for the analysis of large quantities of multidimensional data and introduced some new representation features that have led to a marked increase in their utilization.

Inselberg's representation of parallel coordinates denotes data points as y-axis coordinate values distributed along the x-axis. In this scheme, a specific point in n -dimensional Euclidean space is represented by n y-axis values distributed along the x-axis. In the last decade much research has focused on the development of parallel coordinates in order to

analyse even greater quantities of data. An example of this is the concept of hierarchical parallel coordinates [9].

3. Visualisation Tool

It has been established that parallel coordinates can be used to identify correlations between variables and to convey aggregation information. Subsequently, this focuses on the application of parallel coordinates to the visualization of data produced by the gravity transformation in order to support the investigation of greater numbers of neurons. Naturally, the advantage of parallel axes over orthogonal axes is the fact that their limitations are based on the size of the display area available. Note that since there is no loss of data when using parallel coordinates that there is no “cost” to be considered for the gains achieved.

This paper presents a software analysis tool, VISA, used for the Visualization of Inter-Spike Associations that supports the analysis of multidimensional spike trains using both the gravity transformation and parallel coordinates. In addition to this, it provides additional functionality such as animation of the parallel coordinates display over time thus in this case depicting the aggregation of particles in the gravity transformation data. There is also the capability to view the display output in a static mode. Most significantly, the tool supports the display of any subset of particles for closer inspection. Since the range of values represented by each parallel axis is dependent upon the group of particles viewed on that axis, this is effectively a zoom facility.

Currently, the parallel coordinates may be used for relatively larger values of n than the standard output display of the gravity transformation. Indeed, provided that scrolling windows are deemed acceptable to the user, there is no theoretical limit to the number of neurons that could be displayed in this manner. However, in practice, significant demands for interaction with the graphical user interface reduce the overall effectiveness of the software tool since user perception is a significant factor in the process. Note that the use of hierarchical parallel coordinates offers additional significant opportunities for future development of the VISA.

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