A dendrogram approach to spike trains.

Conor Houghton, Trinity College Dublin
`houghton@maths.tcd.ie`

Motivation

The goal here is extend the range of mathematical tools available to describe the properties of spike trains by defining a quantity which measures sparseness, but does so in a way that is non-parametric and independent of the distribution of inter-spike intervals.
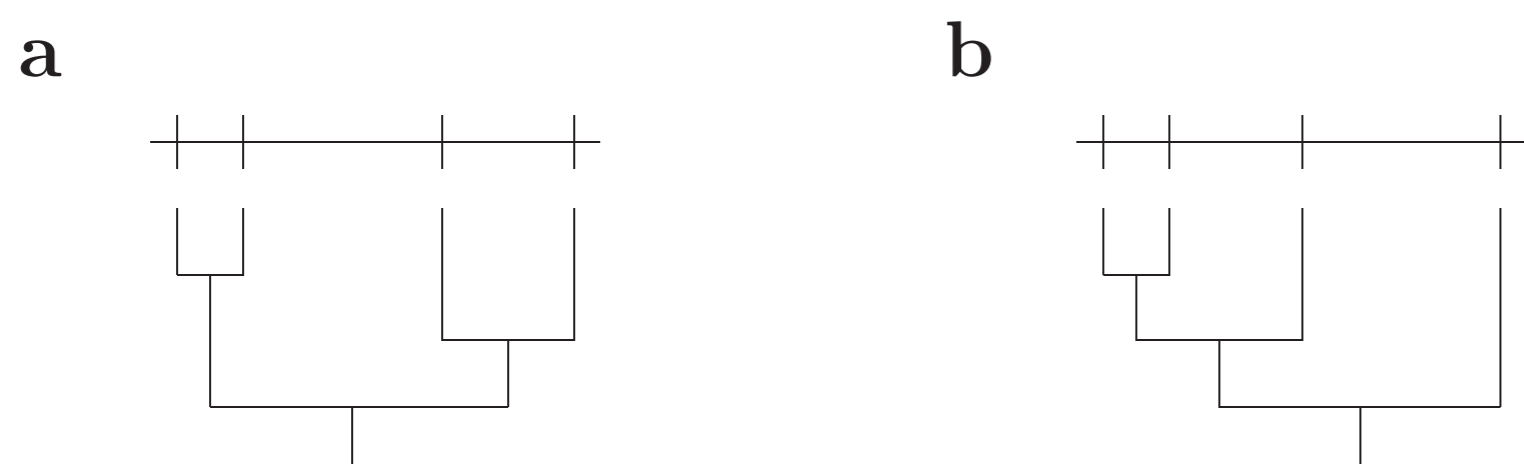
The dendrogram

The central idea is to convert a spike train into a dendrogram by performing hierarchical agglomerative clustering. This requires a clustering parameter ϵ. At $\epsilon = 0$, the clusters all consist of a single spike. As ϵ is increased from zero, any two neighboring clusters are joined if their nearest spikes are ϵ apart. Eventually, for a high enough value of ϵ, all the spikes are in the same cluster.
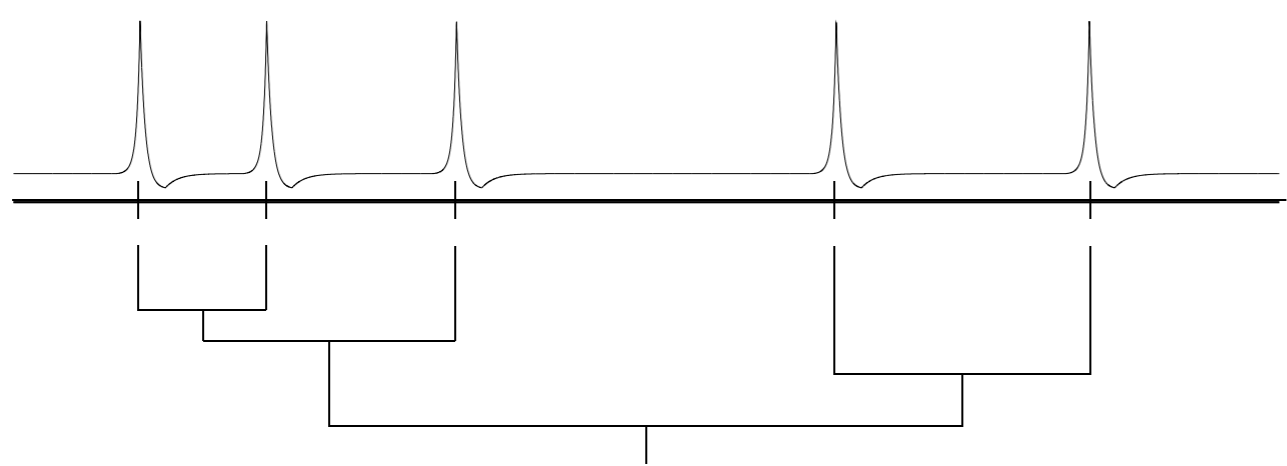
A spike-train dendrogram. **The first two spikes are closest and so they are aggregated first.**

Dendrogram morphology

The distance of each junction from $\epsilon = 0$ corresponds to the gap between two spikes and the distribution of ϵ values at which junctions occur is equivalent to the distribution of inter-spike intervals. However, the dendrogram is not specified by the ϵ values of junctions and the morphology of the dendrogram encodes the temporal pattern of the original spike train. Qualitatively, the morphology of a dendrogram involves the bushiness or leginess of the tree.

a   b

Four-spike dendrograms. There are two morphologically distinct dendrograms for a four-spike spike train. **a** is bushy and **b** leggy.

Quantifying morphology

A suitable quantitative measures of dendrogram morphology is defined in Murtagh (1984a). This assigns a value c to a spike train, c is lower for bushier spike trains and higher for leggier ones, for a large number of spikes a spike train with temporal structure it is $2/3$.

a

b

c
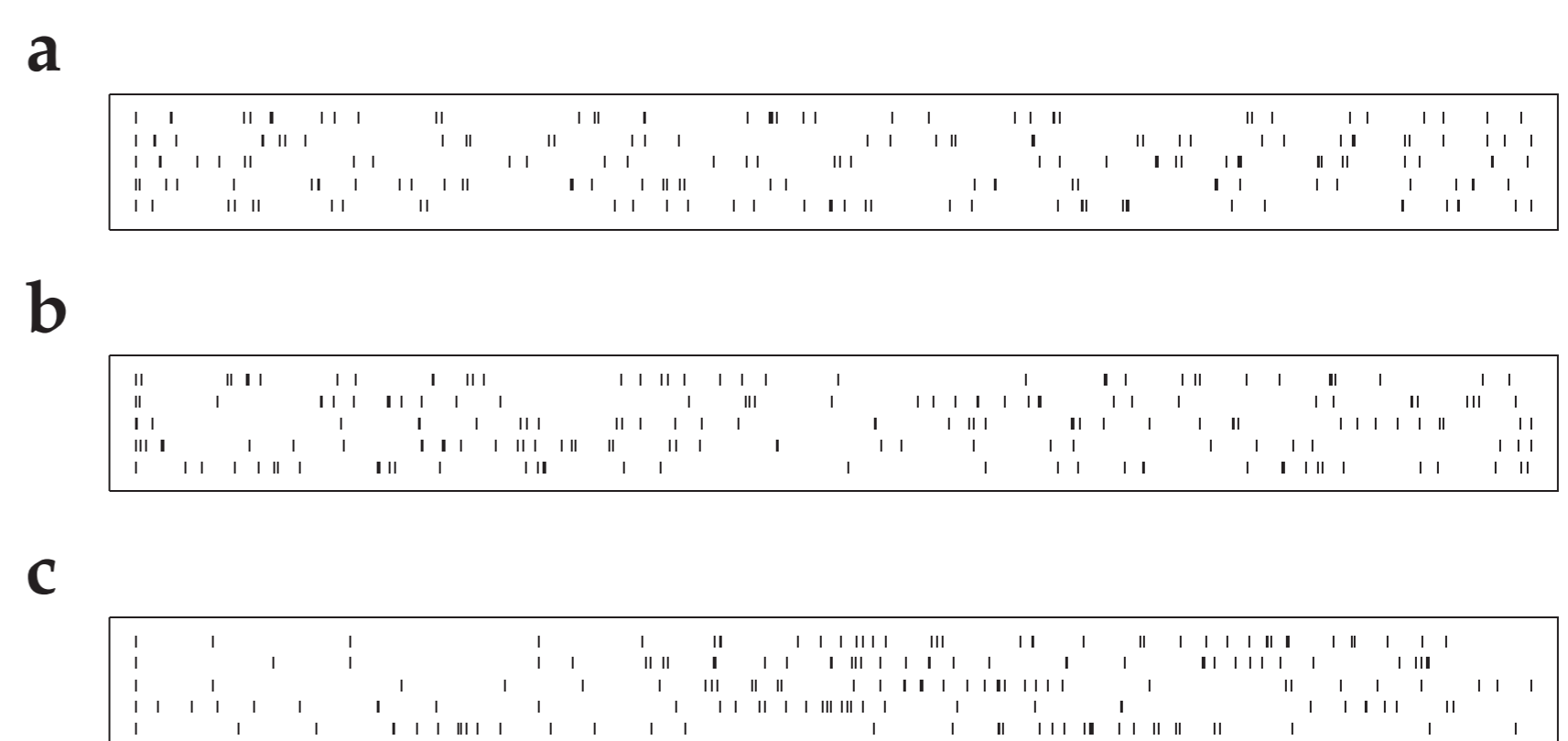
Spike trains with different values of c. These three raster plots show spike trains with the same inter-spike intervals. **a** shows the five spike trains with the highest value of c, they have values greater than 0.762, **b** five whose value of c are numerically identical to the average value of $s = 0.6$ and **c** the five with the lowest value, values less than 0.4.

Real data

To test the quantity c, an example data set has been chosen in which the stimulus eliciting the spiking response has little fine temporal structure. The data, which was obtained from `neurodatabase.org`, is described in DiLorenzo and Victor (2003a). The data consist of single cell recordings from the nucleus of the solitary tract in rat during presentation of taste stimuli. The results show that these spike trains have temporal structure not described by the distribution of inter-spike intervals.