

Neural data analysis – Session 1

Spike-triggered average,
cross-correlation,
autocorrelation

First – a sneak peek at things to come

- Today – time domain stuff, autocorrelation, cross-correlation, spike triggered averaging
- May 29th – Fourier transforms and power spectra
- July 13th – PCA, ICA, basic clustering
- August 3rd – Intro to information theory

Today's Session - Overview

- Types of data
- Hands-on exercises for today:
 - Spike-triggered average
 - Cross-correlation of time series
 - Cross-correlation of two spike trains

Data

- Today we'll be working with two types of data:

- Spike trains:



- Continuous signals (time series):



(very general, could be EEG, experimental stimulus values, etc.)

Representing spike trains

- List of spike times:

$$x = [0.125, 0.249, .56, \dots]$$

- Sum of δ – functions:

$$x = \sum_{i=1}^{\# \text{ spikes}} \delta(t - t_i)$$

- Binary vector (binned train):

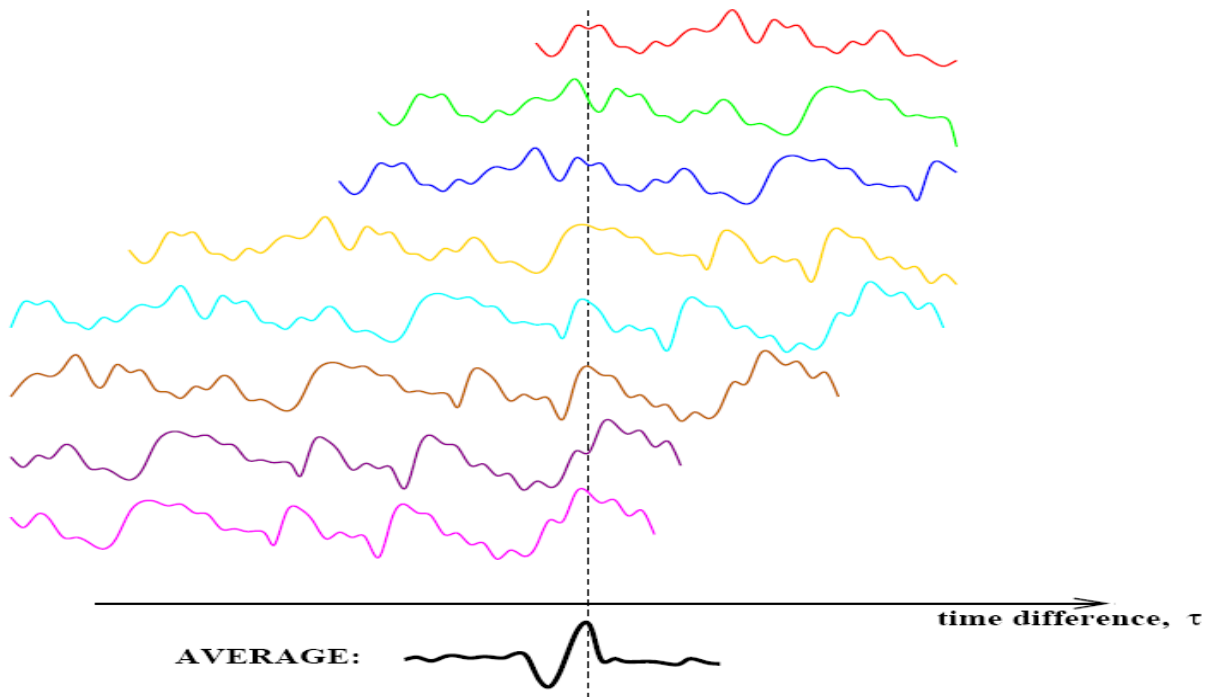
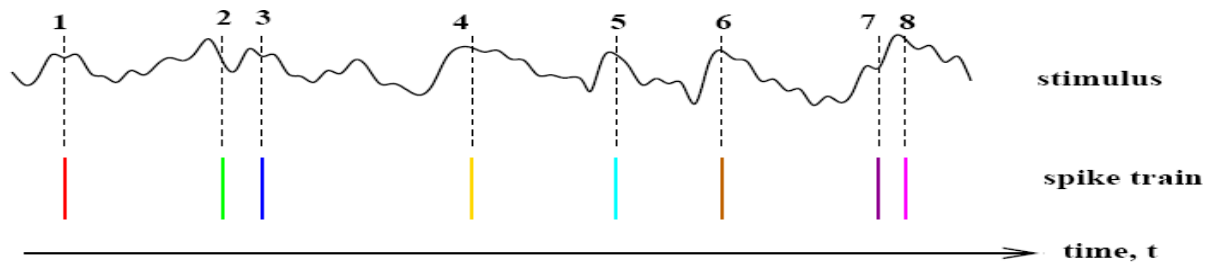
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00100100110100111000101010000100111001

Continuous signals

- Must be sampled/discretized to be analyzed in MATLAB (turned into a time series)
- Represent as a vector

Spike triggered average

- What makes a neuron fire?
- On average, what is a stimulus doing 5 ms before a spike? 10 ms before a spike? Etc.
- Compute something called the Spike Triggered Average (STA) of the stimulus to address these questions



Easy Warm-up

- First try to answer the following questions using MATLAB:
 - How many spikes are in the example spike train?
 - How long is the experiment (in seconds)?
 - What time does the 27th spike occur?
 - What is the value of the stimulus at that time?
 - What is the value of the stimulus 5 ms prior?

Cross-Correlation between time series

- Are two time series related in some way or are they independent?
- Definition:

$$\text{Corr}[g, h]_j = \sum_{i=-\infty}^{\infty} g_i h_{i+j}$$

Cross-correlation

- For finite signals (all we see in practice), can pad the ends with zeros
- Zero lag case:

$$\begin{array}{cccccccc} \dots & 0 & g_1 & g_2 & \dots & g_n & 0 & \dots \\ \dots & 0 & h_1 & h_2 & \dots & h_n & 0 & \dots \end{array}$$

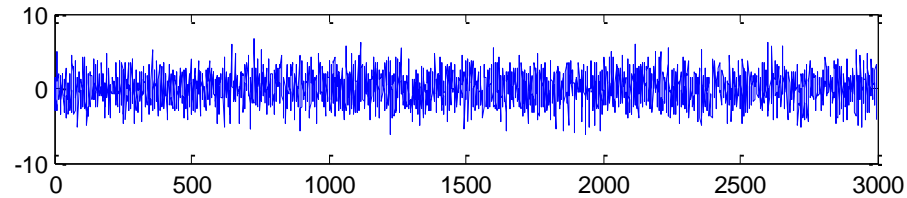
- Other lags correspond to sliding h left or right

The MATLAB `xcorr` function

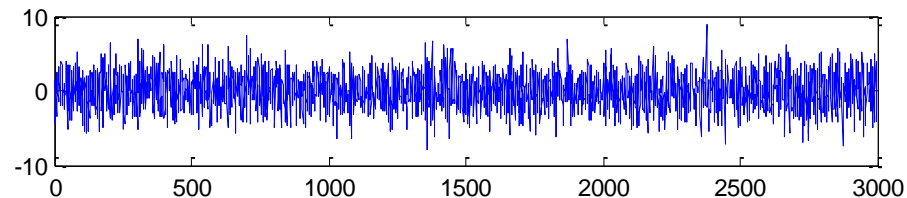
- If `f`, `g` are vectors of length `N`, `xcorr(f,g)` returns a vector of length $2N - 1$
- Can set the maximum window size to something smaller (play around with this during the exercise)
- Type 'help `xcorr`' in Matlab for more info

Exercise - Which pair of signals contains correlations?

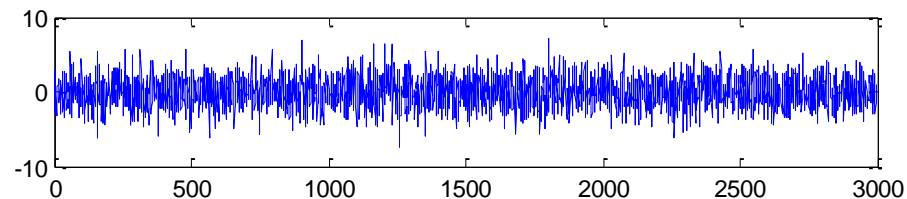
Signal 1



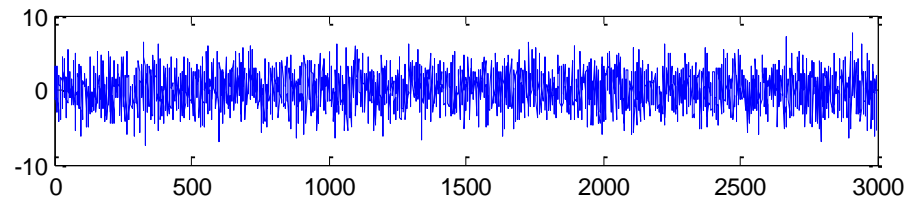
Signal 2



Signal 3



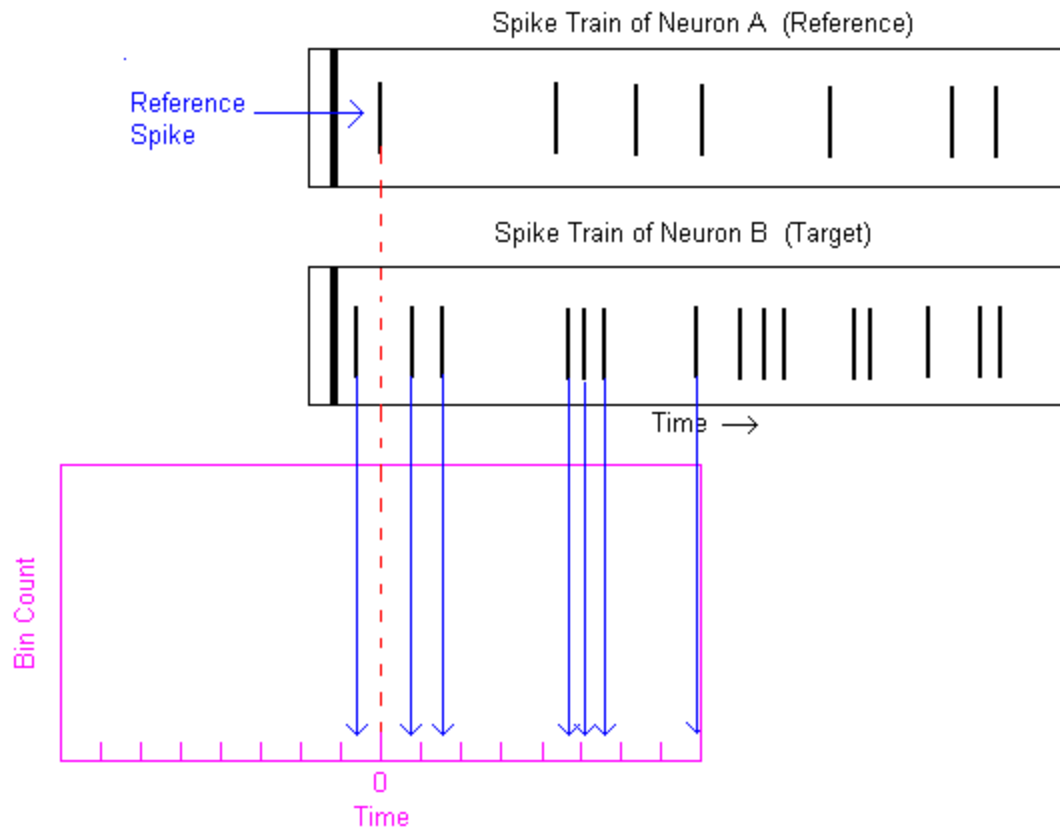
Signal 4

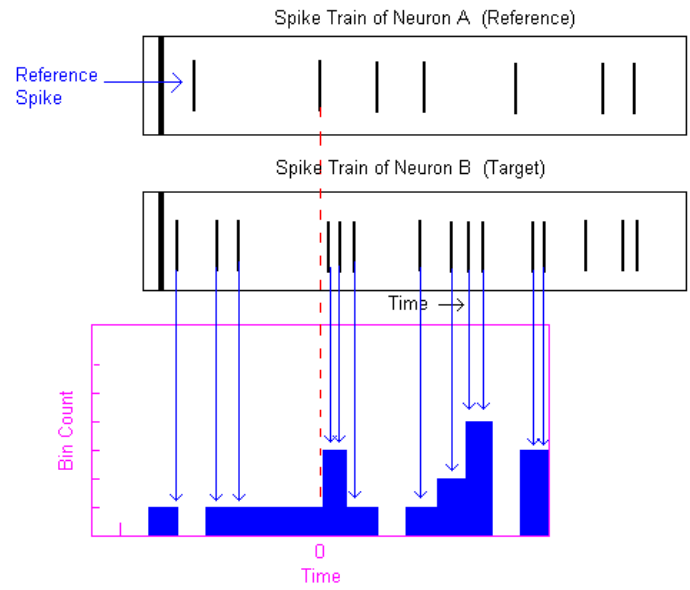
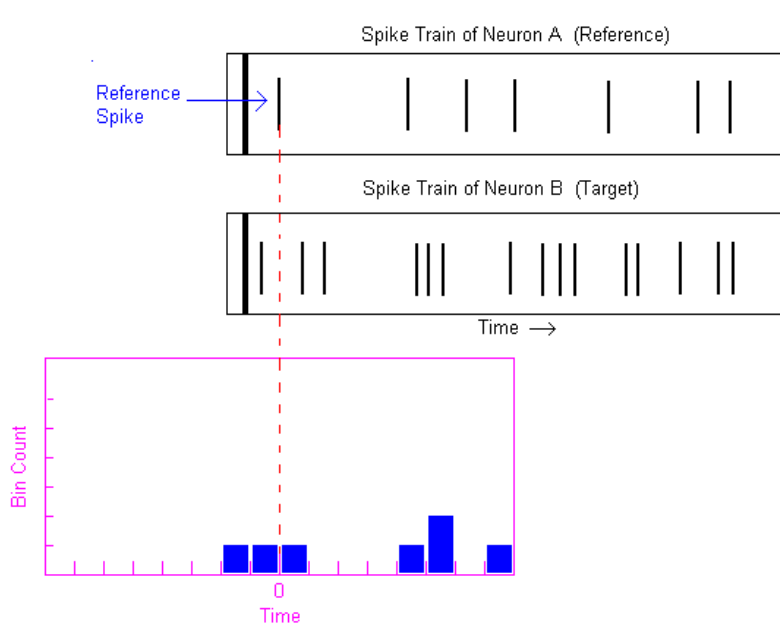


Instructions

- Download sigs.mat from the workshop website. It contains 4 signals represented as vectors
- Use MATLAB's built-in xcorr cross-correlation function to find the correlated pair (type 'help xcorr' to learn about this function)
- Play with the different options of the function (window size, etc.)
- Bonus points: write your own version of xcorr (if the above is too easy)

Cross-correlations in spike train data



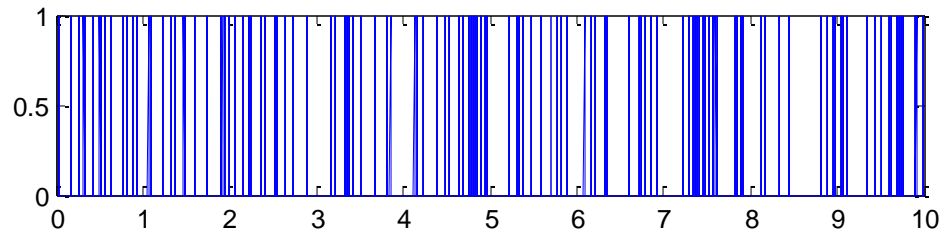


Exercise - Let's write our own code for this one

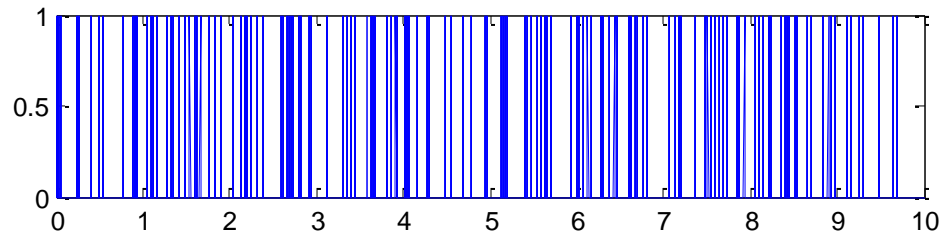
- Things to think about:
 - How to represent the spike trains
 - How to compute and display a histogram
 - What values are plotted in the histogram?
 - Bin size?

Which 2 spike trains contain correlations?

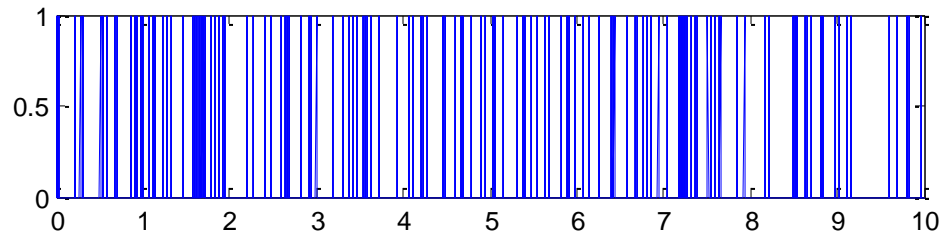
Spikes A



Spikes B



Spikes C



Auto-correlation

- Cross-correlation of a signal (or spike train) with itself
- Examples:
 - Autocorrelation of a Poisson train
 - Autocorrelation of a (almost) periodic train