Exercise – signal and noise in neural activity

The directory /DATA/ contains data from neurons recorded during an eye movement direction tuning task.

Part 1: analysis of the signal

Use the file ‘cell3247.mat’ that contains the information from a single neuron organized in a Matlab structure.

The name of the structure is data. It contains the following fields.

1. spikes: T X N sparse matrix, N is the number of trial and T is time in ms. The matrix indicates times of the spikes in each trial. A value of 1 in indicates that the neuron had an action potential in the corresponding bin.
2. target\_direction: A vector containing the direction in degrees of the target motion.
3. target\_motion: The time of target motion onset and offset in ms.
4. Write a Matlab script that shows the raster for each target motion direction separately. Hints: Matlab functions spy, subplot.
5. For each direction calculate the PSTH in 1 ms bin. Smooth the PSTH with a square window of 100 ms. Normalize the PSTH to firing rate in units of spikes/s. Present all 8 PSTH in a single Matlab plot. Take care of edge effects.

Hints: Matlab function smooth, hold on/off.

1. Calculate the direction tuning of the neuron. Calculate the average firing rate across all the movement time as a function of the direction of movement. Present a plot of the average firing rate across trials as a function of motion direction.
2. Fit the direction tuning to a cosine function:

* 1. Present the fit together with the direction tuning of the cell. Use a resolution of 1 degree to present the results of the fit.
  2. Use the fit to estimate the preferred direction of the neuron.
  3. Advanced question: firing rate cannot drop below 0, add this constraint to the fit.

Hints: Matlab functions fittype and fit.

Part 2: Linear models and the neuron-behavior correlation matrix

Use the data in the file named “cell432.mat”.

The name of the structure is data. It contains the following fields.

1. spikes: T X N matrix, N is the number of trial and T is time in ms. The matrix indicates times of the spikes in each trial. A value of 1 in indicates that the neuron had an action potential in the corresponding bin. All trials are taken from a single movement direction.
2. behavior: T X N X 3 matrix containing the trial-by-trial behavior. N is the number of trials and T is time in ms. The entries in the third dimension correspond to eye position, velocity and acceleration. Movement during saccades was truncated and replaced by NaNs.
3. target\_motion: The time of target motion onset and offset in ms.
4. Plot the spike data as a raster. Hint: Matlab function spy.
5. Calculate the PSTH from the raster, smooth it with a Gaussian filter with a 40 ms windows. Hint: Matlab functions gausswin and filtfilt.
6. Calculate the average behavior. Hints: Matlab function squeeze, use nanmean to deal with missing data (due to saccades).
7. Fit a linear model between the PSTH and the average behavior. Plot the contribution of each kinematic parameter to the firing rate. What is the R2 of the fit? Which parameter contributes mostly to the Firing rate? How is this different from the cell that was presented in the class? Hint: Matlab function regress.
8. Use the linear model and the behavior to calculate the trial-by-trial firing rate predictor.
9. Calculates the trial-by-trial firing rate by smoothing the raster with a Gaussian filter with a 40 ms windows.
10. Calculate the neuron-behavior correlation matrix. Hint: Matlab functions pcolor/imagesc, corr, use the appropriate Matlab argument to deal with missing data (NaNs).
11. Advanced question: estimate the downstream noise.
    1. Calculate the eye standard deviation from the rate predictor.
    2. Calculate the firing rate standard deviation from the smoothed trial-by-trial rate.
    3. Extract the diagonal of the neuron behavior correlation matrix. Hint, Matlab function diag.
    4. Assume the cell represents the neuron-behavior correlation of the population, use a-c to calculate the downstream noise.
    5. Calculate the fraction of eye variability that is downstream to the neuron.