Project 2:

Extracting multi-unit activity from ECoG recordings

Due Oct 30, 2024

As mentioned in class we can record multi-unit activity (mua) from ECoG. Here, we are asking you to extract and plot multi-unit activity from example ECoG recordings (`ECoGData.mat`) with simultaneous optogenetic stimulation from a non-human primate cortex.

In this dataset, there are three signals (`data.Signal`) corresponding to different stimulation patterns. The stimulation patterns are:

1) constant illumination for 1 second (signal 1),

2) illumination with 3Hz sine wave for 1 second (signal 2), and

3) illumination with 10 Hz sine wave for 1 second.

Each pattern is repeated 50 times in each of these signals. The timestamp of the beginning of the 1 second stimulation pattern is provided (`data.StimTimes`) for each signal. The sampling frequency is also stored as `data.SamplingFreq`.

We provide two starting points for this project: one for Matlab, and one for Python.

<u>MATLAB</u>
In part (a) below, you will use a bandpass filter on the provided ECoG data. The provided Matlab script (`filter500to5k.m`) implements the bandpass filter. You can use it in conjunction with Matlab's `filtfilt()` function to filter the data.

<u>Python</u>
If you choose to use Python, you can use the included `example.py` as a starting point. It shows you how to load the ECoG data into `scipy` tensors, and links you to `scipy` functions that you can use to perform the bandpass filter. Note that you should not use any libraries not specifically enumerated in the header of the file. Those are: `numpy`, `scipy`, and `matplotlib`. If you are using google colab, you can mount your drive to load in `ECoGData.mat`.

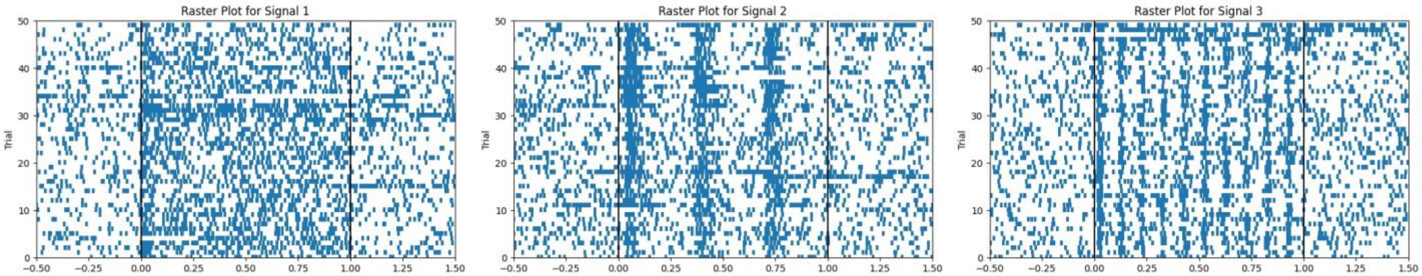
Please follow the steps below, **you need to submit your code along with your plots from part (b) and part (c).**

a. Filter each signal between 500 to 5000 Hz using the Matlab or Python approach discussed above. Then, use the following threshold to detect the time of multi-unit activity for each stimulation pattern.

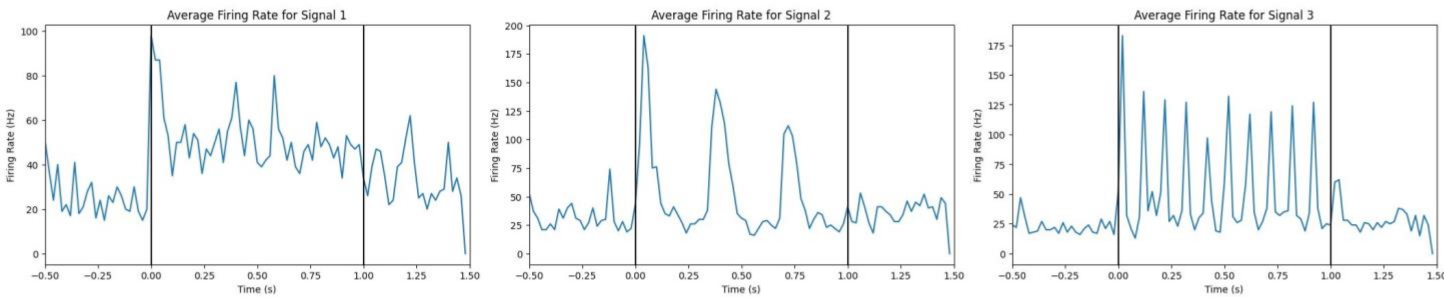
$$Thr = 3\sigma; \quad \sigma = median\left(\frac{|filtered\ signal|}{0.6745}\right)$$

   Note that you need to rectify the signal for threshold detection based on the above threshold equation.
   <u>Tip</u>: you can use the function "`findpeaks()`" in MATLAB.

b. Plot the timing of each multi-unit activity during each trial (from 0.5 seconds before stimulation starts to 0.5 seconds after stimulation stops) for all 50 trials. Note that the best way to show this is using raster plots. **Save your plot to a file named <netid>_part_b.png and submit it along with your code (50 pts)**. See example below. Note the axis limits; yours should be the same.



c. Calculate the firing rate over time for each trial from 0.5 seconds before stimulation starts to 0.5 seconds after stimulation stops. Plot the average firing rate across trials for each of the 3 stimulation patterns. <u>Hint</u>: This data was shown in class. **Save your plot to a file named <netid>_part_c.png. Submit it along with your code (50 pts)**.



<u>Tip</u>: the firing rate at a given time is # spikes or multi-unit activity during an interval T divided by length of T (i.e. bin size). You can choose a small bin size here, such as 20 ms, to plot firing rate over time.

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20 points extra credit:

Explain how to use a Kalman filter for a brain computer interface--include equations. Explain the decoding section that was not covered in class after reading Wu et al, NIPS 2003.