EE 486E: Homework 1

Spring 2015

47 points

Due: TUE 20 JAN

Directions for submission

Turn in a paper copy of your writeup at the beginning of class on the due date. Your writeup should consist of typed, numbered answers to each question followed by an addendum containing only the **PLOTS** requested in all-caps bold red font, followed by your code. Include two plots per page, each with a title indicating which problem it answers and axes labels that have proper units. In addition, upload your *Matlab code only* to Google Drive (`EE486E_CLASS\EE486E_DROPBOX\<YOURNAME>_EE486E_DROPBOX`). Your code may be split into more than one m-file but it must have a single main file, `RunHw<X>_<YOURNAME>.m`, that calls all of the others.

The data sets required for this and all other homework assignments can be found on Google Drive in the appropriate subfolder of `EE486E_CLASS\EE486E_DATA_FILES\HOMEWORK`.

1 Unit Activity

`units.mat` contains an example of a multi-unit microelectrode recording made in a human surgical patient. The data were recorded by Dr. Itzhak Fried and colleagues at UCLA using 40 micron diameter platinum-iridium electrodes. The sample units are microvolts.

Whenever you get new and potentially unfamiliar data, one of the best places to start is by visualizing it: plot it, zoom in and out, study the characteristics of its prominent features (in this case, the large-amplitude neural spikes, for example).

1.1 What is the sampling rate, in Hz, of the recording? (Hint: data in the `info` struct should help. Incidentally, you can access the fields of a Matlab structure using dot notation; for example `y=info.lowcut_Hz;` will assign the value 300 to the variable `y`.) (1 pt)

1.2 What is Nyquist frequency, in Hz? (1 pt)

1.3 What would happen if the original analog microelectrode signal contained frequency components greater than the Nyquist frequency? (2 pts)

1.4 How long (in seconds) is the recording? (1 pt)

1.5 **PLOT** the seventh second of the recording, labeling the x-axis in seconds relative to the beginning of the extracted 1-second data segment (in other words, after extracting the appropriate segment, consider the first sample to be at t=0 s rather than t=6 s). (3 pts)

1.6 If you were tasked with detecting spikes by setting a threshold "trigger" what might be an appropriate threshold? (1 pt)

1.7 Using this threshold value, write a short bit of code to do just this: find the times of each spike peak (i.e., the time of the maximum spike amplitude) in this 1-second segment. Your algorithm should return only one detection time per spike, not the time of every data sample that is above the threshold! What is the time, **in msec**, of the third spike in this 1-second segment as returned by your algorithm? (3 pts; +2 bonus points if you can do it without using Matlab's `findpeaks` function.)

1.8 How many spikes does your algorithm detect when run on the entire data file? (2 pts)

2 Seizure Activity

`Seizure.mat` contains an example of human iEEG data displaying seizure activity. It is recorded from a single "channel" (i.e., it is a differential voltage measurement between two electrode contacts) implanted in the hippocampus of a patient with temporal lobe epilepsy being evaluated for surgery. As before, plot all of the data, which in this case is stored in the variable `RT2`, and play around to get a feel for it, noting its similarities to and differences from the unit data you saw in Part 1.

2.1 How does the duration of this recording compare with the data in `units.mat`? (1 pt)

2.2 How do the voltage amplitudes compare? (1 pt)

2.3 **PLOT** the segment of the recording between 10 and 20 seconds. The latter should be a period of mostly normal activity prior to the seizure. (3 pts)

2.4 What differences in amplitude and frequency do you notice about this 10-second segment and the full 10-second recording you worked with in Part 1? (4 pts)

2.5 The unit activity sample was bandpass filtered between 300 and 3000 Hz. Assume that the seizure activity sample has no such bandpass preprocessing. Load the file `rawData.mat`. This file contains unfiltered unit data (though not the same data set as in Part 1). Plot it. How does this data compare to the seizure and unit data plots you made earlier? (3 pts)

2.6 Now bandpass filter the raw data between 300 and 3000 Hz using a 6th order Butterworth filter. You can use the sequence of commands `[b,a] = butter(3,[c1 c2]); filteredData = filtfilt(b,a,RawData);` to accomplish this, where `c1` and `c2` are the cutoff frequencies expressed as a fraction of the Nyquist frequency. **PLOT** the filtered data. What is different about the data now? Is it similar to the unit data you plotted in part 1? (5 pts)

2.7 Assume that the power in a narrow frequency band for neurophysiological signal is inversely proportional to the center frequency of the band. How might the differences in preprocessing between the units data in Part 1 and the seizure data in Part 2 explain, at least in part, the differences you noted in question 2.4 above? (4 pts)

3 Evoked Potentials

The data in `ep.mat` contains an example of a very common type of experiment and neuronal signal, the evoked potential (EP), in this case recorded with microelectrodes. The data show the response of the whisker barrel cortex region of rat brain to an air-puff stimulation of the whiskers. The `stim` array shows the stimulation pattern, where the falling edge of the stimulus indicates the start of the air puff, and the rising edge indicates the end. The `ep` array shows the corresponding evoked potential.

Once again, play around with the data, perhaps looking at all of the stimuli and EPs overlaid on the same plot (using `hold on` and different colors for each trace) and then zooming in on shorter time-segments. Get a sense for how long each trial is (i.e., the interval between stimuli) and how long the entire experiment (i.e., the full set of stimuli and responses) is.

3.1 Based on your observations, should we use all of the data or omit some of it? (There's no right answer here; just make your case either way in a sentence or two.) (2 pts)

3.2 What is the average time, in msec, over all trials, of the peak response after the onset of the stimulus? (Hint: think in terms of matrix operations rather than loops. Matlab's `reshape` and `max` functions may come in handy). (4 pts)

3.3 We often want to get a sense for the prototypical response as well as characterize the variability of the response at each point in time. A simple (and simplistic) way to do this is to compute the average EP as well as the standard deviation of the EP at each time point. Use Matlab's `errorbar` to **PLOT** the mean response with gray-colored error bars of length $\pm$ 1 standard deviation above and below the mean, respectively, at each time point. (Use `'Color'` and `[0.7 0.7 0.7]` as the last two arguments to `errorbar` to accomplish this). Finally, to make the mean response stand out, use `hold on` and re-plot the mean EP as an overlay in red. (4 pts)

3.4 We often want to get a sense for the noise power in a signal. Propose a method to do this for the EP data. (There is no need to implement the method.) (2 pts)