Data Analysis in Geophysics (CERI 7104/8104)
Homework 3 – Due 10/27/17

In this assignment, we use MATLAB to do some analysis on real data. We will focus on two experimental dataset (available on the course web page) from the Penn State Rock Mechanics Lab. You should be able to do this analysis in concise vectorized format (without any `for` loops), but that is not required – I only mention this to remind you to think about how to write fast and efficient MATLAB code. The datasets are from experiments looking at friction and failure in a sheared granular material with the following set-up:

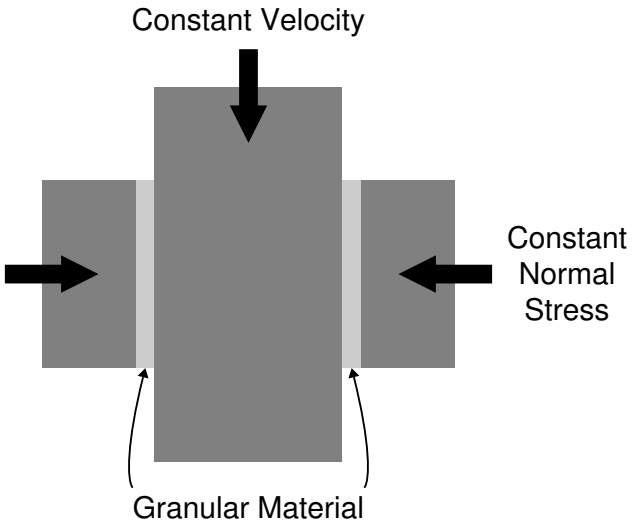

Figure 1: Schematic of the Penn State bi-axial deformation apparatus. Two granular layers (light gray) are sheared under a constant applied force (or normal stress) from the side. The center block is driven at a constant velocity. During the experiment, the apparatus measures the force necessary to drive the center block at a constant velocity (from which the shear stress on the layers can be determined). The layer thickness also changes during the experiment and is recorded.

1. First, we will look at the dataset "p1894.dat" which is in ASCII format. The data contains 9 columns and 55710 rows. The columns represent the following, all measured during the experiment (from left to right, with units in parenthesis): load point displacement (μm), shear stress (MPa), layer thickness (μm), normal stress (MPa), time (s), friction coefficient (-), shear stain (-), elastically corrected displacement (μm), and vibrational acceleration (V). Do not worry about the meaning of the shear strain or elastically corrected displacement; we will not consider these here.

   Read the data into MATLAB, and then perform the following analysis steps.

2. Plot the shear stress as a function of time. Describe what is going on over the course of the experiment (a close-up plot may be of use). This behavior is what is known as stick-slip, and it can be thought of as a series of tiny laboratory earthquakes.

3. Identify the time of the stick-slip events. (*Hint:* it is useful to think of the time derivative of the shear stress. Is there a way do this without a `for` loop?) What is the average waiting time between events?

4. Look at the layer thickness as a function of time. Notice that it decreases approximately linearly with time (this is due to a couple of effects: the material spreads out as it shears, and some material is lost at the edges). We would like to remove this effect.

   First, we will do this manually. Fit a linear function to the thickness data as a function of time (the `polyfit` function will be useful here). Subtract this fit from the data to detrend it. Try to do this without a `for` loop.

   MATLAB has a built-in function to do this for us, called `detrend`. Verify that both our manual detrending and the `detrend` function give the same results (include a plot showing both results).

5. In this experiment, the apparatus was vibrated several times. The amplitude of vibration (measured in volts, so this only gives us relative amplitudes) is included in the data file. Using the vibration amplitude, identify one of the stick-slip events that occurred when vibration was applied. (The later times in the experiment are better than the earlier ones). Zoom in to a time window surrounding this stick-slip event and plot the shear stress as a function of time. Can make your script find the event and set the horizontal time limits automatically without requiring you to enter specific values manually? (This is not required, but if you are processing many datasets of this type, it would be a pain to have to figure it out for each individual experiment.) Include this close-up plot, along with a description in words as to what is happening in your write-up.

6. Now we will work with the dataset "p2394.dat" which is in binary format. The data is saved as double precision floats, and little endian byte order. The data contains the same 9 columns as the dataset that you used in the first part of the homework, and an unspecified number of rows.

   Read the data into MATLAB and perform the following analysis. Just as before, you should do this without any `for` loops.

7. What is different about this experiment? Show an appropriate plot of the data and explain what is different about this experiment when compared to the previous one.

8. Does the friction coefficient change with normal stress? Make a plot to illustrate your conclusions.

9. Does the time between stick-slip events change with the applied normal stress? You can re-use your code from the first dataset to investigate. Show a scatter plot illustrating the behavior that you identify.

You should submit the following:

- Your code (organized however you like, but please label each part of your code with appropriate comments so I know what you are doing). As usual, I recommend writing small functions to do each individual piece, plus a driver script that calls each of them and plots the results.

- All requested plots in PDF, PNG, or EPS format (please do not submit MATLAB .fig files as they are harder to look at in detail).

- Answers to all questions/descriptions in the assignment in a text file or word processor document. You should include several sentences for each question.