**Total Points: 100 Due:** Week 4 in Lab

The project must be completed independently.

**Objective**

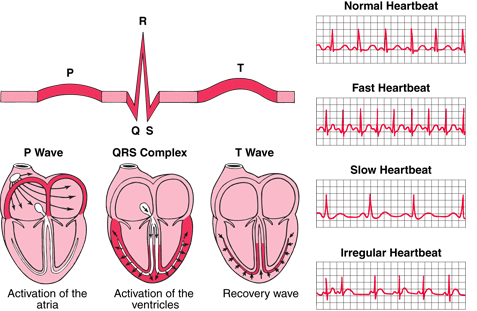
The project is designed to introduce the students to fundamental array operations and MATLAB functionality when working with large data arrays. MATLAB plotting and statistical functions are reinforced. New MATLAB function, *findpeaks*, is introduced.

**Submit**

This project is to be completed in MATLAB Editor. Make sure to name your script file as *lastname\_ECG.m*. Upon completion, publish your program to a Word file with the same name. Format the size of your code in the Word document such that it fits nearly onto the page. Email *lastnmame\_ECG.m* and *lasname\_ECG.doc* to me at [imas@msoe.edu](mailto:imas@msoe.edu) by 8 am on Thu of Week 4.

**Data**

Please download *ECGnormal.txt* and *ECGafib.txt* from Blackboard. The *ECGnormal.txt* contains Electrocardiogram (ECG) data from a patient with a normal sine heart rhythm. The *ECGafib.txt* contains the ECG data from the same patient during an episode of atrial fibrillation. Figure 1 shows the typical ECG signals, associated with normal, fast, slow, and irregular heartbeats. The ECG morphology of each heart beat is also described, and the PQRST complex is defined graphically.



**Figure 1:** Electrocardiogram (ECG) signals

**Program Specifications**

You are to design a MATLAB program to perform an automated PQRST detection in the ECG rhythm for the computation of heart rate, average PQRST complex, and average total power in a normal and in an atrial fibrillation ECG signals.

**Data Conditioning and Display**

1. Using one of the MATLAB designated commands (**load** or **importdata**), load two ECG data files and make sure that the appropriate variable names are assigned to two data arrays.
2. Invert the amplitude of both ECG signals such that the largest peaks in the signal (R peaks) have a positive amplitude. The signals must look like the examples in Figure 1.
3. Plot the inverted ECG signals in **Figure 1** in two subplots (2x1 layout) as a function of time. Add grid to both plots. The units of the ECG signals are µV. The units of time are seconds. Label your axis accordingly. Include descriptive titles on both plots. Make the color of the ECG atrial fibrillation signal red.
   * Compute the time axis to plot your signals by starting at 0 and specifying the time increment of 1/250 seconds. The final time value should be equal to seconds. If you do everything correctly, you should stop at 9.996 seconds. To determine the number of points in your ECG signals, you are required to use the function **length**.

**PQRST Detection**

In this part of the project, you are required to use the MATLAB function *findpeaks* to locate only the R peaks in each of the two ECG signals. You will then use the peak location information to calculate the heart rate of the patient in both conditions, and then to extract all PQRST complexes for additional processing.

Using MATLAB help, investigate the use of *findpeaks* function, and use it to find onlythe R peaks (maxima) in eachPQRST complex of both signals. You may end up locating one erroneous peak at the very end of each signal. That is ok. You will be ignoring it in later calculations.

* The output of the *findpeaks* function must contain the R peak amplitude and the data index (location) at which the peak occurs.
* Plot the peak amplitudes as a function of their data indices over the corresponding ECG plots in **Figure 2**. Display the peaks as stars (\*) in green color. Once completed, your plots should like my Figure 2. Here, when plotting the ECG signals, do not plot the ECG signals as a function of time. Instead, plot the ECG signals as a function of their data indices (data points, e.g. **plot(x)**). As in Figure 1, arrange your subplots in the 2x1 layout.

Figure 2: ECG Signals with R Peaks Detected

* ***Note*:** you need to read the help file carefully and find the implementation that would only locate the R peaks. I suggest that you start with the simplest implementation described in the help file, plot your results and reassess. This part will require some data mining on your part to get it just right. You may not be able to get rid of the last erroneously found peak, so you will have to deal with it later.

**Heart Rate Calculation**

In this part of the program, you will use the R peak information obtained above to compute the heart rate of the patient in units of Beats per Minute (BPM) in two conditions, and display it in command window. You will need the following information to compute the patient’s heart rate.

* Use the data indices arrays associated with the R peaks in each condition to determine all consecutive R-R intervals in units of seconds/beat as follows. When completed, you should have an array of consecutive R-R intervals for each of two conditions.
* Convert values in each of two conditions to heart rate in Beat-Per-Minute (BPM). You should have about twelve heart rate values (one for each RR interval) for each condition.
* For each condition, plot all heart rate values as a function of their corresponding data indices in **Figure 3**. Label x and y axes appropriately. Create an appropriate title for this figure (e.g. “Heart Rate Data”). Include a grid in the figure. Make the heart rate data for the atrial fibrillation signal red. Assign figure legends to your plots to differentiate between two average signals. Make sure the legends are labeled properly.
* Compute the average heart rate by averaging values in each of two conditions and converting the result to Beat-Per-Minute (BPM).
* Display the heart rate in BPM it in command window accompanied by the following text.
  + “The heart rate detected in normal ECG is **[normal heart rate variable]** BPM.”
  + “The heart rate detected in atrial fibrillation ECG is **[afib heart rate variable]** BPM.”

**PQRST Extraction and Averaging**

In this part of the program, you will use the R peak location information (their data indices) to extract all PQRST complexes from each of the two ECG signals.

1. Use the R peak location information to identify the location of each PQRST complex in the ECG signal. By selecting 110 points to the left and 110 points to the right of the R peak. When extracted, each PQRST should be of length of 221 data points.
   * No *for* loops is required to do this! This is a semi-manual extraction based on the R peak location information computed previously.
   * You will extract 12 PQRST complexes from the normal ECG, and 11 complexes from the atrial fibrillation ECG (ignore the first peak).
   * In both cases, ignore the last erroneous peak if it was detected.
2. Create two arrays, **NormECG** and **AfibECG**, of the size 221 x 12 and 221 x 11, respectively, containing only zeros. Use an appropriate MATLAB function to do so.

1. Place the corresponding PQRST complexes into the columns of the **NormECG** and **AfibECG** arrays, such that the first detected PQRST is placed into the first column of the array, the second PQRST into the second column, and so on.
2. Using the *mean* command, average the columns of the **NormECG** and **AfibECG** to compute an average PQRST complex for each condition. Name the resulting 221 x 1 vector arrays **NormAve** and **AfibAve**, respectively.
3. In **Figure 2**, plot **NormAve** and **AfibAve** as a function of time in the same figure window. Change the color of **AfibAve** to be different from **NormAve**. To compute the time vector, assume the starting time of 0, an increment of 1/250 seconds, and the final time value of 0.88 seconds. Assign figure legends to your plots to differentiate between two average signals. Make sure the legends are labeled properly. Label your figure and axis appropriately. Make sure to include the units of time as seconds, and the units of signal amplitude as µV.

**Average Total Power Computation**

In this part of the project, you will compute the total average power of the **NormAve** and **AfibAve** signals using the following equation. Feel free to use either *sum* or *mean* command assist in this computation.

* Once computed, display the power values in the command window with the following accompanying text.
  + “Total average power of Normal Average PQRST is **[average normal power variable]** Watts.”
  + “Total average power of Afib Average PQRST is **[average afib power variable]** Watts.”

**Grading Rubric**

**15 pts – Data Conditioning and Visualization**

* Data files are loaded correctly and assigned to appropriate variables.
* Data files inverted correctly.
* Data files are displayed in the figure as specified.

**20 pts – PQRST Detection**

* The function *findpeaks* is used.
* The function *findpeaks* is used with appropriate input and output arguments, such that only R peaks are detected.
* Both the amplitudes of R peaks and the corresponding data indices are located.
* No erroneous peaks are detected (other than the last one in the atrial fibrillation file).
* The peaks are added to Figure 1 as specified.

**15 pts – Heart Rate Calculation**

* The program correctly computes the heart rate in BPM in two conditions.
* The program correctly makes use of the signal timing information in the calculation.
* The program correctly and with the use of the appropriate MATLAB function, identifies the number of heart beats in the given time interval.
* The calculated heart rates are correctly displayed in the command window.

**20 pts – PQRST Extraction and Averaging**

* The arrays designated to contain the individual PQRST complexes have been correctly initialized (contain only zeros). The designated MATLAB command was correctly used for this purpose.
* All PQRST complexes (other than the first one in atrial fibrillation signal) were placed in the corresponding columns of their respective arrays using appropriate array operations.
* The PQRST extraction made correct use of peak location indices.
* The resulting data arrays contain 12 normal and 11 atrial fibrillation PQRST complexes.
* The average normal and atrial fibrillation PQRST signal was calculated by averaging the columns of the respective data arrays. The averaging made use of the appropriately executed designated MATLAB function.
* The average normal and atrial fibrillation PQRST signals are plotted in Figure 2 as specified.

**15 pts – Total Average Power Computation**

* The program correctly computes the total average power in the average normal and atrial fibrillation PQRST signals.
* The program makes correct use of appropriate MATLAB functions to do so.
* The program correctly displays the power values in the command window.

**15 pts – Optimization, Organization, Creativity, Comments**

* The program contains appropriate commenting per specifications provided in class. If you are not sure of the specifications, please see me before you submit this project.
* The program is organized into meaningful execution sections.
* The program makes use of the variables in all calculations (whenever possible).
* Whenever possible, the program is automated, such that it does not depend on the hard-coded numerical values, but makes use of outputs of specific MATLAB functions, such as *size* and *length*. Please see me and I will explain this point in detail, if unclear.
* The program is optimized as much as possible at this point in the class.
* The program opens with *clear*, *close*, and *clc* commands.