MATLAB REPORT: ANALYSIS OF AN ANNOTATED ECG SIGNAL

MAT188H1: Linear Algebra

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Electrocardiography (ECG) is the process of documenting the electrical activity of the heart over a period of time using electrodes placed on a patient's body, producing an electrocardiogram. This information is valuable for physicians as it identifies different cardiac abnormalities using the electrical activity produced by the heart. These abnormalities can be broadly classified as arrhythmia, meaning an unusual heart rate. *Bradycardia arrhythmia* is recognized as having a heart rate slower than 60 beats per minute, while *tachycardia arrhythmia* is a heart rate faster than 100 beats per minute. Therefore, a healthy heart rate is between 60 and 100 beats per minute. A general electrocardiogram consists of three primary components, them being a *P-wave*, *QRS complex*, and a *T-wave*. A graphical representation of this is shown below in *Figure 1*.

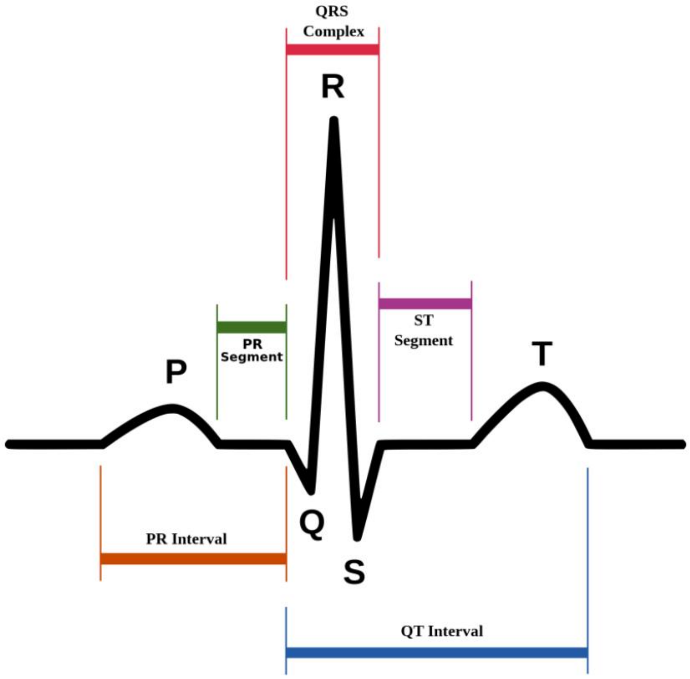

Figure 1. An electrocardiogram of a healthy human heartbeat.

For this report, three patient's ECG signals were documented by a physician, with a designated marker representing each critical point *(PQRST)*, such that 0 represents a point with no specific feature in the ECG signal, 1 represents a P-wave peak, 2 represents the Q point, 3 represents the peak of an R-wave, 4 represents a S point, and 5 represents a T-wave peak. These ECG signals are plotted with voltage (mV) versus time (seconds). Let us assume the physician wishes to analyze these signals to determine the relative cardiac health of his patients; to verify if they have arrhythmia. This will mean determining the average heart rate of his three patients. The formula for calculating heart rate is

$$Heart\ Rate = \frac{number\ of\ heartbeats}{minute}$$

A heartbeat will always have these repeating *PQRST* points, therefore, to simplify the calculating process an assumption can be to only choose *one* of these points in the electrocardiogram and determine how often does it occur. It should be noted that the point chosen is not relevant as the same five points would have been between any two same points, therefore a relatively accurate approximation of how many heartbeats can be calculated.

So, let us choose point S in the electrocardiogram, meaning that every time a marker is equal to 4, that corresponds to a single heartbeat occurring. To find how many times the marker is equal to 4, a *sum function* can be used to find the sum of the elements in the ECG array that satisfy our condition. Then the total time taken from the electrocardiogram can be identified using *matrix indexing*. The total seconds is provided by the number of columns in the matrix, such that a single column is equal to one second. Therefore, to find the total number of minutes passed, the value of the end column of the matrix for the patient's time can be evaluated which is then divided by 60; because the total time in the matrix is in *seconds*, and heart rate is in *minutes*. Lastly, these two values can be computed using the aforementioned equation for heart rate. This same process is equivalent for any electrocardiogram, and therefore was repeated for all three patients. *Figure 2* depicts this method for patient number 1.

```
%Patient no. 1 defined when marker is equal to 4 (S Point)
marker1 = sum(data1.marker==4);

%Patient no. 1 total time in minutes
time1 = (data1.time(:,32838)/60);

%Heart rate = heart beat / total time
no1_avgheartrate = marker1 / time1
```

Figure 2. Code for determining the first patient's average heart rate.

After computing the average heart rate for all three patients, the following is the resulting values and diagnosis.

Patient No.	Average Heart Rate	Diagnosis
First Patient	137.0343 beats per minute	Tachycardia arrhythmia
Second Patient	67.0261 beats per minute	Healthy / Normal
Third Patient	43.0252 beats per minute	Bradycardia arrhythmia

Next, is to model and graph the electrocardiogram of each patient with the purpose of observing how they behave. The expectation is that the general shape of each patient's ECG graph will resemble the '*PQRST model*'. To determine an approximation of this 'function', it is possible to use the matrix values as points and connect them with lines. Just as before, to simplify the problem the ECG graph can be modelled or represented for instances when point S is present. Therefore, it is necessary to find the corresponding ECG and time value when the marker is equal to 4. Thus, disregarding all other values. This will make the graph less accurate as important points are not considered, but again, this is done for simplicity sake. There is however an issue that while the dimensions of the marker and ECG matrices are equivalent, the same is not true for time. This is problematic since compatibility is necessary to plot the two matrices, so they must share dimension sizes. To solve this, the transpose of each *time matrix* is set as the *new* time matrix specifically for plotting. From there, using *matrix indexing* again, it is possible to set a new matrix for ECG and time values, using their corresponding values when the values in the marker matrix is 4. Then finally, using a 'standard' plot code format to plot the two matrices against each other; with ECG acting as the *y-axis*, and time as the *x-axis*. This process is shown in *Figure 3* for one of the plots, and yet again the same code structure can be repeated for the other two patients.

```
%Patient no. 1 Average ECG Graph Plot
marker1_values = data1.marker==4; %Only use values when the marker is equal to 4
time1_values = transpose(data1.time); %Find transpose so that the dimensions of all matrices are the same

Patient1_ecgvalues = data1.ecg(marker1_values,:); %Find the corresponding ECG values for when the marker is 4
Patient1_timevalues = time1_values(marker1_values,:); %Find the corresponding time values for when the marker is 4

%Plot information (Use LaTeX font for aesthetic)
figure
plot(Patient1_timevalues, Patient1_ecgvalues,'r','MarkerSize',10);
title('Patient No. 1 Average ECG','Interpreter','latex', 'FontSize', 14);
xlabel('Time ($sec$)','Interpreter','latex','FontSize', 12);
ylabel('ECG ($mV$)','Interpreter','latex','FontSize', 12);
```

Figure 3. Code for the first patient's heartbeat during the duration of the ECG test using only points S.

Finally, to compare all three patient's electrocardiograms visually and concisely, a graph can be constructed as shown in *Figure 4*. This is simply done by combining the patient's results and using the *hold on* and *off* function. This will also verify or contradict the previously estimated average heart rate. So, it is clearly shown in the graph that *patient 1*, represented by the red line, has a significantly faster heart rate. Similarly, *patient 3*, represented by the black line, has much lower minimums than the other graphs, showing a slower heart rate.

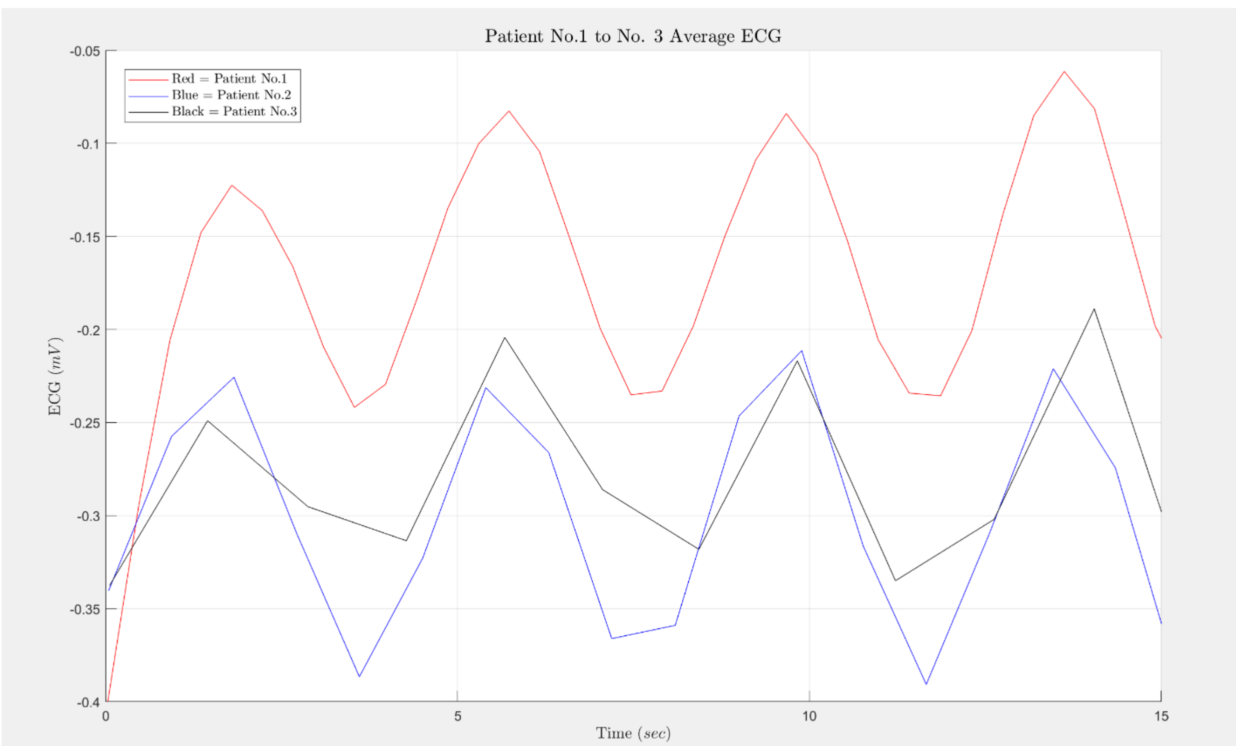

Figure 4. The ECG of each patient; allowing for easy comparison.

Therefore, this compilation of ECGs confirms the trend that was calculated previously, and the physician should be able to properly diagnosis *patient 1* with tachycardia arrhythmia, and *patient 3* with bradycardia arrhythmia.