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MATLAB Final Project

Engineering Problem #1: Analysis of an Annotated ECG Signal

Problem Statement

Considering the ECG signals for three patients comment on the relative cardiac health of these patients. Analyze the measures of heartrate and the average *PR*-interval.

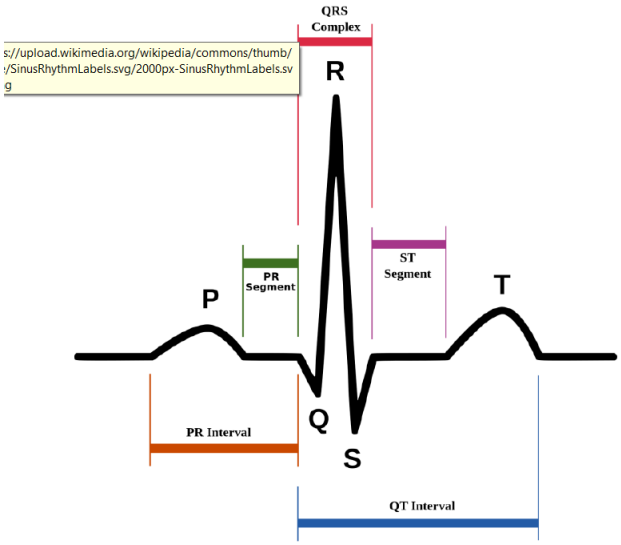

Fig 1. Representation of a normal heartbeat of the human[1].

Background for the Problem Statement

A heart rate between 60 and 100 beats per minute is considered normal. A heart rate slower than 60 beats per minute is said to be bradycardic and a rate faster than 100 beats per minute is said to be tachycardia. (Final Project Instructions)

A normal PR interval is 0.12 to 0.20 s (3 - 5 small squares).

For a short PR segment, consider Wolff-Parkinson-White syndrome or Lown-Ganong-Levine syndrome (other causes - Duchenne muscular dystrophy, type II glycogen storage disease (Pompe's), HOCM).

For long PR interval see first degree heart block and 'trifasicular' block. (ECG Library)

A Description of your Engineering Problem Solving Process

- Addressing each of the four key aspects of Pólya's Problem Solving Process

Step 1: Understanding the Problem

My goal is to comment on the relative cardiac health of three patients based on the provided ECG signals of each patient. The relevant information I am given includes the ECG values, time values, and the marker code annotation that was made by an expert physician. I am also provided a website link which I can use to conduct my analysis of the PR interval and other useful information about ECG signals. The fundamental scientific concepts that I have to use to solve this problem includes basic knowledge about heartbeats and heart activity of patients. The fundamental mathematical

concepts that I would have to use to solve this problem includes knowledge about calculating sums, subtractions, averages and analyzing graphs.

Step 2: Devising a Plan

First, I would import the *ecg.1mat*, *ecg2.mat*, and *ecg3.mat* file which contain three columns: *time* (in seconds), *signal voltage* (mV), and a *marker code* into MatLab Workspace. Second, I would plot the three patient's data of signal voltage (mV) (y-axis) against the time (in seconds) (x-axis). Next, using a for loop, I would import the marker code and plot the five points per each heartbeat on the signal voltage and time graph. Using the peak point number 3, which represents the peak of the R-wave, I would use the find function and the count function to count the number of peak R-waves occur in the data. Next, I would divide this number by the time in seconds and multiply by 60 seconds/minute to get the average heartbeat per minute of each patient. I would compare this value to the range of 60-100 bpm normal values to determine whether the patient has a normal heart rate, or they have a high or low heart rate. To determine the PR interval of each patient, I would find all the peak R-wave points (marker code 3) and the peak P-wave points (marker code 1) and subtract each of their time values. Now, what remains are all the PR interval times. I would use the sum functions and a for loop to add all of these times up, and then I would divide this total time by the number of PR intervals to get the average PR interval time for the patient. Thereafter, I would compare the average PR interval times with the analysis posted on the ECG Library website provided and conduct analysis based off of that information.

Step 3: Carrying Out Your Plan

Below I have included the final MatLab Script and all the relevant plots generated for the project. I have also included comments on the code for a breakdown of each step of the code I used.

Final MatLab Script

```
% First, I loaded the ECG files to workspace using the load
function
load (ecg1.mat); load (ecg2.mat); load (ecg3.mat)
% Now, I need to plot the time against the ECG values for
each patient
% Below are the calculations for the first patient
plot (time1, ecg1);
% This for loop plots the five major point annotations for
each heartbeat
for i=1:5
    mark1=find(marker1==i);
    hold on;
    plot (time1(mark1), ecg1(mark1), ".");
end
title ("Electrical Activity of Patient 1");
xlabel ("Time (seconds)");
ylabel ("Voltage (mV)");
grid on;
```

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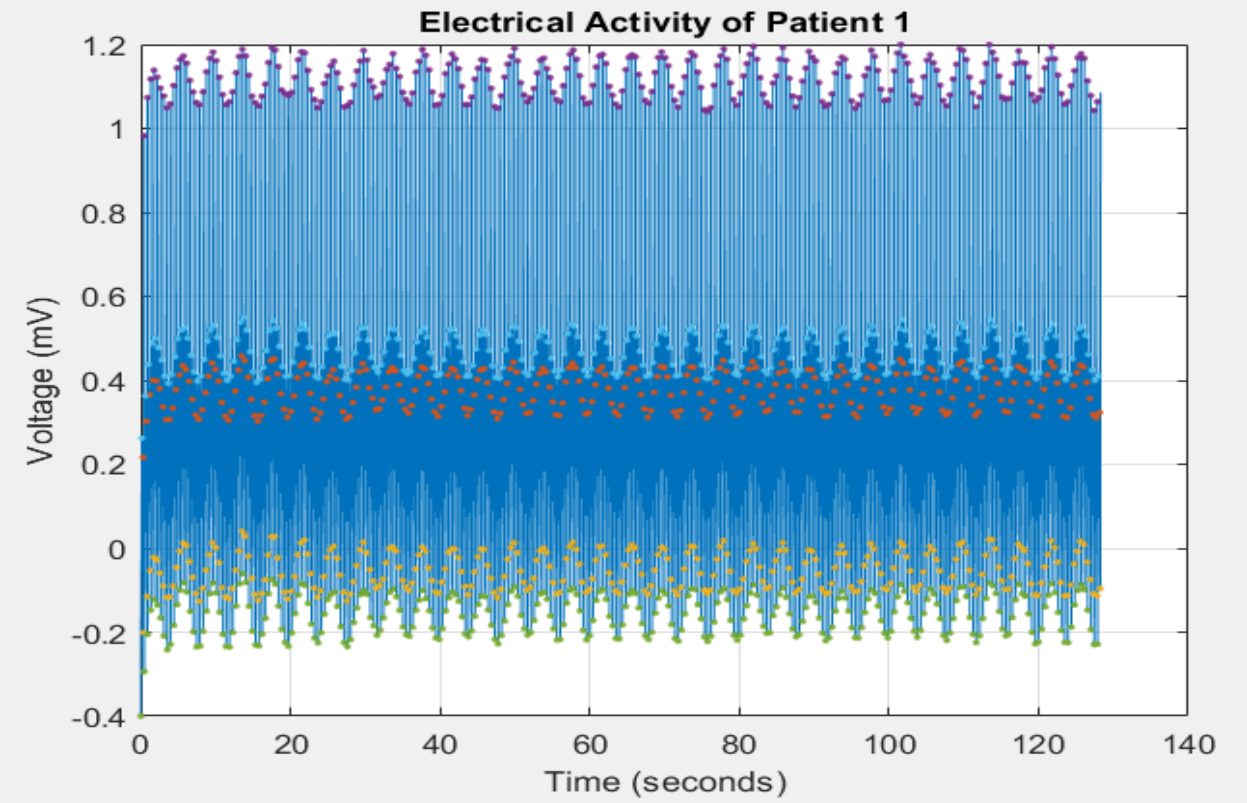
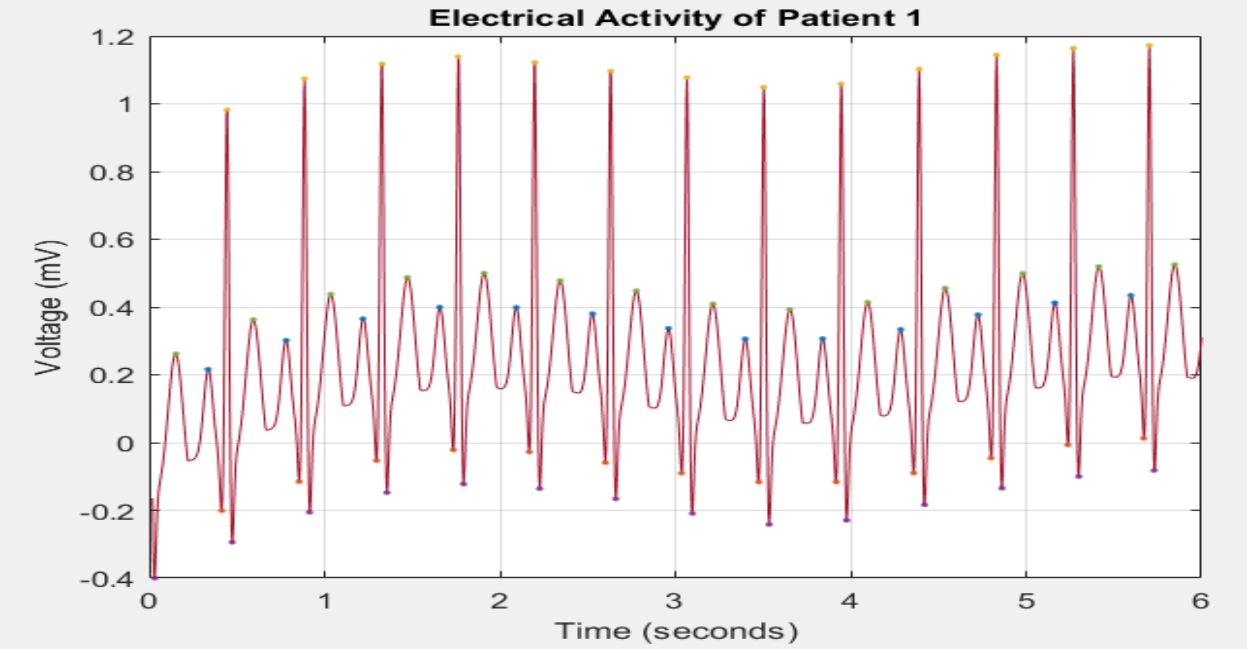



```
figure;
plot (time1, ecg1);
xlim ([0,6]);
```




```
R=find(marker1==3);
count=length(R);
AverageBPMofPatient1 = length(R)/time1(end)*60;
```

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```
% The average heartbeats per minute of patient one is
136.58 which is a higher bpm than the normal range of 60-
100 bpm
% The patient has tachycardia

% I used the P and R peaks and subtracted them from one
another
% I set that value to total PR (tPR1) and summed all values
and divided by the length of tPR to get the average PR
length (avgtPR1)
tP1=find(marker1==1);
tR1=find(marker1==3);
tP1(293)=[];
% The data includes an extra P wave peak with not R wave
peak. This why this value was removed from the data
tPR1=time1(tR1)-time1(tP1);
sum1=0;
for j=1:1:length(tPR1)
    sum1=sum1+tPR1(j);
end
avgtPR1=sum1/length(tPR1);
% The average PR interval (avgtPR1) = 0.1054 seconds
% This is below the 0.12 to 0.20 s average PR range
% This indicates that the patient might have Wolff-
Parkinson-White syndrome or Lown-Ganong-Levine syndrome


% Now, I will do the calculations for the second patient
figure;
plot (time2, ecg2);
for k=1:5
    mark2=find(marker2==k);
    hold on;
    plot (time2(mark2), ecg2(mark2), ".");
end
title ("Electrical Activity of Patient 2");
xlabel ("Time (seconds)");
ylabel ("Voltage (mV)");
grid on;
```

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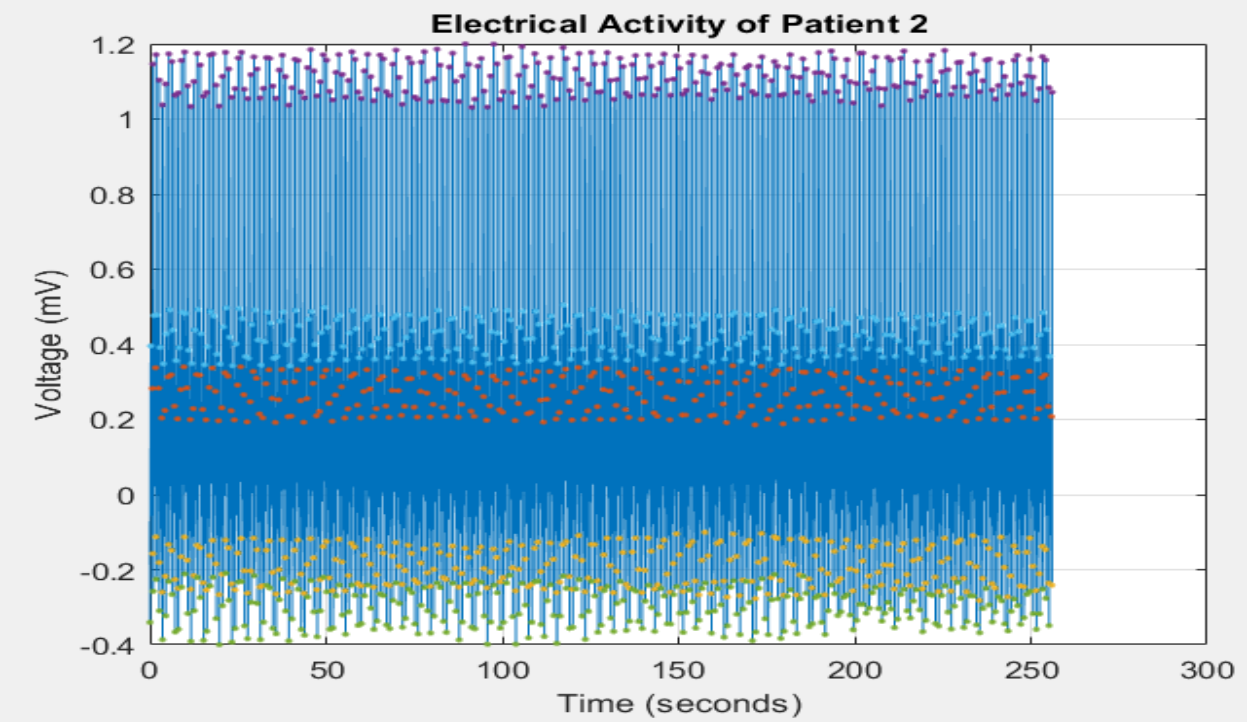
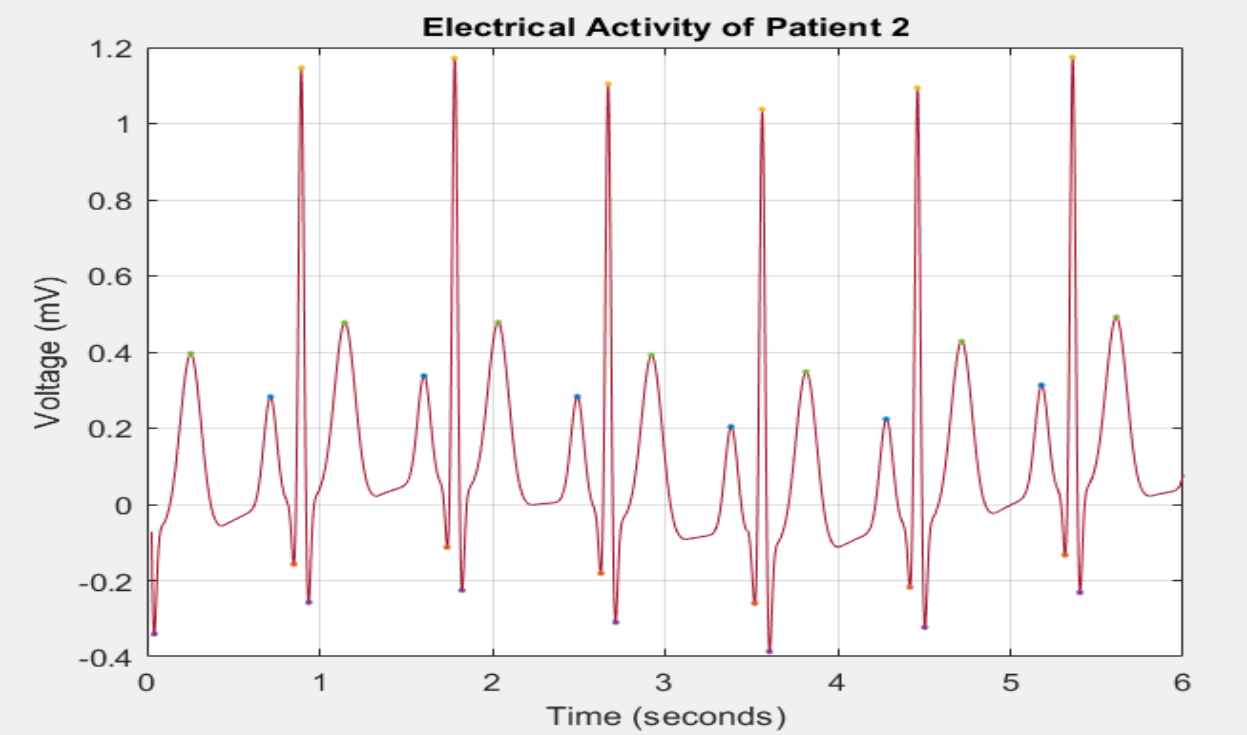



```
figure;
plot (time2, ecg2);
xlim ([0,6]);
```




```
S=find(marker2==3);
count=length(S);
AverageBPMofPatient2 = length(S)/time2(end)*60;
```

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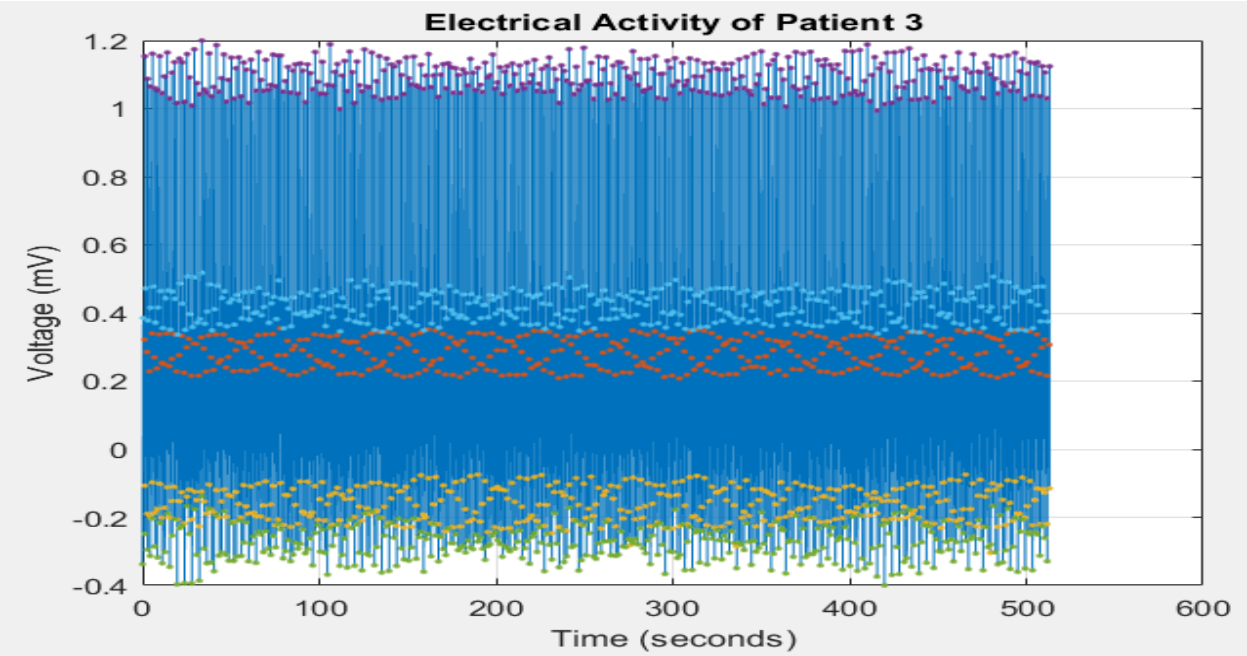
```
% The average heartbeats per minute of patient two is 67.03
% The patient has a normal bpm that is within the range of
60-100bpm

tP2=find(marker2==1);
tR2=find(marker2==3);
tPR2=time2(tR2)-time2(tP2);
sum2=0;
for l=1:1:length(tPR2)
    sum2=sum2+tPR2(l);
end
avgtPR2=sum2/length(tPR2);
% The average PR interval (avgtPR2) = 0.1794 seconds
% This is between the 0.12 to 0.20 s average PR range
% Overall this is a healthy patient

% Now, I will do the calculations for the third patient
figure; plot (time3, ecg3);
for m=1:5
    mark3=find(marker3==m);
    hold on;
    plot (time3(mark3), ecg3(mark3), ".");
end
title ("Electrical Activity of Patient 3");
xlabel ("Time (seconds)");
ylabel ("Voltage (mV)");
grid on;
```



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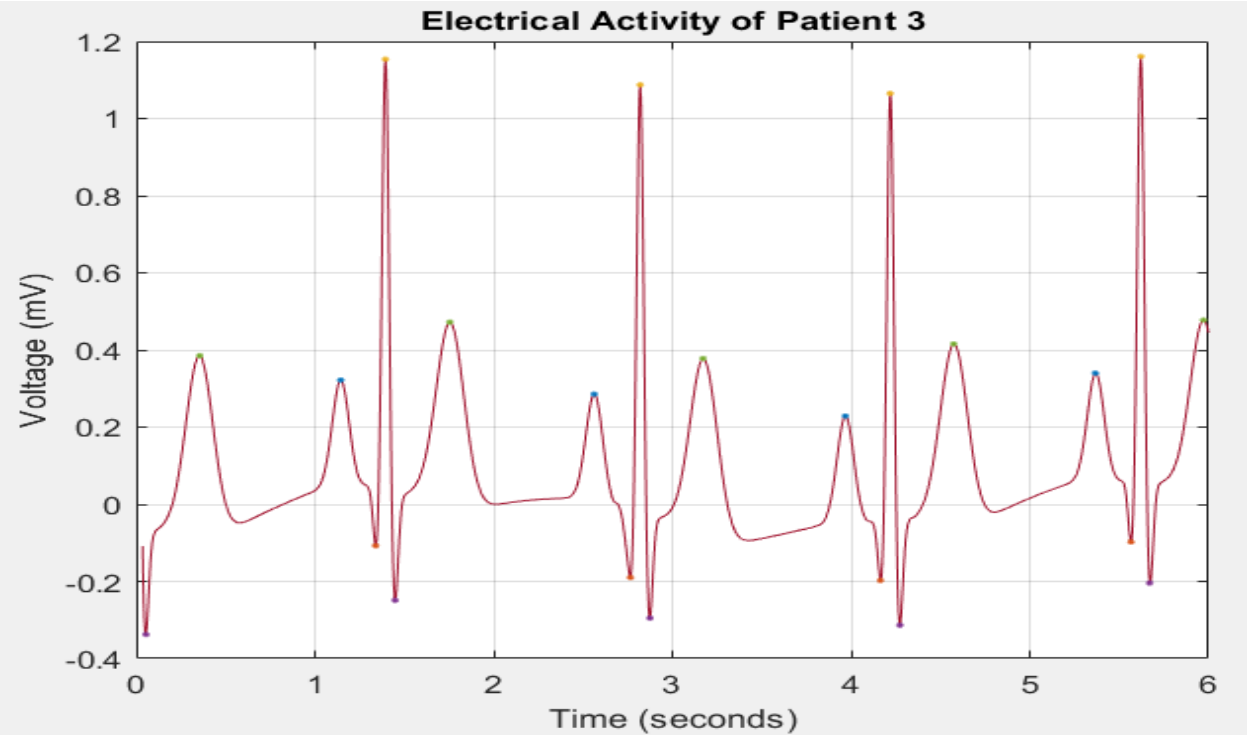
```
figure;
plot (time3, ecg3);
xlim ([0,6]);
```




```
T=find(marker3==3);
count=length(T);
AverageBPMofPatient3 = length(T)/time3(end)*60;
% The average heartbeats per minute of patient three is
43.03
% The patient has a lower bpm that is below the range of
60-100bpm
% The patient has a bradycardic heartbeat

tP3=find(marker3==1);
tR3=find(marker3==3);
tPR3=time3(tR3)-time3(tP3);
sum3=0;
for n=1:1:length(tPR3)
    sum3=sum3+tPR3(n);
end
avgtPR3=sum3/length(tPR3);
% The average PR interval (avgtPR3) = 0.2504 seconds
% This is above the 0.12 to 0.20 s average PR range
% This patient might have first degree heart block and
'trifasicular' block
```

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A brief description of ways in which I had to adapt my plan from that which you originally envisioned in Step 2 above:

There are a lot of minor tweaks and adjustments I had to make along the way when creating the MatLab script. I decided to include two graphs for each patient since the first graph of voltage against time that includes all the data is too compact and uneasy to read. The second graph displayed the voltage against the first 6 seconds to get a more general understanding of the patient's heartbeat activity. I also had to use a lot of relational operators in my script, which I did not originally think that I would use. For the first patient, I was also provided one more value of the P wave, which did not have a corresponding R wave. This is why I had to remove that last data point to find the average PR interval, which I was unable to originally find since the matrices were different sizes. Apart from other minor changes, the functions that I had originally wanted to use, ended up doing what I originally planned for.

Step 4: Looking Back

I know that I have adequately addressed the problem since my MatLab calculations, script, and plots are able to answer the problem statement for the lab. Based on the calculations, I was able to draw conclusions and comment on the relative heart activity of each of the three patients. Within the script, I was also able to use all the requirements for this lab including design parameters (for loops) and plots making sure that I have achieved my goal. I learned several things about the fundamental scientific and mathematical concepts while using MATLAB for engineering problem solving. First of all, I learned that there will be a lot of critical thinking and planning involved during the problem-solving process. Furthermore, this process is very iterative and requires a lot of changing overtime to get the solution to the problem. During this lab, I learned a lot about ECG graphs, which I had not a lot of knowledge about before this lab. I think this is very useful knowledge that might become important later on in life. In general, I learned that I am able to apply all of my current knowledge of problem solving and MatLab skills to solve many complex problems in the world.

Concluding Statement

Considering the ECG signals for three patients and analyzing the average measures of heartrate and the average *PR*-interval I can make the following conclusions.

Patient one has tachycardia since his heartbeat per min is 136.58. It is likely that patient one has Wolff-Parkinson-White syndrome or Lown-Ganong-Levine syndrome since their average PR interval is 0.1054 seconds which is well below the 0.12 to 0.20 s average PR range.

Patient two has a normal heartbeat with 67.03 beats per minute. Patient two also has a normal average PR interval of 0.1794 seconds. Based on these two factors from the ECG signals, patient two has a healthy heartbeat activity.

Patient three has bradycardic heartbeat with an average of 43.03 bpm. This patient also has a very high average PR interval of 0.2504 seconds which is well above the normal 0.12 to 0.20 s average PR range. Based on that, the patient might have first degree hear block and 'trifasicular' block.