ANALYSIS OF ECG SIGNAL AND DETERMINATION OF ABNORMALITY

A "J" COMPONENT PROJECT REPORT

Submitted for the subject

ECE 1004

SIGNALS AND SYSTEMS

By

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CERTIFICATE

This is to certify that the Project work titled "***Analysis of ECG Signals and Deterination of Abnormality***" that is being submitted by "***Meghna, Mayuri and Ipsita"***, is a record of bonafide work done under my guidance.

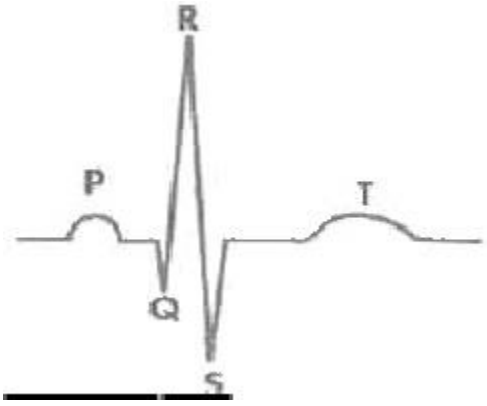
Abstract

Abnormalities are very common problems in the medical world. It is a disease which should be treated immediately which otherwise may result in the death of the patient. For this purpose a detection mechanism is very important. In this project we have tried to write a MATLAB code which takes the heart signals as input and detect if there is any problem with the person's heart. This is a very useful mechanism which is used in the field of medical science to save millions of lives over the years.

1. **Introduction**

The electrocardiogram (ECG) is a diagnostic tool that measures and records the electrical activity of the heart in exquisite detail. Interpretation of these details allows diagnosis of a wide range of heart conditions.
The ECG records this electrical activity and depicts it as a series of graph-like tracings, or waves. The shapes and frequencies of these tracings reveal abnormalities in the heart's anatomy or function
The ECG records the electrical activity that results when the heart muscle cells in the atria and ventricles contract.

- Atrial contractions show up as the P wave.
- Ventricular contractions show as a series known as the QRS complex.
- The third and last common wave in an ECG is the T wave. This is the electrical activity produced when the ventricles are recharging for the next contraction (repolarizing).
- Interestingly, the letters P, Q, R, S, and T are not abbreviations for any actual words but were chosen many years ago for their position in the middle of the alphabet.
- The electrical activity results in P, QRS, and T waves that are of different sizes and shapes. The QRS complex lasts for not more than 0.10 seconds.



<u>Signal Acquisition Challenges:</u>
Noise can be produced in the ECG signal because of the large DC offset and various interference signals that may come from power supplies, motion artifacts due to patient movement, radio frequency interference from electro-surgery equipment, or other monitoring equipment.
For this reason, the noise filtering and DE trending of data is required.
And then further, the peaks are located, R-R intervals are determined, and hence heartbeat is calculated. By comparison, the diseases are found out.

2. Project Description

2.1 Methodology

With the use of MATLAB software the P, Q, R, S peaks have be determined and finally compared with the normal ECG and thus the abnormality has been found.

This includes the following steps:

1. GENERATION OF THE ECG SIGNAL
2. FINDING PEAKS IN THE SIGNAL
3. FINDING PROMINENT PEAKS
4. FILTERING OUT SATURATED PEAKS
5. DETRENDING DATA
6. FINDING QRS COMPLEX
7. DETECTION OF R PEAKS
8. DETECTION OF S PEAKS
9. PLOTTING R AND S PEAKS
10. DETECTION OF Q WAVES
11. THRESHOLDING PEAKS IN SIGNALS
12. ABNORMALITIES IN QRS COMPLEX

About the Abnormalities:

Bradycardia:-Bradycardia is a heart rate below 60 beats a minute. The elderly are more prone to bradycardia. A slow heart rate is not always dangerous. It may cause such symptoms as fainting, dizziness, light-headedness and fatigue. If the pumping action of the heart is severely depressed, then the blood does not circulate as it should and organ damage may result. Treatment may include the use of a cholinergic blocking agent such as atropine. If medication does not regulate the heartbeat, then an artificial pacemaker may be surgically implanted.

Tachycardia:-A heart that beats more than 100 times per minute is a condition known as tachycardia and is most prevalent in the elderly. According to medrounds.org, 88 percent of those over the age of 70 have experienced a type of fast heart rate called sinus tachycardia. Some circumstances can bring about this kind of fast heart rate including shock, pain, anemia, exercise and strong emotion. Some beverages and medications may also cause a rapid heart rate including coffee, tea, alcohol, epinephrine, isoproterenol and atropine. The symptoms of tachycardia include dizziness, heart palpitations and sometimes chest pain.

2.2 MATLAB Code & Explanation

```
close all;
clear all;
clc;
%%Select a filename in .mat format and load the file.
%[fname path]=uigetfile('*.mat');
%fname=strcat(path,fname);
%y1 = load(fname );
%file =load('I:\BIOM_Signal_processing\Hw5\ECGsignal_1.mat')
load('C:\Users\Mayuri V\Desktop\samples (12).csv')
disp('Contents of workspace after loading file:')
whos
fs = 250; % find the sampling rate or frequency
y1=csvread('C:\Users\Mayuri V\Desktop\samples (12).csv');
T = 1/fs;% sampling rate or frequency
% find the length of the data per second
N = length(y1);
ls = size(y1);
t = (0 : N-1) / fs;% sampling period
%t = (0 : N-1) *T;
%t = (0:1:length(y1)-1)/fs;
%subplot (2,2,2)
%plot (t,data);
figure; %subplot(1,2,1);
      plot(t,y1);
    %plot(x,y2, 'g');
title ('plot of the original of ECG signal')
xlabel ('time (sec)')
ylabel ('Amplitute (mv)')
grid on;

y1_n=(y1-min(y1))/(max(y1)-min(y1));          % normalize between 0-1
fnyquist = fs/2;

%% find P
m1=max(y1)*.60;
P=find(y1>=m1);
y1_1500 = y1(1:1000);
t2 = 1:length(y1_1500);
figure;
plot(t2,y1_1500);
title ('plot of subset of the ECG signal')
xlabel ('time (msec)')
ylabel ('Amplitute (mv)')
grid on
%% used the snip code from this website.
%%%%http://www.mathworks.com/help/signal/examples/peak-analysis.html
%Detrending Data
%The above signal shows a baseline shift and therefore does not represent the true
amplitude. In order to remove the trend, fit a low order polynomial to the signal and
use the polynomial to detrend it.
[p,s,mu] = polyfit((1:numel(y1_1500))',y1_1500,6);
f_y = polyval(p,(1:numel(y1_1500))',[],mu);
ECG_data = y1_1500 - f_y;         % Detrend data
```

```
N1= length (y1_1500);
t1 = (0 : N1-1) / fs;% sampling period
figure
%plot(t1,ECG_data); grid on
plot(t2,ECG_data); grid on
ax = axis; axis([ax(1:2) -2.2 2.2])
%ax = axis; axis([ax(1:2) -3.2 3.2])
title('Detrended ECG Signal')
xlabel('time msec'); ylabel('Voltage(mV)')
legend('Detrended ECG Signal')

%Thresholding to Find Peaks of Interest
%The QRS-complex consists of three major components: Q-wave, R-wave, S-wave. The R-
waves can be detected by thresholding peaks above 0.5mV. Notice that the R-waves are
separated by more than 200 samples. Use this information to remove unwanted peaks by
specifying a 'MinPeakDistance'.

[~,locs_Rwave] = findpeaks(ECG_data,'MinPeakHeight',0.5,...
                                    'MinPeakDistance',120);
%Finding Local Minima in Signal

%Local minima can be detected by finding peaks on an inverted version of the original
signal.
ECG_inverted = -ECG_data;
[~,locs_Swave] = findpeaks(ECG_inverted,'MinPeakHeight',0.4,...
                                        'MinPeakDistance',120);
%The following plot shows the R-waves and S-waves detected in the signal.
figure
hold on
plot(t2,ECG_data);
plot(locs_Rwave,ECG_data(locs_Rwave),'rv','MarkerFaceColor','r');
plot(locs_Swave,ECG_data(locs_Swave),'rs','MarkerFaceColor','b');
%axis([0 1850 -1.1 1.1]); grid on;
axis([0 1850 -2.2 2.2]); grid on;
legend('ECG Signal','R-waves','S-waves');
xlabel('time msec'); ylabel('Voltage(mV)')
title('R-wave and S-wave in ECG Signal')

[~,locs_Twave] = findpeaks(ECG_data,'MinPeakHeight',-0.02,...
                                     'MinPeakDistance',50);
figure;
hold on
plot(t2,ECG_data);
plot(locs_Twave,ECG_data(locs_Twave),'X','MarkerFaceColor','y');
plot(locs_Rwave,ECG_data(locs_Rwave),'rv','MarkerFaceColor','r');
plot(locs_Swave,ECG_data(locs_Swave),'rs','MarkerFaceColor','b');
grid on
title('Thresholding Peaks in Signal')
xlabel('time msec'); ylabel('Voltage(mV)')
ax = axis; axis([0 1850 -2.2 2.2])
legend('ECG signal','T-wave','R-wave','S-wave');

[~,locs_Pwave] = findpeaks(ECG_data,'MinPeakHeight',-0.09,...
                                     'MinPeakDistance',25);
figure;
hold on
```

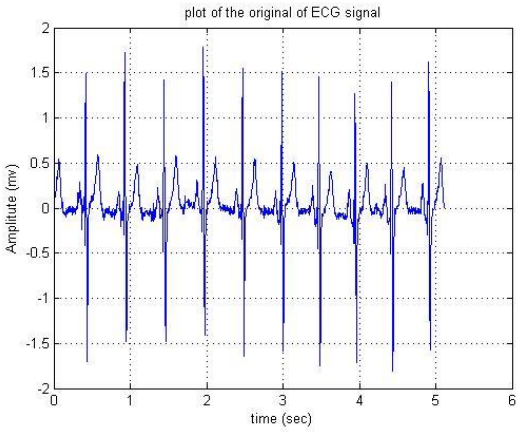
```
plot(t2,ECG_data);
plot(locs_Pwave,ECG_data(locs_Pwave),'x','MarkerFaceColor','y');
plot(locs_Twave,ECG_data(locs_Twave),'X','MarkerFaceColor','g');
plot(locs_Rwave,ECG_data(locs_Rwave),'rv','MarkerFaceColor','r');
plot(locs_Swave,ECG_data(locs_Swave),'rs','MarkerFaceColor','b');
grid on
title('Thresholding Peaks in Signal')
xlabel('time msec'); ylabel('Voltage(mV)')
ax = axis; axis([0 1850 -2.2 2.2])
legend('ECG signal','P-wave','T-wave','R-wave','S-wave');


[~,locs_qwave] = findpeaks(ECG_data,'MinPeakHeight',-0.2);
figure;
hold on
plot(t2,ECG_data);
plot(locs_qwave,ECG_data(locs_qwave),'x','MarkerFaceColor','y');
% link and zoom in to show the changes
%linkaxes(ax(1:2),'xy');
%axis(ax,[60 230 0.006 -0.04])



%Next, we try and determine the locations of the Q-waves. Thresholding the peaks to
locate the Q-waves results in detection of unwanted peaks as the Q-waves are buried
in noise. We filter the signal first and then find the peaks. Savitzky-Golay
filtering is used to remove noise in the signal.
smoothECG = sgolayfilt(ECG_data,1,3);
figure
plot(t2,ECG_data,'b',t2,smoothECG,'r'); grid on
axis tight;
xlabel('time msec'); ylabel('Voltage(mV)');
legend('ECG Signal','Filtered Signal')
title('Filtering Noisy ECG Signal')

%We perform peak detection on the smooth signal and use logical indexing to find the
locations of the Q-waves.
%[~,min_locs] = findpeaks(-smoothECG,'MinPeakDistance',29);
%[~,min_locs] = findpeaks(smoothECG,'MinPeakDistance',2);%Twave
[~,min_locs] = findpeaks(smoothECG,'MinPeakDistance',50);
% Peaks between -0.2mV and -0.5mV
%locs_Qwave = min_locs(smoothECG(min_locs)>-0.3 &
%-smoothECG(min_locs)<-0.1); %Twave
locs_Qwave = min_locs(smoothECG(min_locs)>-0.3 & -smoothECG(min_locs)<-0.11);

figure
hold on
plot(t2,smoothECG);
plot(locs_Qwave,smoothECG(locs_Qwave),'rs','MarkerFaceColor','g');
plot(locs_Rwave,smoothECG(locs_Rwave),'rv','MarkerFaceColor','r');
plot(locs_Swave,smoothECG(locs_Swave),'rs','MarkerFaceColor','b');
grid on
title('Thresholding Peaks in Signal')
xlabel('time msec'); ylabel('Voltage(mV)')
ax = axis; axis([0 1850 -2.2 2.2])
```

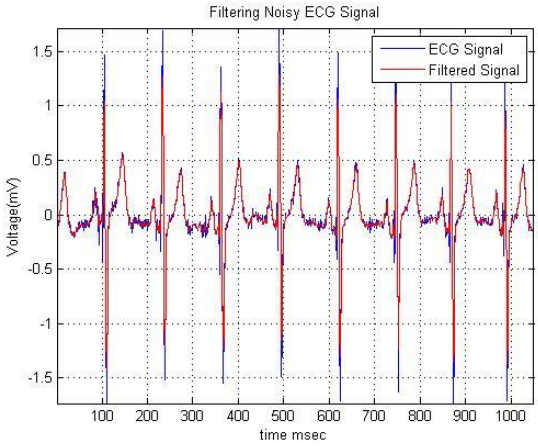
```
legend('Smooth ECG signal','T-interval','R-wave','S-wave');

%The above figure shows that the QRS-complex successfully detected in the noisy ECG
signal.
%Error Between Noisy and Smooth Signal
%Notice the average difference between the QRS-complex in the raw and the detrended
filtered signal.

% Values of the Extrema
[val_Qwave, val_Rwave, val_Swave] = deal(smoothECG(locs_Qwave),
smoothECG(locs_Rwave), smoothECG(locs_Swave));

meanError_Qwave = mean((y1_1500(locs_Qwave) - val_Qwave))
meanError_Rwave = mean((y1_1500(locs_Rwave) - val_Rwave))
meanError_Swave = mean((y1_1500(locs_Swave) - val_Swave))

%% find PP interval
 i = 0;  %% to make the code start from 0.
 rr = 0; %% each time the code run, rr distance two peaks
 hold off % for the next graph
 rrinterval = zeros(3600,1); % create an array to strore 2 peaks
beat_count =0;
for k = 2 : length(y1)-1
    %the peak has to be greater than 1 and greater than the value before it and
greater then the value after it.
    if(y1(k)> y1(k-1) && y1(k) > y1(k+1) && y1(k)> 1);
     beat_count = beat_count +1;
     if beat_count ==1;
        rr =0;
     else
         rr = k-i;
         rrinterval(k)=rr;
         i=k;
     end
    else
        rrinterval(k)= rr;
    end
end

figure;
plot (rrinterval);
xlabel('Time in sec*10^-2'), ylabel('Distance betweeen 2 Heatbeats (R-R) in sec*10^-
2'), title('R-R intervals');

%% find PP interval
%% heart rate analysis
% count the dominat peak
beat_count =0;
for k = 2 : length(y1)-1
    %the peak has to be greater than 1 and greater than the value before it and
greater then the value after it.
    if(y1(k)> y1(k-1) && y1(k) > y1(k+1) && y1(k)> 1)
         beat_count = beat_count +1;
    end
end
display (k);
```

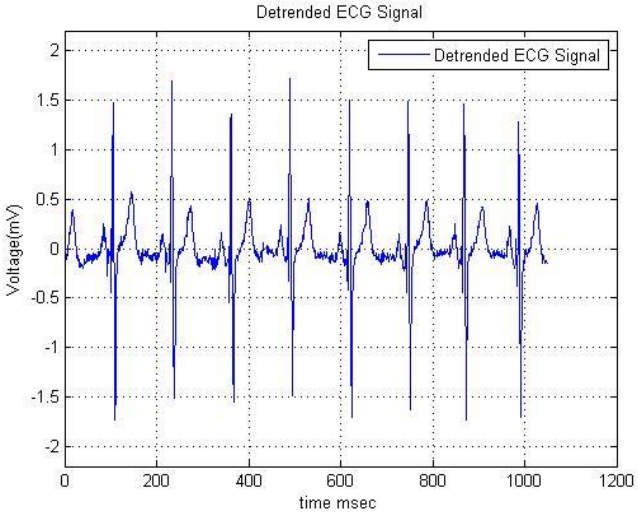
```
disp('dominant peaks');
%% divide the peak count by the duration in minute
duration_in_sec = N/fs;
duration_in_minute = duration_in_sec/60;
BPM = beat_count/duration_in_minute;
heartbeat=BPM
disp('Heartbeat=');
disp(heartbeat);

%%%  DFT to describe the signal in the frequency
NFFT = 2 ^ nextpow2(N);
Y = fft(y1, NFFT) / N;
f = (fs / 2 * linspace(0, 1, NFFT / 2+1))'; % Vector containing frequencies in Hz
amp = ( 2 * abs(Y(1: NFFT / 2+1))); % Vector containing corresponding amplitudes
figure;
plot (f, amp);
title ('plot single-sided amplitude spectrume of the ECG signal')
xlabel ('frequency (Hz)')
ylabel ('|y(f)|')
grid on;

max_value=max(y1);
mean_value=mean(y1);
threshold=(max_value-mean_value)/2;
if(heartbeat>100)
    disp('Tachychardia')
else if(heartbeat<60)
    disp('Bradycardia')
    end
end
```

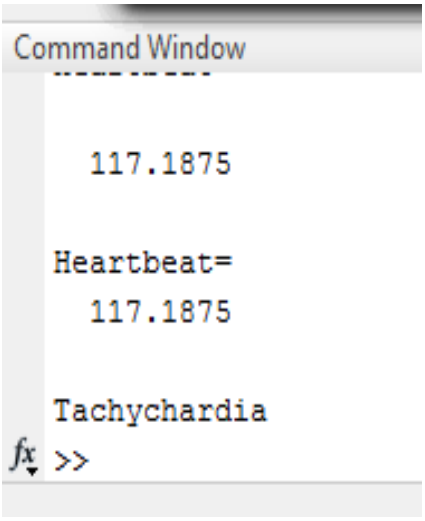
3. Project Description

Sample 10:

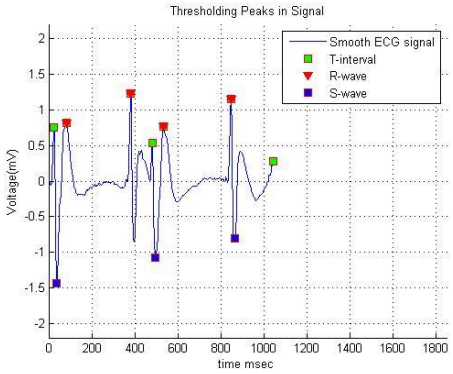


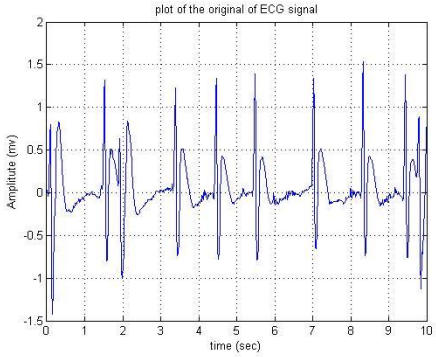


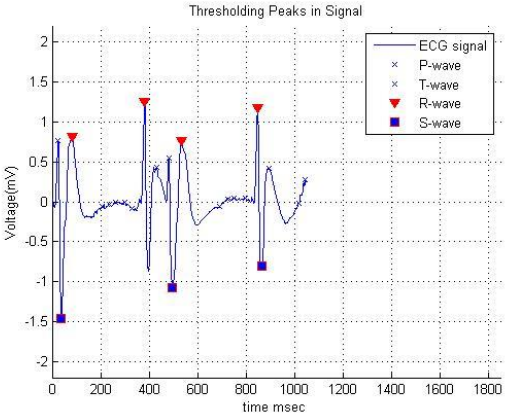


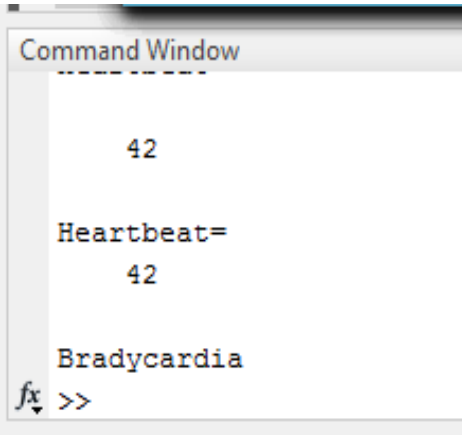


Sample 21:

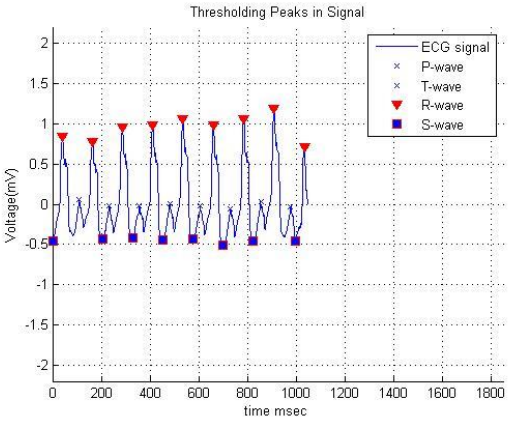

Thresholding Peaks in Signal
Smooth ECG signal
T-interval
R-wave
S-wave
Voltage(mV)
time msec

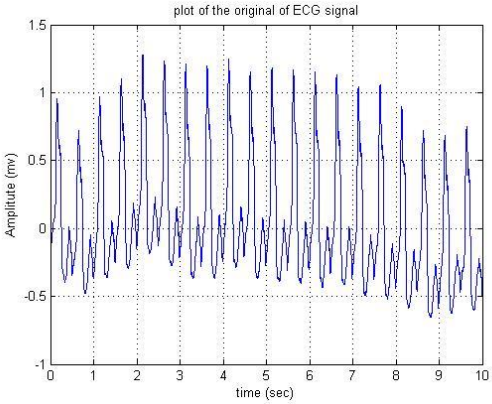

plot of the original of ECG signal
Amplitute (mv)
time (sec)


Thresholding Peaks in Signal
ECG signal
P-wave
T-wave
R-wave
S-wave
Voltage(mV)
time msec


Command Window
42
Heartbeat=
42
Bradycardia
>>

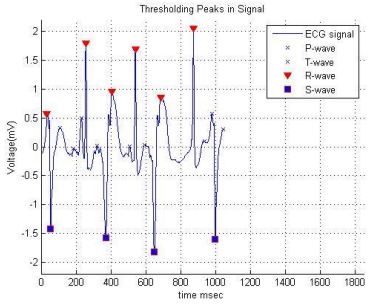
Sample 22:

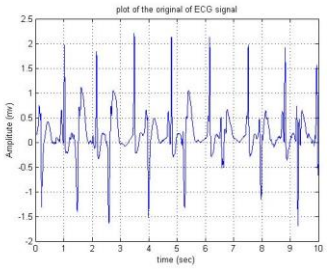

Thresholding Peaks in Signal
ECG signal
P-wave
T-wave
R-wave
S-wave
Voltage(mV)
time msec


plot of the original of ECG signal
Amplitute (mv)
time (sec)

```
Command Window

heartbeat =

    72

Heartbeat=
    72

fx >>
```

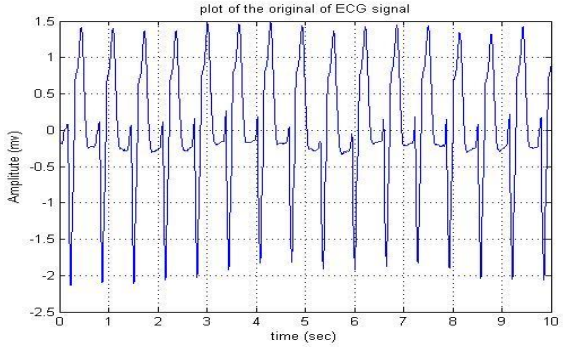
Sample 23:

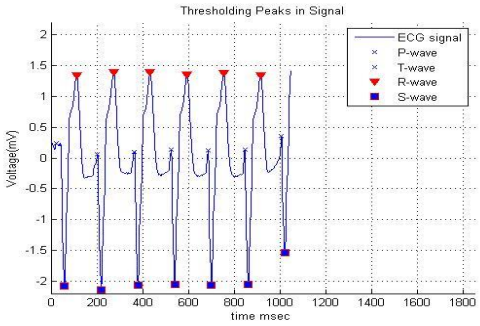





```
Command Window

heartbeat =

    72

Heartbeat=
    72

fx >>
```

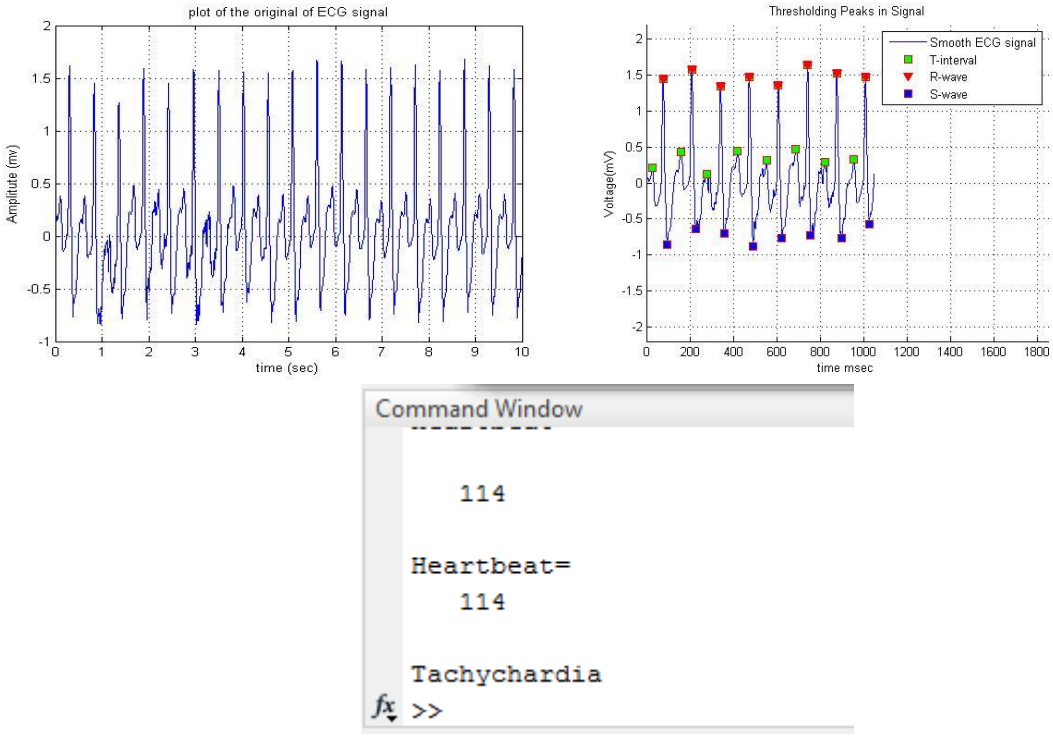
Sample 24:






```
Command Window

    48

Heartbeat=
    48

Bradycardia
fx >>
```

Sample 25:



4. Result

- We have compared the output for the sample data with that of a normal heart's data.
- Here, we have included the comparison of the PQRS peaks, R-R intervals, and the heart rate.
- Based on the differences, we found out the abnormality possessed by that person.
- We processed 20 different ECG signals of patients of age greater than 60 and we got the correct output for the type of abnormality present, although exceptions might be there as in the case of athletes, 40 bmp is a normal heartbeat.
- We identified whether the Heartbeat was normal or not. Abnormalities detected were Bradycardia and Tachychardia.

5. Conclusion

- The concept of ECG signal analysis helped us to understand signal processing in a better way.
- We used the plot of variation of heart beat with respect to time to study the movement of heart muscles.
- The ECG records the electrical activity of the heart and depicts it as a series of graph-like tracings, or waves. The shapes and frequencies of these tracings reveal abnormalities in the heart's anatomy or its function.
- The proposed method of ECG signal analysis can be of immense biomedical use as we can detect the abnormality present in the signal by the method of signal processing.