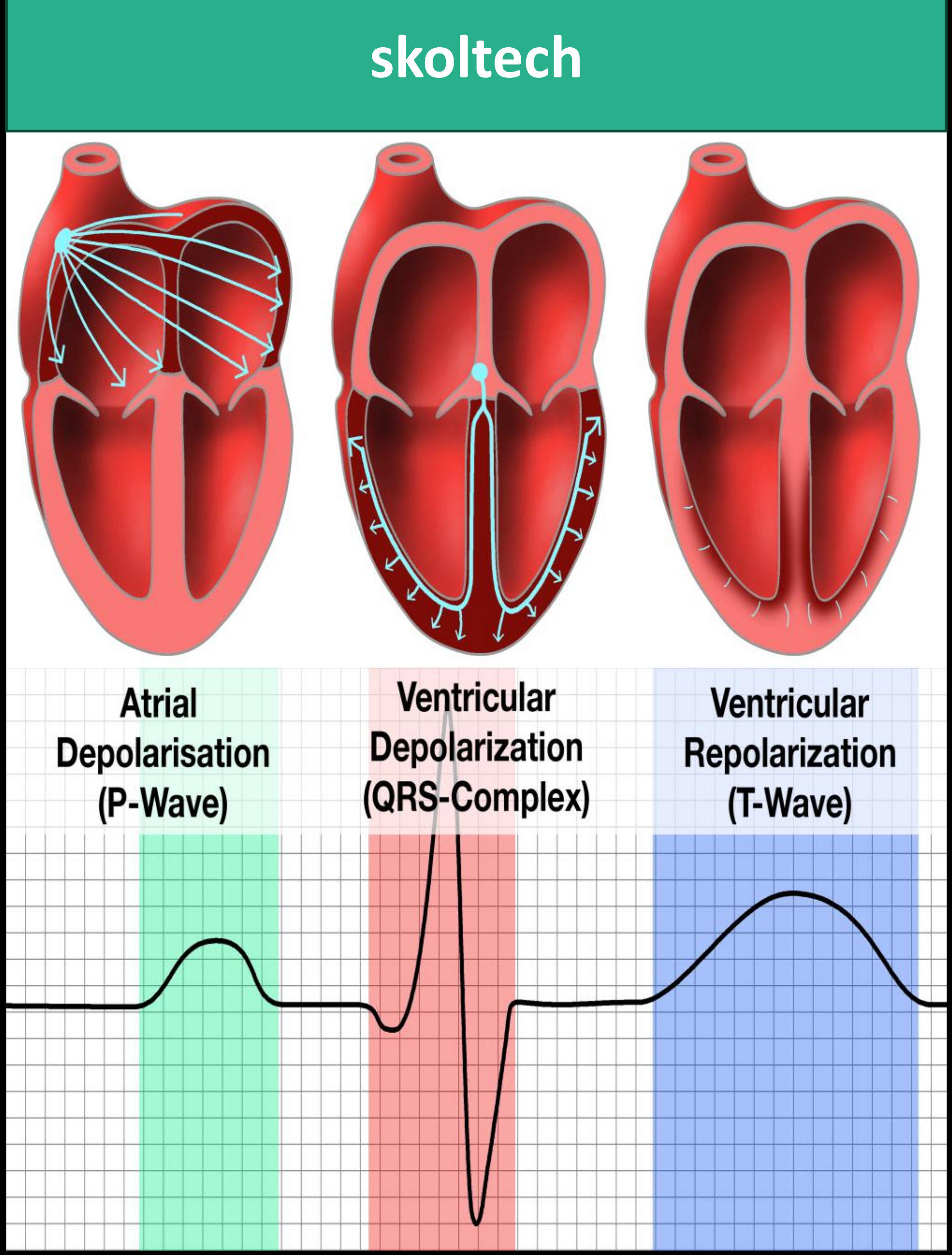
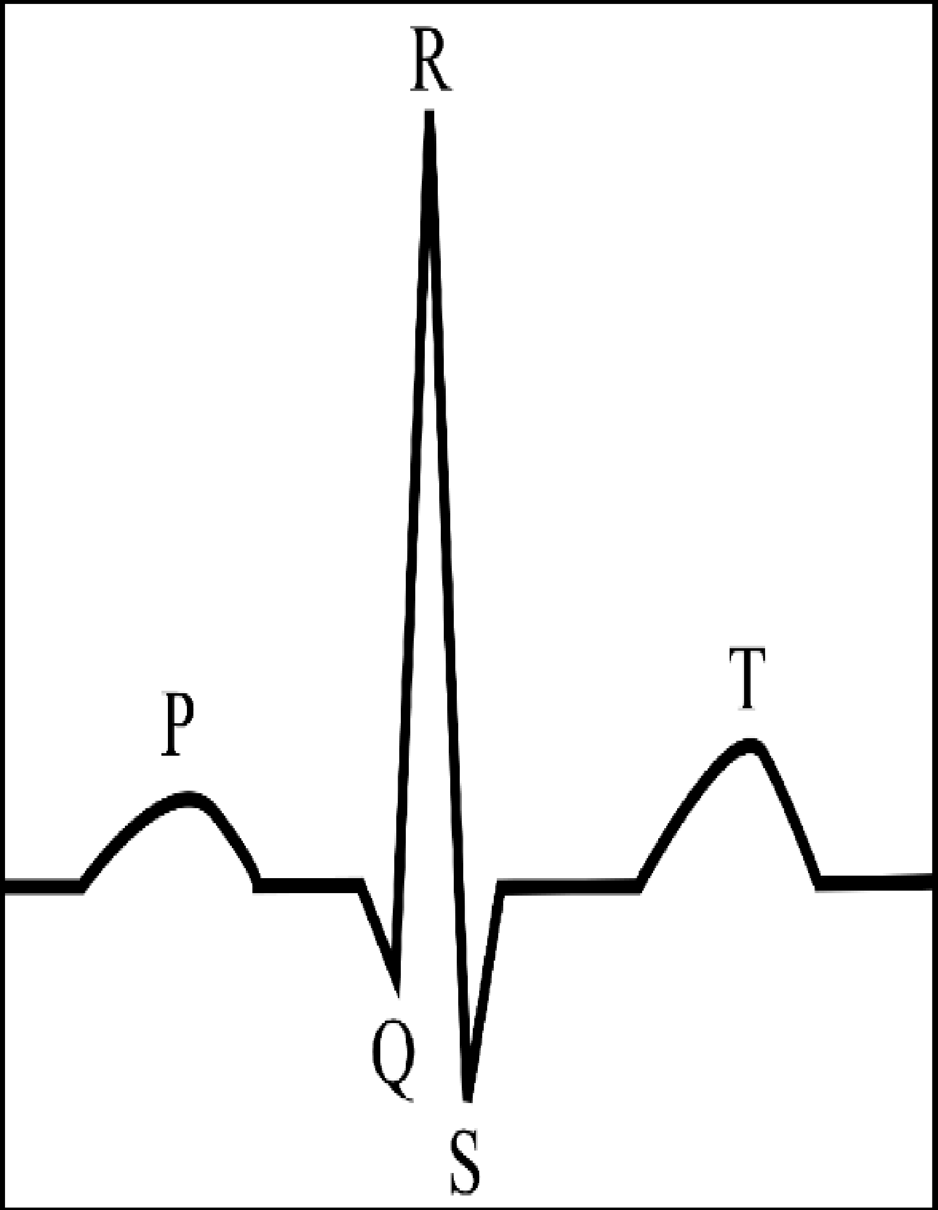



# Peak detection of ECG signal for betterment of heart diseases diagnosis

By Addisu A Zena




# Objective

Detecting peak of electrocardiographic signal for Heart diseases diagnosis

# Introduction:

- Heart-related ailments stand as a predominant cause of mortality on a global scale. As reported by the World Health Organization (WHO) in the 2018 World Health Report [1], cardiovascular diseases accounted for 17.9 million fatalities.
- In response to this concerning trend, there has been a growing emphasis on automated electrocardiogram (ECG) analysis for disease prevention.
- The ECG serves as a pivotal diagnostic tool, playing an indispensable role in clinical cardiology.
- It captures and records electrical signals emanating from the heart's activities throughout its cardiac cycles.
- The ECG trace reveals distinctive deflections arising from the activation, depolarization, and repolarization of cardiac cells (P-QRS-T) [2-3].
- Widely adopted by medical professionals, the ECG is a fundamental noninvasive instrument for diagnosing heart conditions [2]. Hence, the utilization and meticulous processing of ECG signals emerge as crucial components in the realm of healthcare.

# Application

- Electrocardiogram (ECG) signal peak detection plays a crucial role in analyzing heart activity.
- The primary application is in the field of cardiology for diagnosing and monitoring heart conditions.

**Here's a brief overview:**

- 1. **Diagnosis of Cardiac Disorders:** ECG peak detection helps identify important features like the P, Q, R, S, and T waves. Abnormalities in these waves can indicate various cardiac disorders such as arrhythmias, ischemia, or myocardial infarction.
- **2. Heart Rate Measurement:** By detecting R-peaks (the highest point in the QRS complex), one can calculate the heart rate. Monitoring heart rate variations is essential for understanding the heart's condition and response to different activities or medications.
- **3. Arrhythmia Detection:** Analyzing the intervals between peaks aids in identifying irregular heart rhythms or arrhythmias. This is crucial for early detection and intervention in conditions like atrial fibrillation.

# Conti…..

- **4. Holter Monitoring:** Continuous ECG monitoring over an extended period (Holter monitoring) relies on accurate peak detection to assess heart activity throughout daily life, providing a comprehensive view of cardiac health.
- **5. Exercise Stress Testing:** During stress tests, ECG peak detection helps assess the heart's response to physical exertion. Abnormal peaks or patterns can indicate potential issues.
- **6. Remote Patient Monitoring:** With advancements in technology, ECG devices can now transmit data for remote monitoring. Accurate peak detection facilitates real-time assessment without the need for frequent hospital visits.
- **7. Research and Clinical Studies:** ECG peak detection is crucial for researchers studying cardiac physiology, drug effects, and the impact of various interventions on the heart.[1]

# Back ground

- various signal processing techniques are employed for peak detection.
- Algorithms, such as Pan-Tompkins, Wavelet Transform, and machine learning models, are commonly used to enhance accuracy and automate the process.
- These methods analyze the amplitude, frequency, and temporal characteristics of the ECG signal to identify key peaks.

- Overall, ECG peak detection is fundamental for both clinical diagnosis and ongoing monitoring of cardiac health, contributing significantly to the field of cardiology.

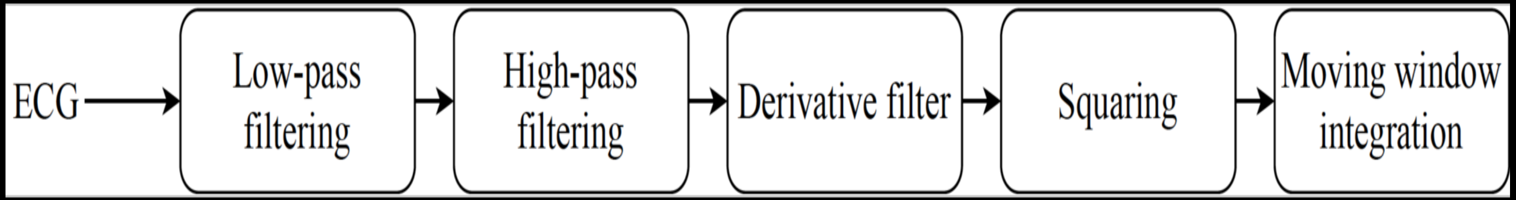
# Problem statement

Implemented algorithm like pan Tompkins has limitation,

- Limitation of pan and Tompkins: removal of important  signal components:
- In the Pan-Tompkins algorithm, the low-pass and high-pass filters are cascaded to achieve around 5–15 Hz passband.

# Existing solution

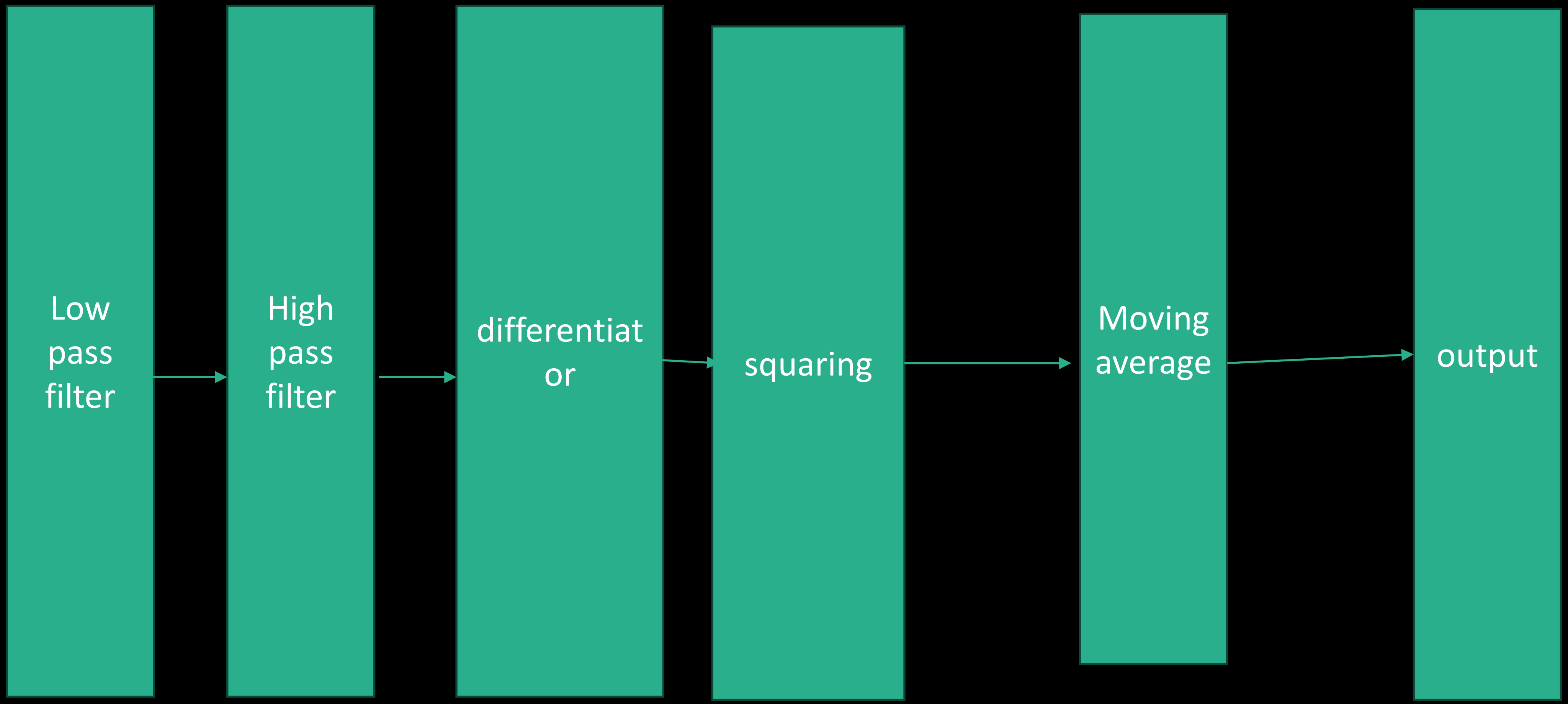
- Applying series of filter to remove noise
- Square signal to amplify peak.
- Adaptive threshold to detect peaks




- $H(z) = \frac{(1 - z^{-6})^2}{(1 - z^{-1})^2}$ for a second-order low-pass filter with a gain of 36 and a processing delay of 5 samples;
- $H(z) = \frac{(-1/32 + z^{-16} - z^{-17} + z^{-32}/32)}{(1 - z^{-1})}$ for a high-pass filter with a unity gain and a processing delay of 16 samples.

$H(z) = 0.1(-z^{-2} - 2z^{-1} + 2z^{1} + z^{2})$ for a 5-point derivative filter with gain of 0.1 and a processing delay of 2 samples.

Source:https://en.wikipedia.org/wiki/Pan%E2%80%93Tompkins_algorithm#/media/File:Pan-Tompkins_algorithm_BlockDiagram.png


Low pass filter
High pass filter
differentiator
squaring
Moving average
output

1 **Low pass filter**: eliminate noise such as 50hz power line noise

$$Y(n)=2y(n-1)-y(n-2)+x(n)-2x(n-6)+x(n-12)$$

2 **High pass filter** : eliminate lower frequency components such as motion artifacts,pwave,and T wave)

$$Y(n)=y(n-1)-x(n)/32+x(n-16)-x(n-17)+x(n-32)/32$$

3 **Differentiator**: to obtain information on slope and overcome base line drift problem.

$$8y(n)=2x(n)+x(n-1)-x(n-3)-2(x-4)$$

**4** **Squaring** :Emphasis higher frequency component and attenuate lower frequency component .$y(n)=x(n)^2$

5 **Moving average** : acts as to smooth the signal

$$Y(n)=(x(n-(N-1))+x(n-(N-2)+................x(n))/N$$

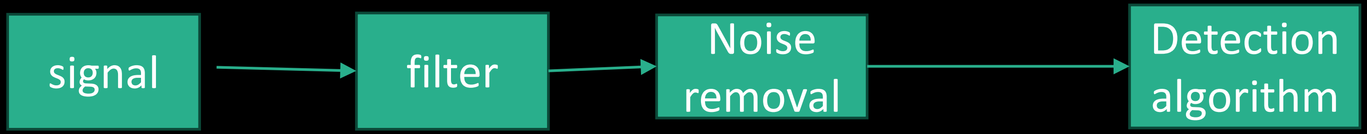
Where N=length of filter

# Proposed solution

- Adaptive thresholding:
- We have to initialize the threshold
- Take Max of the 1st sampling point .
- Define two kind of peak:1 signal peak , 2 noise peak
- Max value=max(input(1:N))
- Spk=0.13*maxvalue
- Npk=0.1*spk
- Th=0.25*spk+0.75*NPK
- Peak>threshold, mark as qrs complex
- Peak value<th, mark as noise.
- opt to utilize a bandpass filter with a passband of 5–18 Hz. This preserves the significant signal components within 15–18 Hz.
- Try 5-17,5-16 hz, at least  to preserve some important signal component.

# Data Preprocessing

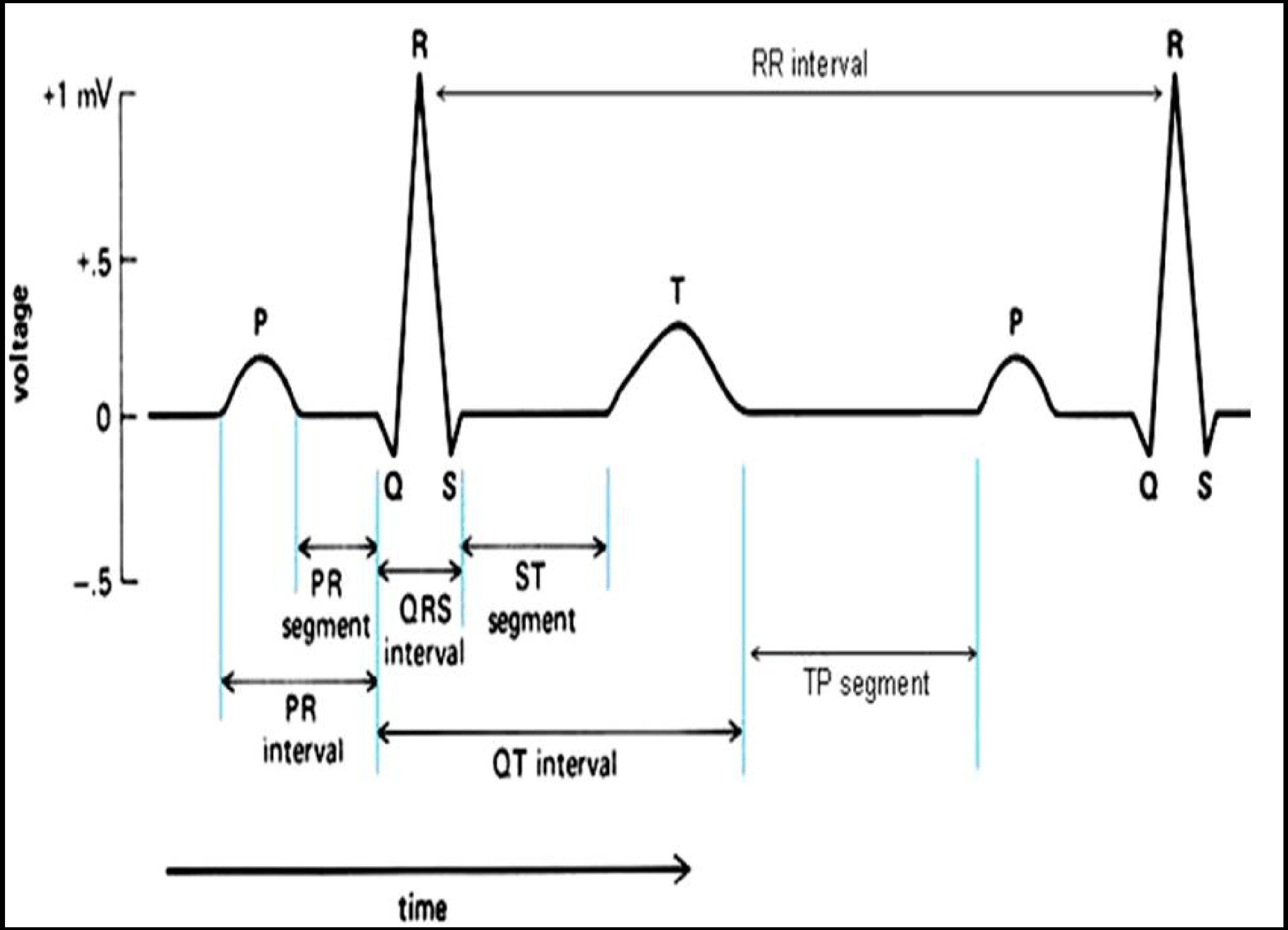
- Usually for ECG signal, the frequency range over 80Hz is noise. So first, we need to remove this high frequency part.
- Next, in ECG signal, there is also one critical noise that is called POWER LINE NOISE. Since every electrical device is based on the power line of your grid (in your country 50Hz or 60Hz).
- Because of this, in bio-metric signals like ECG or EEG based on this grid power, there is always noise of 50Hz (or 60Hz , it depends on country).
- So that by using notch filter for 50Hz, we can remove this noise.




Source data: https://www.physionet.org/content/mitdb/1.0.0/

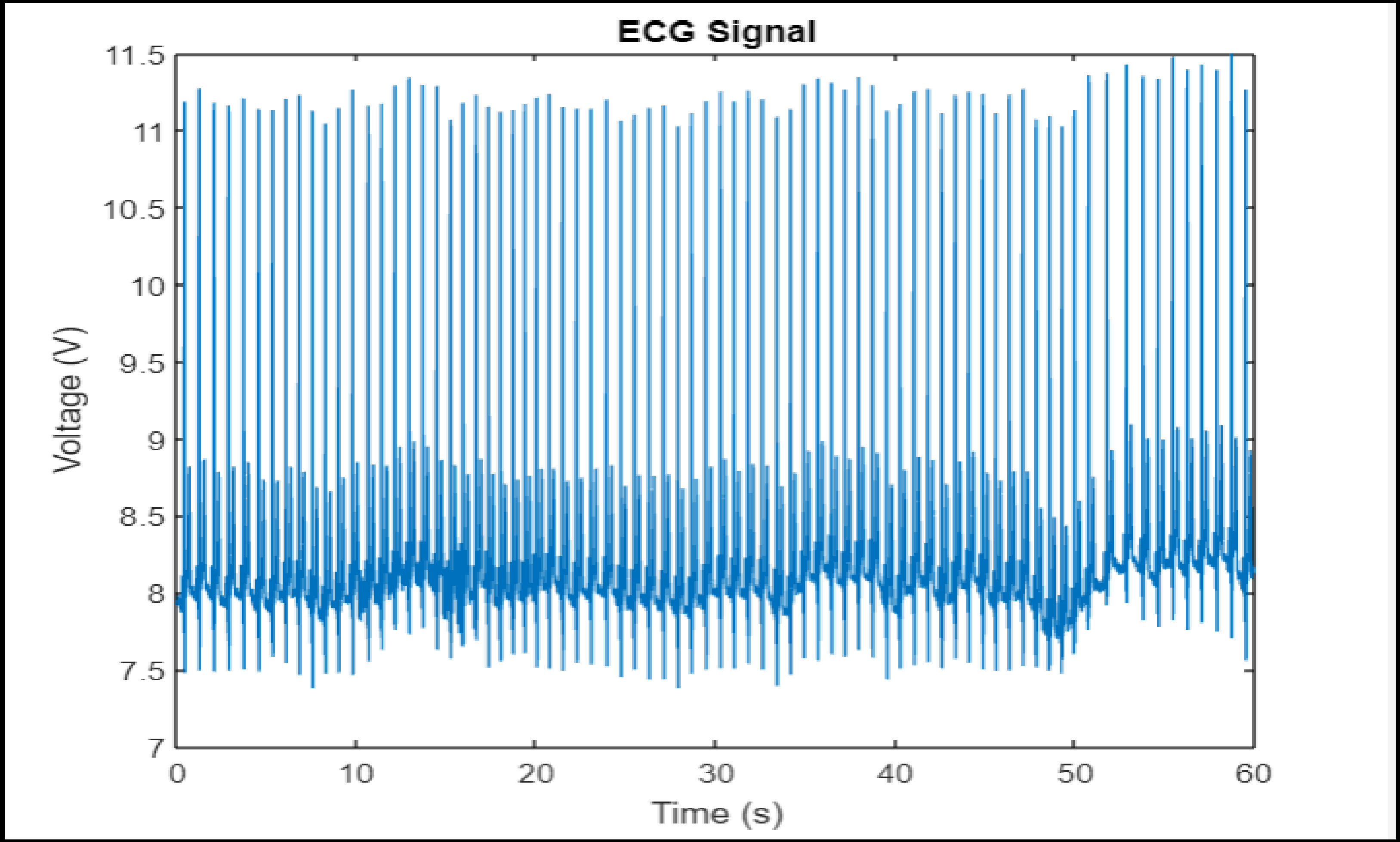
# Data Preprocessing –

The QRS complex is composed by a downward deflection (Q wave), a high upward deflection (R wave) and a final downward deflection (S wave).

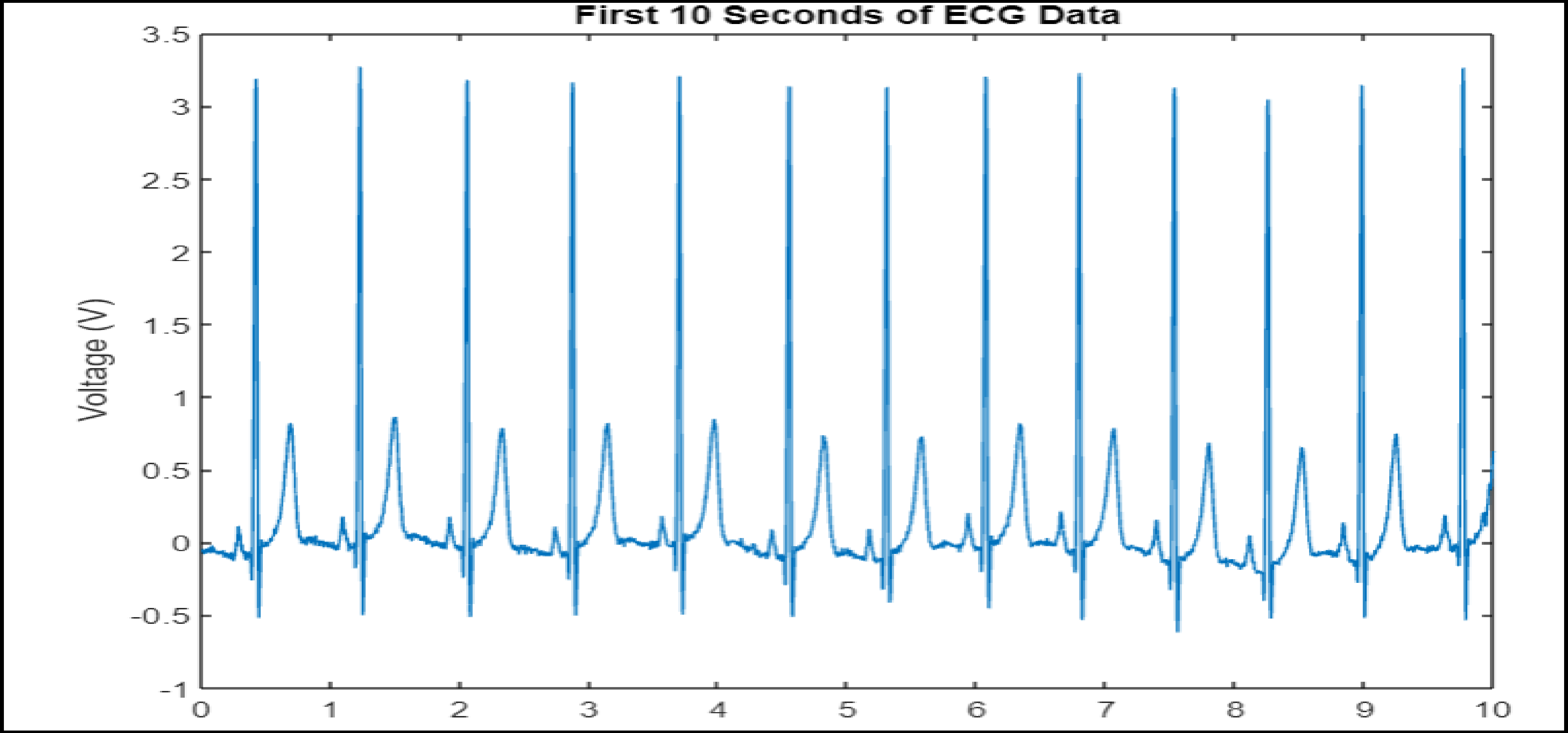


# Sample output

- .



# Data visualization

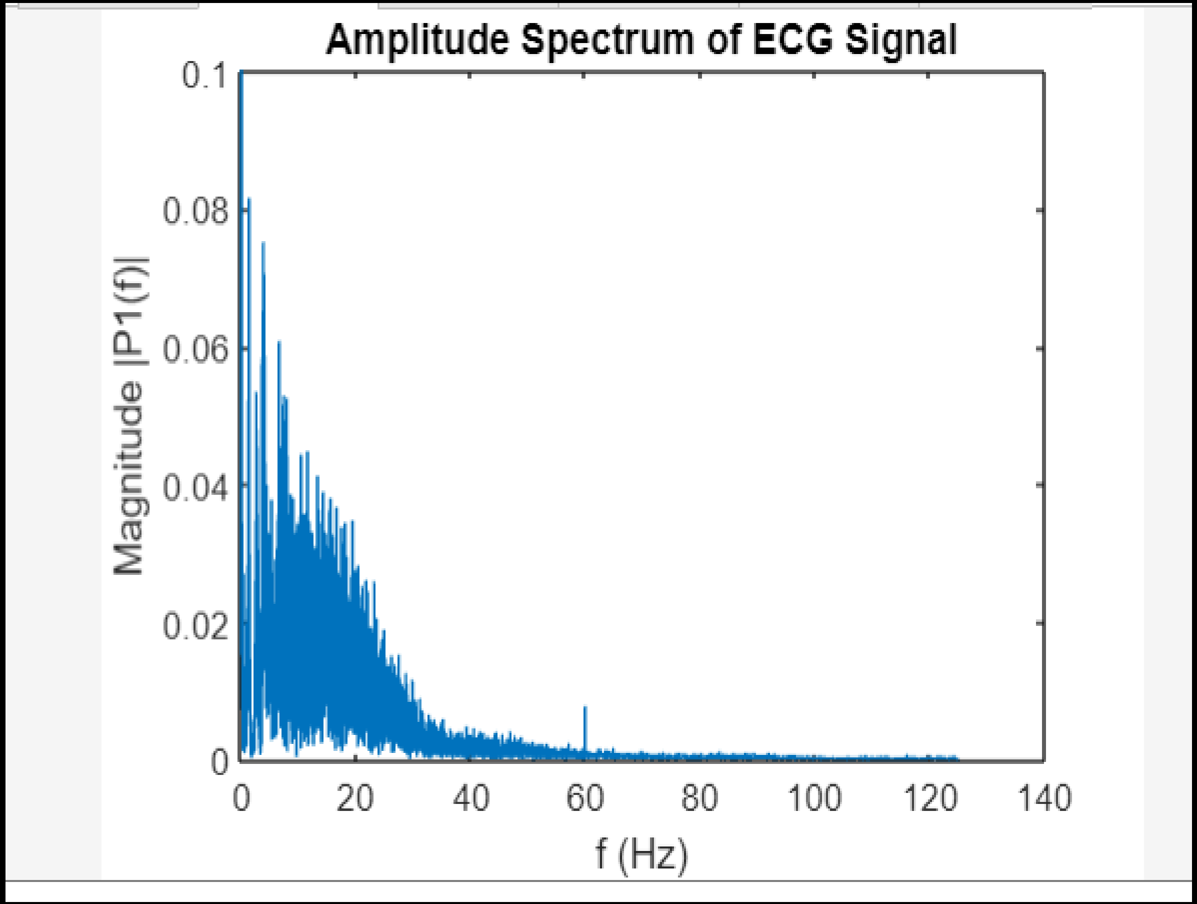


# Cont……………

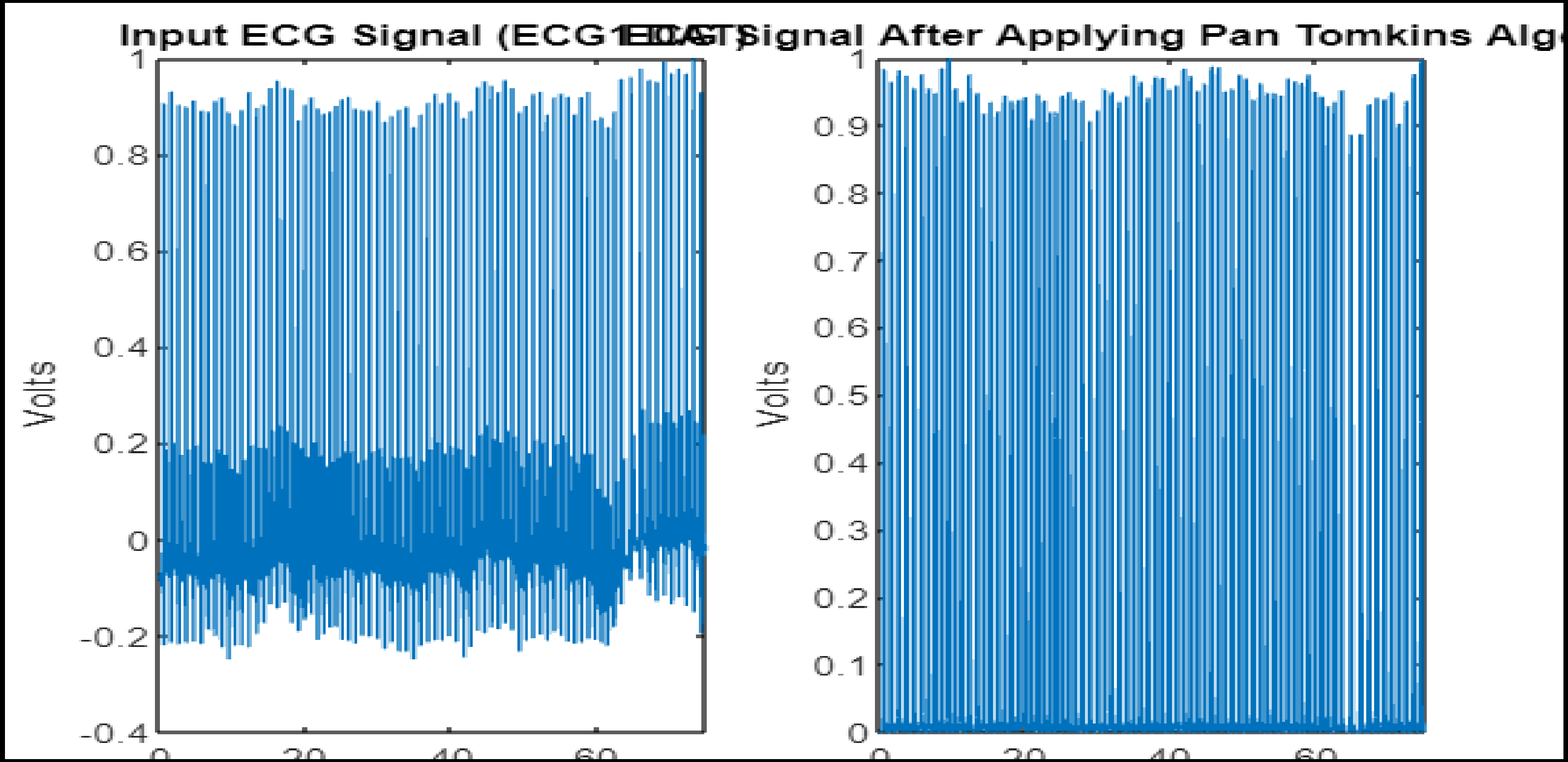
```
A = importdata('408A1_ECG_25.txt');
samples = 0:length(A)-1;        % Sample Indices Vector
Fs = 250;            % Sampling Frequency (Hz)
t = samples/Fs;          % Time Vector (seconds)

%% Plotting ECG data versus time
figure
plot(t,A); % 60 Seconds worth of data / 15000 samples at 250 Hz
title('ECG Signal');
xlabel('Time (s)');
ylabel('Voltage (V)');

%% Computing and Plotting Amplitude Spectrum
L = length(A);
Y = fft(A);
```

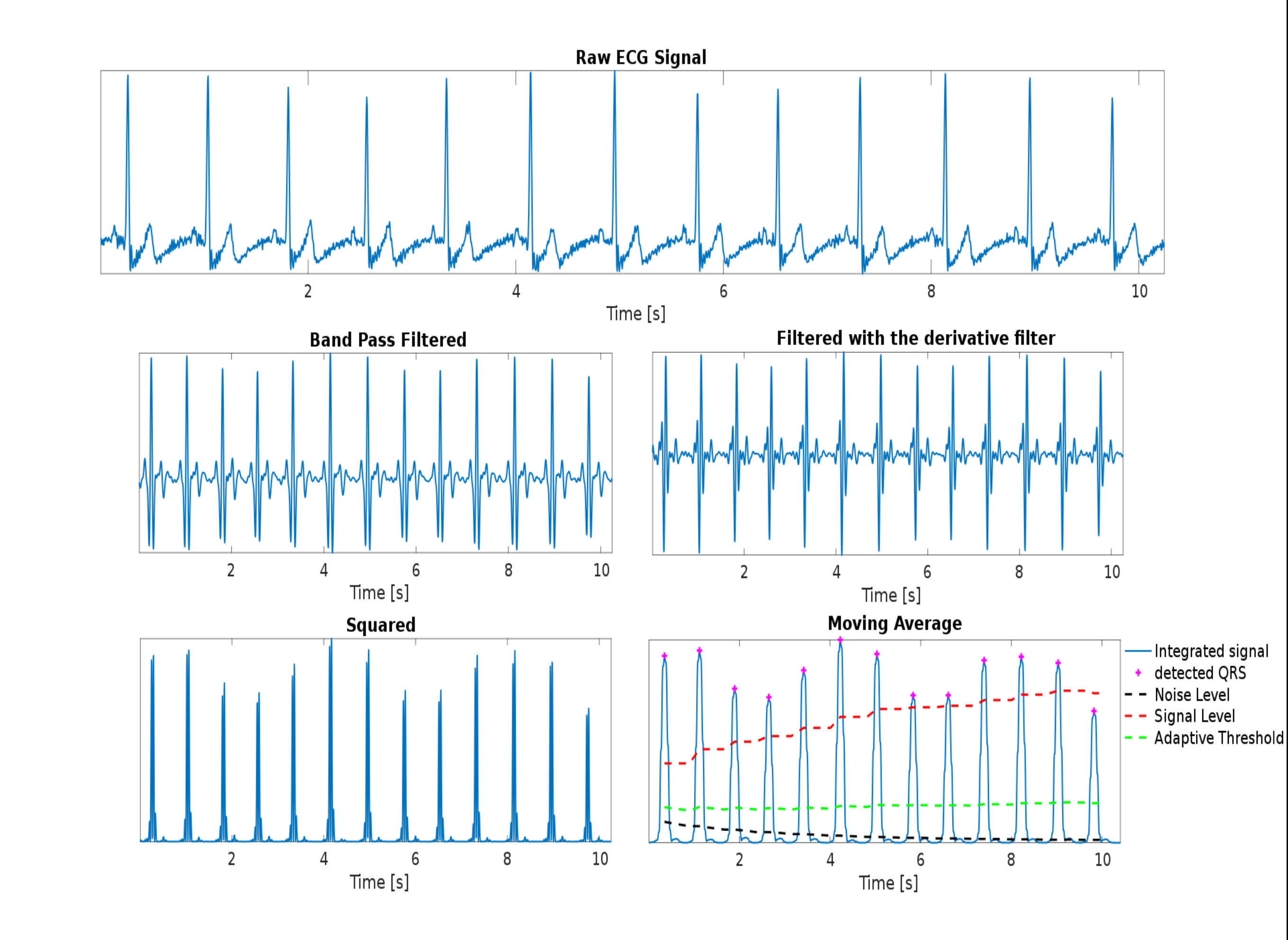


# pan and Tompkins



# Pan and Tompkins

- The filtered signal is squared to enhance the dominant peaks (QRSs) and reduce the possibility of erroneously recognizing a T wave as an R peak.
- Then, a moving average filter is applied to provide information about the duration of the QRS complex.

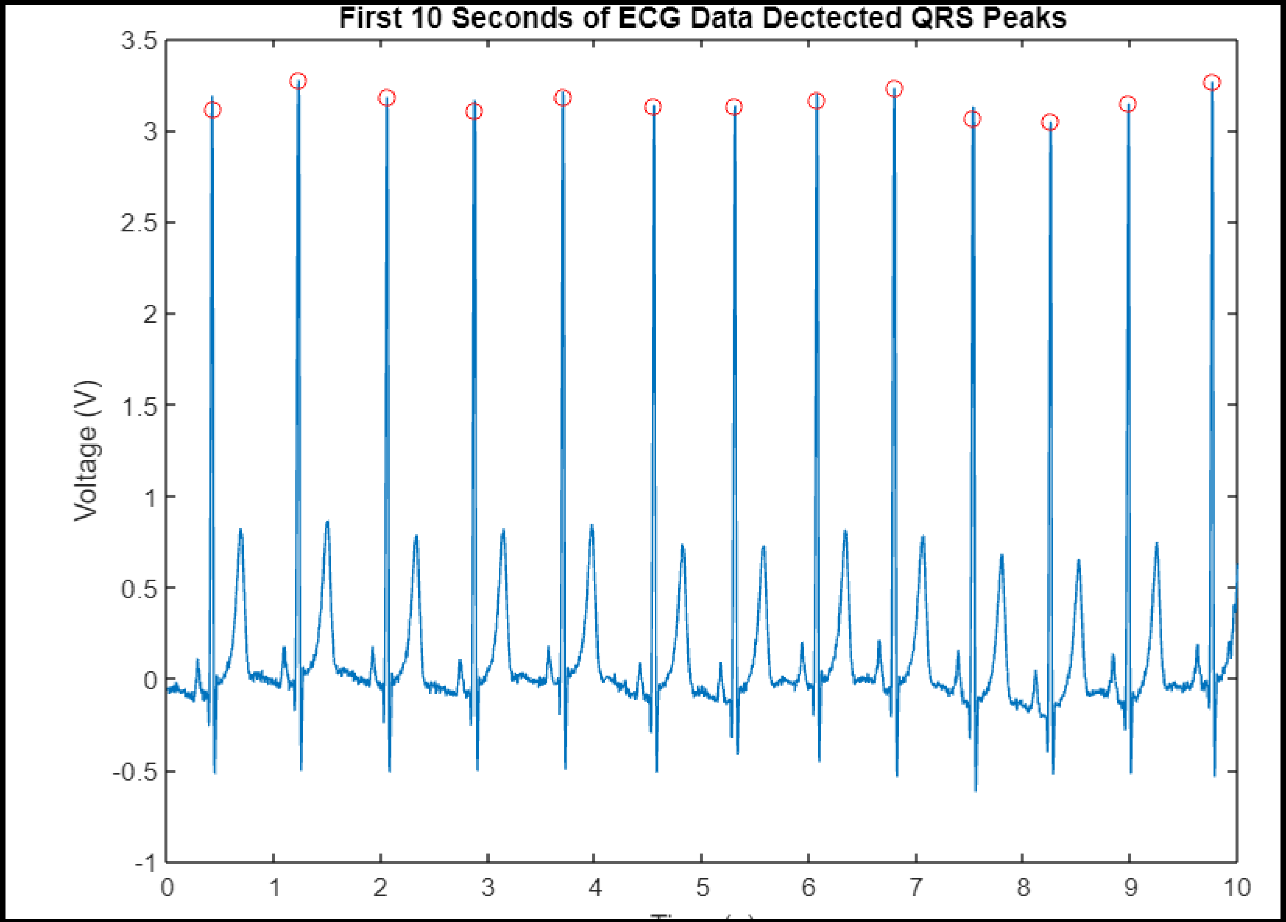


# Comparative analysis

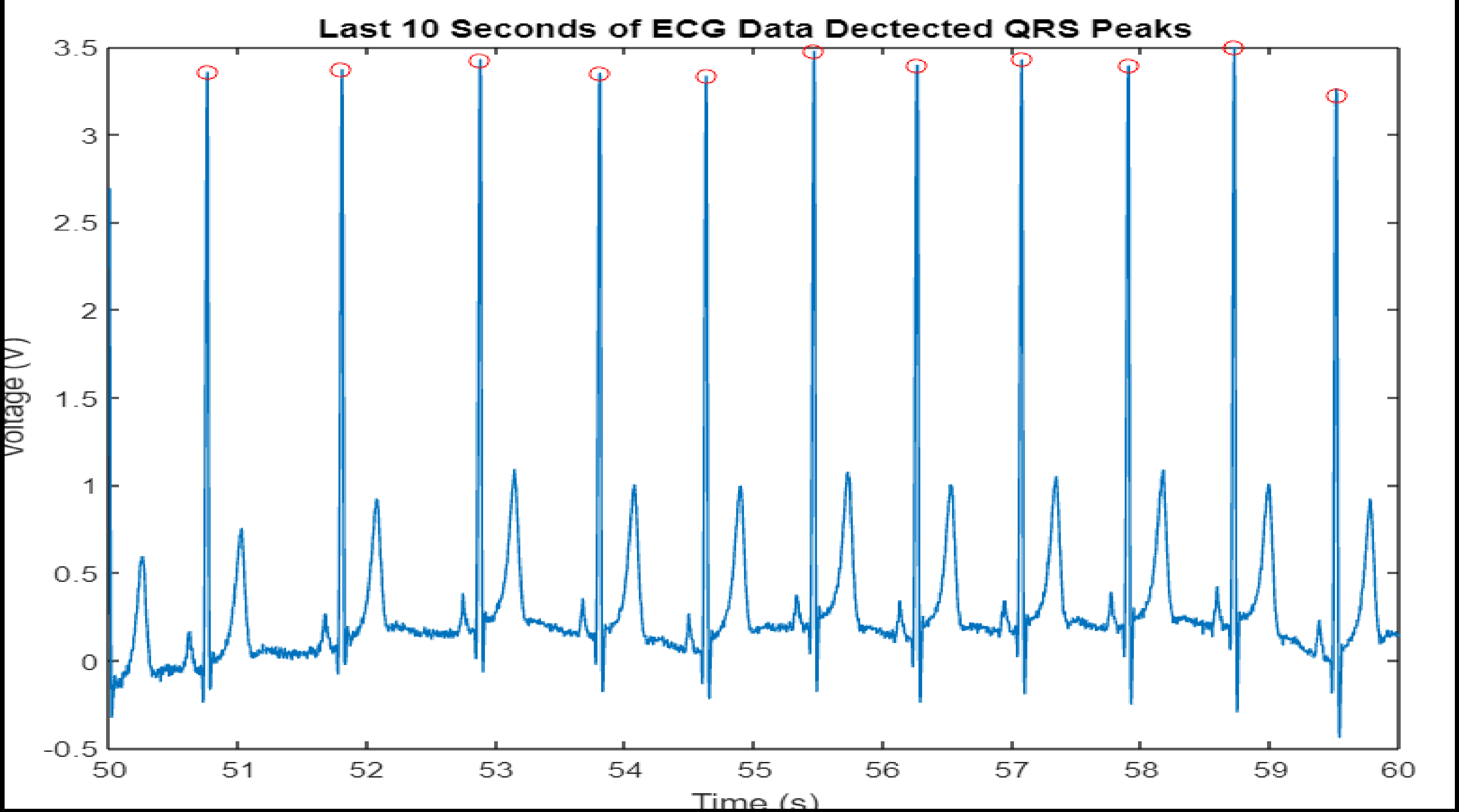
- We can preserve most significant part of signal by changing threshold .
- Still, Iam struggling working to solve this problem, I do not have solution for that so far.
- Because , it need time to find solution.
- I implemented only existed solution.
- But among ,existed solution, pan and Tompkins is most practical, even though, it avoid detecting low peak R signals.

# Results

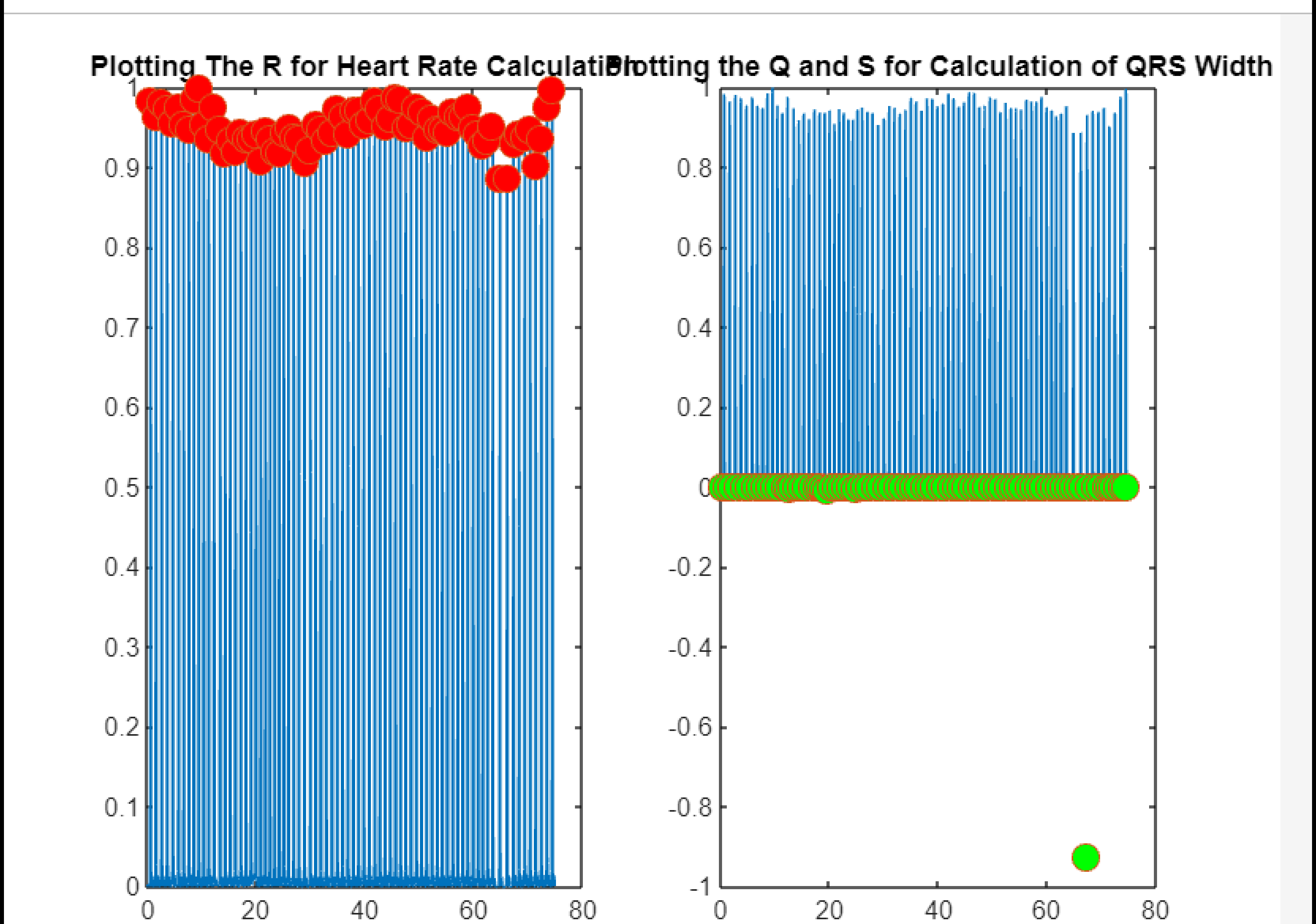
Adaptive
Thresholding with Tompkins



# Result using adaptive thresholding with Tompkins



Result using Tompkins only



# summary

- There are different kind of  method for ecg peak detection, but Pan and Tompkins algorithm is the most practical.
- How ever Pan and Tompkins algorithm has still disadvantage, No peak after exceptionally high R-peak ,but with adaptive thresholding optimization, we can increase the accuracy of detecting peak.

# conclusion

- Adaptive thresholding  is good method ,even though obtaining optimal threshold value is difficult.
- It is effective if we use adaptive thresholding with pan and Tompkins algorithm for peak detection.

# Reference

[1] World Health Organization, (2018). ICD-11 for mortality and morbidity statistics.
[2] Maleki M., Alizadehasl A. and Haghjoo M., (2017) “Practical Cardiology”. Elsevier.
[3] Yeh, Y. and Wang, W., (2008) “QRS complexes detection for ECG signal: The Difference Operation Method”. Computer methods and
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[7] https://www.mayoclinic.org/tests-procedures/ekg/about/pac-20384983

Thank you