

Abstract

Electrocardiogram (ECG), a noninvasive technique is used as a primary diagnostic tool for cardiovascular diseases. A cleaned ECG signal provides necessary information about the electrophysiology of the heart diseases and ischemic changes that may occur. It provides valuable information about the functional aspects of the heart and cardiovascular system. The objective of the project is to automatic detection of cardiac diseases from ECG signal. The aim of this work is to detect automatically the R peaks, the T and P wave maxima, separately. After having represented the ECG equivalent in time frequency domain, we detect the slope of the QRS complex and T wave. By our process we will be able to determine Myocardial Infarction, Myocardial Ischemia and the Heart Rate. The method is tested on inputs taken from MIT-BIH (MASSACHUSETTS INSTITUTE OF TECHNOLOGY - BETH ISRAEL HOSPITAL) website.

Introduction

Electrocardiogram

Electrocardiogram (ECG) is a diagnosis tool that reported the electrical activity of heart recorded by skin electrode. The morphology and heart rate reflects the cardiac health of human heart beat. It is a noninvasive technique that means this signal is measured on the surface of human body, which is used in identification of the heart diseases. Any disorder of heart rate or rhythm, or change in the morphological pattern, is an indication of cardiac arrhythmia, which could be detected by analysis of the recorded ECG waveform. The amplitude and duration of the P-QRS-T wave contains useful information about the nature of disease afflicting the heart. The electrical wave is due to depolarization and re polarization of Na^+ and K^+ ions in the blood. The ECG signal provides the following information of a human heart:

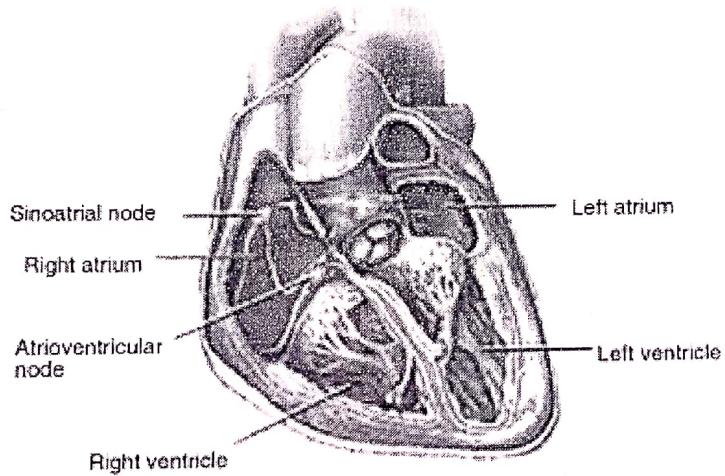
- Heart position and its relative chamber size
- Impulse origin and propagation
- Heart rhythm and conduction disturbances
- Extent and location of myocardial ischemia
- Changes in electrolyte concentrations
- Drug effects on the heart.

ECG does not afford data on cardiac contraction or pumping function.

The heart anatomy

The heart contains four chambers that is right atrium, left atrium, right ventricle, left ventricle and several atrioventricular and sinoatrial node as shown in the below figure. The two upper chambers are called the left and right atria, while the lower two chambers are called the left and right ventricles. The atria are attached to the ventricles by fibrous, non-conductive tissue that keeps the ventricles electrically isolated from the atria. The right atrium and the right ventricle together form a pump to circulate blood to the lungs. Oxygen-poor blood is received through large veins called the superior and inferior vena cava and flows into the right atrium.

The right atrium contracts and forces blood into the right ventricle, stretching the ventricle and maximizing its pumping (contraction) efficiency. The right ventricle then pumps the blood to the lungs where the blood is oxygenated. Similarly, the left atrium and the left ventricle together form a pump to circulate oxygen-enriched blood received from the lungs (via the pulmonary veins) to the rest of the body.



The Heart conduction system

In heart Sino-Atrial (S-A) node spontaneously generates regular electrical impulses, which then spread through the conduction system of the heart and initiate contraction of the myocardium. Propagation of an electrical impulse through excitable tissue is achieved through a process called depolarization. Depolarization of the heart muscles collectively generates a strong ionic current. This current flows through the resistive body tissue generating a voltage drop. The magnitude of the voltage drop is sufficiently large to be detected by electrodes attached to the skin. ECGs are thus recordings of voltage drops across the skin caused by ionic current flow generated from myocardial depolarisations. Atrial depolarisation results in the spreading of the electrical impulse through the atrial myocardium and appears as the P-wave. Similarly, ventricular depolarization results in the spreading of the electrical impulse throughout the ventricular myocardium.

Leads in ECG

The standard ECG has 12 leads: which includes 3 - bipolar leads, 3 - augmented unipolar leads and 3 - chest (precordial) leads. A lead is a pair of electrodes (+ve & -ve) placed on the body in designated anatomical locations & connected to an ECG recorder. Bipolar leads: record the potential difference between two points (+ve & -ve poles). Unipolar leads: record the electrical potential at a particular point by means of a single exploring electrode. 4 Leads I, II and III are commonly referred to bipolar leads as they use only two electrodes to derive a view. One electrode acts as the positive electrode while the other as the negative electrode (hence bipolar).

Standard Leads	Limb Leads	Chest Leads
Bipolar leads	Unipolar leads	Unipolar leads
Lead I	AVR	V1
Lead II	AVL	V2
Lead III	AVF	V3
		V4
		V5

Einthoven leads:

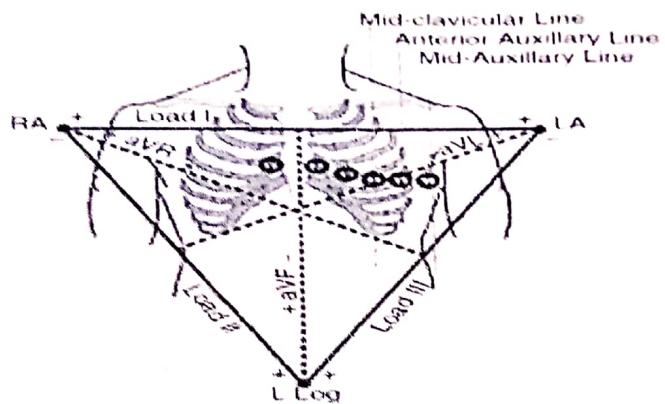
Lead I: records potentials between the left and right arm,

Lead II: between the right arm and left leg, and

Lead III: those between the left arm and left leg

Goldberger leads are unipolar augmented limb leads in the frontal plane.

Unipolar Limb leads: (when the +ve terminal is on the right arm: aVR, left arm aVL, or left leg, aVF) One lead connected to +ve terminal acts as the different electrode, while the other two limbs are connected to the -ve terminal serve as the indifferent (reference) electrode [5]. Wilson leads (V1–V6) are unipolar chest leads positioned on the left side of the thorax in a nearly horizontal plane. The indifferent electrode is obtained by connecting the 3 standard limb leads. When used in combination with the unipolar limb leads in the frontal plane, they provide a three-dimensional view of the integral vector.



Precordial chest electrodes are normally placed on the left side of the chest

Chest (precordial) leads

V1: 4th intercostal space, right sternal edge.

V2: 4th intercostal space, left sternal edge.

V3: between the 2nd and 4th electrodes.

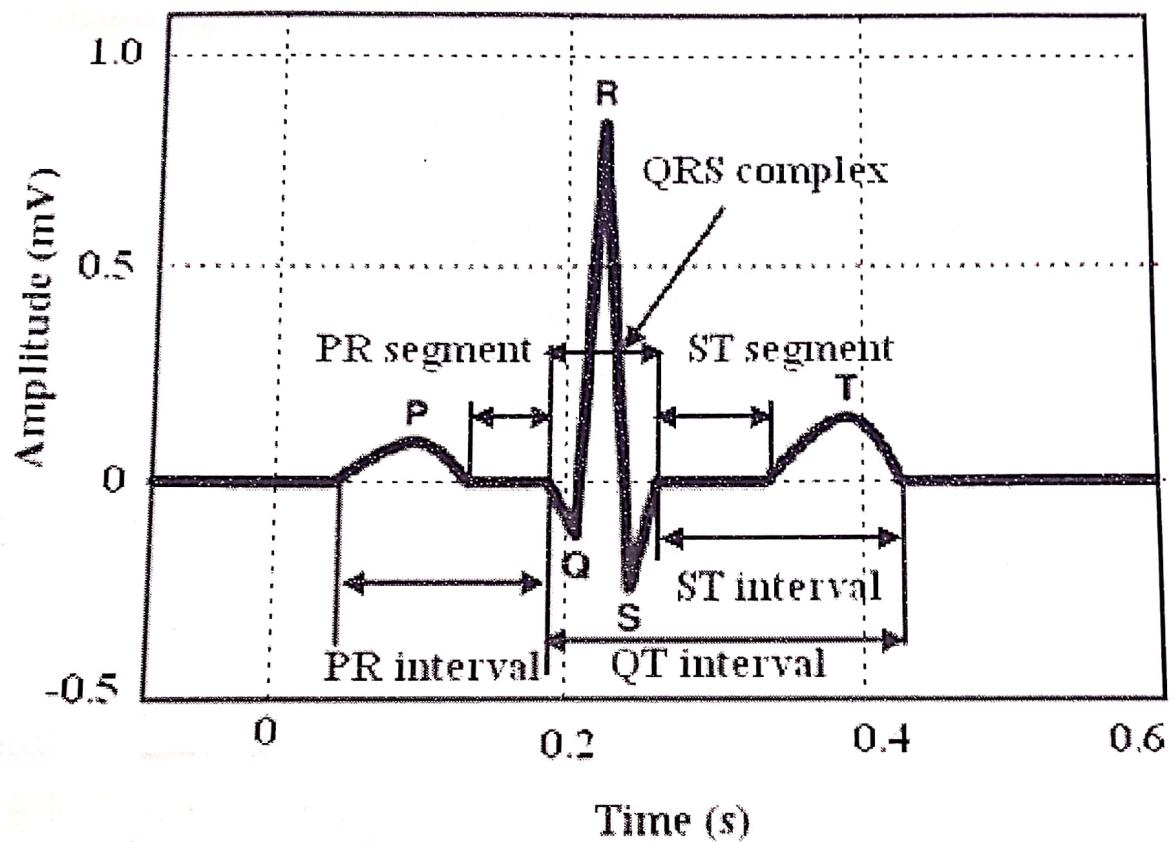
V4: 5th intercostal space in the midclavicular line.

V5: on 5th rib, anterior axillary line.

V6: in the midaxillary line.

To make recordings with the chest leads (different electrode), the three limb leads are connected to form an indifferent electrode with high resistances. The chest leads mainly detect potential vectors directed towards the back. These vectors are hardly detectable in the frontal plane. Since the mean QRS vector is usually directed downwards and towards the left back region, the QRS vectors recorded by leads V1–V3 are usually negative, while those detected by V5 and V6 are positive. In leads V1 and V2, QRS = -ve because, the chest electrode in these leads is nearer to the base of the heart, which is the direction of electronegativity during most of the ventricular depolarization process. In leads V4, V5, V6, QRS = +ve because the chest electrode in these leads is nearer the heart apex, which is the direction of electropositivity during most of depolarization.

ECG waves and interval



Schematic representation of normal ECG waveform.

Waves	Representation
P wave	<p>the amplitude level of this voltage signal wave is low (approximately 1 mV) and represent depolarization and contraction of the right and left atria [2].</p> <p>A clear P wave before the QRS complex represents sinus rhythm.</p> <p>Absence of P waves may suggest atrial fibrillation, junctional rhythm or ventricular rhythm.</p> <p>It is very difficult to analyze P waves with a high signal-to-noise ratio in ECG signal.</p>
QRS complex	<p>The QRS complex is the largest voltage deflection of approximately 10–20 mV but may vary in size depending on age, and gender.</p> <p>The voltage amplitude of QRS complex may also give information about the cardiac disease [6].</p> <p>Duration of the QRS complex indicates the time for the ventricles to depolarize and may give information about conduction problems in the ventricles such as bundle branch block.</p>

T wave Represents ventricular repolarization
 Large T waves may represent ischemia, and Hyperkalaemia

Amplitude and duration of waves, intervals and segments of ECG signal.

Sl. no.	Features	Amplitude (mV)	Duration (ms)
1	P wave	0.1-0.2	60-80
2	PR-segment	-	50-120
3	PR- interval	-	120-200
4	QRS complex	1	80-120
5	ST-segment	-	100-120
6	T –wave	0.1-0.3	120-160
7	ST-interval	-	320
8	RR-interval	-	(0.4-1.2)s

The Table shows features of P-wave, QRS complex and T wave in maximum amplitude and its duration. According to medical definition, the duration of each RR-interval is about 0.4-1.2s.

Noise in ECG Signal

Generally the recorded ECG signal is often contaminated by different types of noises and artifacts that can be within the frequency band of ECG signal, which may change the characteristics of ECG signal. Hence it is difficult to extract useful information of the signal. The corruption of ECG signal is due to following major noises:

Power line interferences

Power line interferences contains 60 Hz pickup (in U.S.) or 50 Hz pickup (in India) because of improper grounding. It is indicated as an impulse or spike at 60 Hz/50 Hz harmonics, and will appear as additional spikes at integral multiples of the fundamental frequency. Its frequency content is 60 Hz/50 Hz and its harmonics, amplitude is up to 50 percent of peak-to-peak ECG signal amplitude. A 60 Hz notch filter can be used remove the power line interferences.

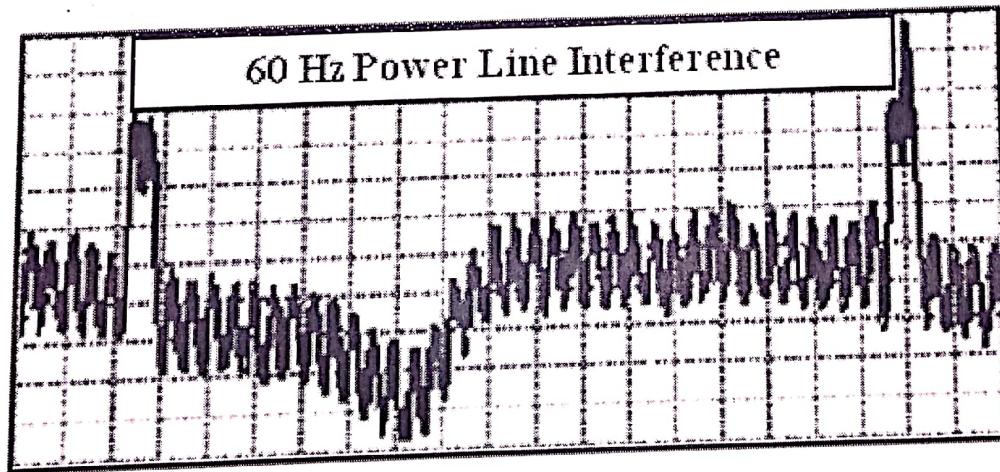
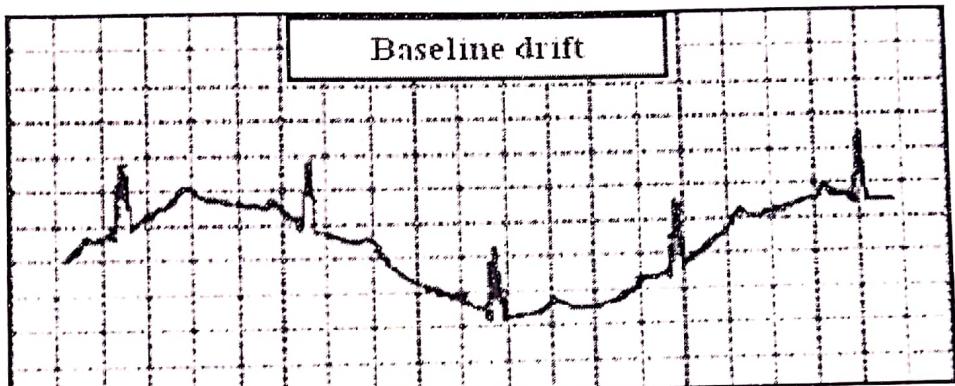


Fig. 60 Hz Power line interference

Baseline drift

Base-line drift may be caused in chest-lead ECG signals by coughing or breathing with large movement of the chest, or when an arm or leg is moved in the case of limb-lead ECG acquisition. Base-line drift can sometimes caused by variations in temperature and bias in the

instrumentation and amplifiers. Its frequency range generally bellows 0.5 Hz. To remove baseline drift a high pass filter with cut-off frequency 0.5 Hz is used.



Baseline drifts in ECG signal.

ECG Database

MIT-BIH Arrhythmias database

The MIT/BIH arrhythmia database is used in the study for performance evaluation.

The database contains 48 records, each containing two-channel ECG signals for 30 min duration selected from 24-hr recordings of 47 individuals. There are 116,137 numbers of QRS complexes in the database [11]. The subjects were taken from, 25 men aged 32 to 89 years, and 22 women aged 23 to 89 years and the records 201 and 202 came from the same male subject. Each recording includes two leads; the modified limb lead II and one of the modified leads V1, V2, V4 or V5. Continuous ECG signals are band pass-filtered at 0.1–100 Hz and then digitized at 360 Hz. Twenty-three of the recordings (numbered in the range of 100–124) are intended to serve as a representative sample of routine clinical recordings and 25 recordings (numbered in the range of 200–234) contain complex ventricular, junctional and supraventricular arrhythmias. The database contains annotation for both timing information and beat class information verified by independent experts.

AAMI Standard

MIT-BIH heartbeat types are combined according to Association for the Advancement of Medical Instrumentation (AAMI) recommendation. AAMI standard emphasize the problem of classifying ventricular ectopic beats (VEBs) from the non- ventricular ectopic beats.

AAMI also recommends that each ECG beat can be classified into the following five heartbeat types:

- i. N (Normal beat)
- ii. S (supraventricular ectopic beats (SVEBs))
- iii. V (ventricular ectopic beats (VEBs))
- 15
- iv. F(fusion beats)
- v. Q (unclassifiable beats)

Each class includes heartbeats of one or more types as shown in Table 1.2. Class N contains normal and bundle branch block beat types and escape beat, class S contains supraventricular ectopic beats (SVEBs), class V contains Premature ventricular contraction beats and ventricular escape beat, class F contains beats that result from fusing normal and VEBs, and class Q contains unknown beats including paced beats.

Mapping the MIT-BIH arrhythmia database heartbeat types to the AAMI heartbeat classes.

AAMI beat class description	Normal beat (N)	Supraventricular ectopic beat (S)	ventricular ectopic beat(V)	Fusion beat (F)	Unknown beat (Q)
MIT-BIH heart beat types	Normal beat (N)	Atrial premature beat (A)	Premature ventricular contraction (V)	Fusion of ventricular and normal beat (F)	Paced beat (/)
	Left bundle branch block beat (L)	Aberrated atrial premature beat (a)	ventricular escape beat (E)		Fusion of paced and normal beat (f)
	Right bundle branch block beat (R)	Nodal (junctional) premature beat (J)			Unclassified beat (Q)
	Atrial escape beat (e)	Supraventricular premature beat (S)			
	Nodal (junctional) escape beat (j)				

Review of papers

The fetal electrocardiogram was first observed by M. Cremer in 1906. The early works in this area were performed by using the galvanometric apparatus of that time, which were limited by the very low amplitude of the fetal signals. As measurement and amplification techniques improved, fetal electrocardiography became more feasible and popular. The limiting factor was then the low fetal SNR, especially in presence of the strong maternal cardiac interference; a problem which exists up to now. In the 1960's intra-uterine electrodes (placed between the intact membranes of the foetus and the wall of the uterus) provided SNR improvement for ECG analysis. However, the technique was short lived due to the inherent danger of premature rupture of the membranes induced by the insertion of the electrode. Hon introduced the use of the first *direct* electrode, inserted through the cervix, and fixed to the presenting part of the fetus after rupture of the membranes (typically to the fetal scalp).

Shortly afterwards, with the developments in computer science and signal processing techniques, automatic signal processing and adaptive filtering techniques were used for fetal R-wave detection, and maternal cardiac interference cancellation from abdominal electrodes . However, the techniques never provided more than approximate fetal heart rate estimates, and the issue of ECG analysis has since been considered as challenging problem for both the biomedical and signal processing communities.

We can see that after a sharp peak in the 1960's, the trend seems to have been decreasing until the year 2000 (of course in terms of the number of publications). But in the last decade, the interest has again increased, especially for fetal magnetocardiography. This should be partially seen as a result of novel low-noise and low-price measurement and digitizing systems, and partially due to the developments in array signal processing and adaptive filtering techniques. Of course, comparing this with the total number of publications in the field of electrocardiography and magnetocardiography (both for adults and fetuses). We notice that fetal cardiography is still in its preliminary stages and there is still a long way to go, for making fetal cardiography a clinically trustable means of fetal cardiac monitoring. It should also be noted that as illustrated, despite the increase in the number of investigations involving the electrcardiogram or magnetocardiogram, when normalizing the number of these works by the total number of publications registered in PubMed over the same period, we notice that the percentage of studies in ECG studies has decreased since the 1980's, while MCG research has gained more interest.

Proposed Project

1. The primary objective of this project is to determine the position of the QRS complex in the heart beat , calculate the area under the QRS segment and on the basis of the calculations determine the coronary disease a particular person is suffering from.

Diseases detectable from QRS complex abnormalities:

- Hyperkalemia
- Cardiac hypertrophy
- Presence of infarction
- Malignant ventricular arrhythmia

2. Analysis of the T wave of the heart beat to detect abnormalities in its structure and determine the corresponding disease.

Diseases detectable from T wave abnormalities:

- Ventricular Hypertrophy
- Pre excitation syndrome
- Myocardial ischemia
- Digitalis effect

3. Calculation of the R-R interval in a heartbeat so as to determine the pulse rate of a particular person.

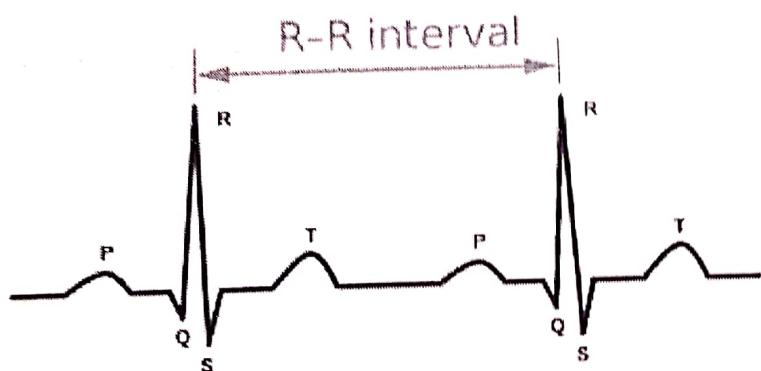
Algorithm Discussion

Steps for detection of R peaks

1. Remove low frequency components
 - a. Change to frequency domain using FFT
 - b. Remove low frequency components
 - c. Back to time domain using IFFT
2. Find local maxima using windowed filter
3. Store significant values removing small ones
4. Adjust filter size and repeat step 2,3

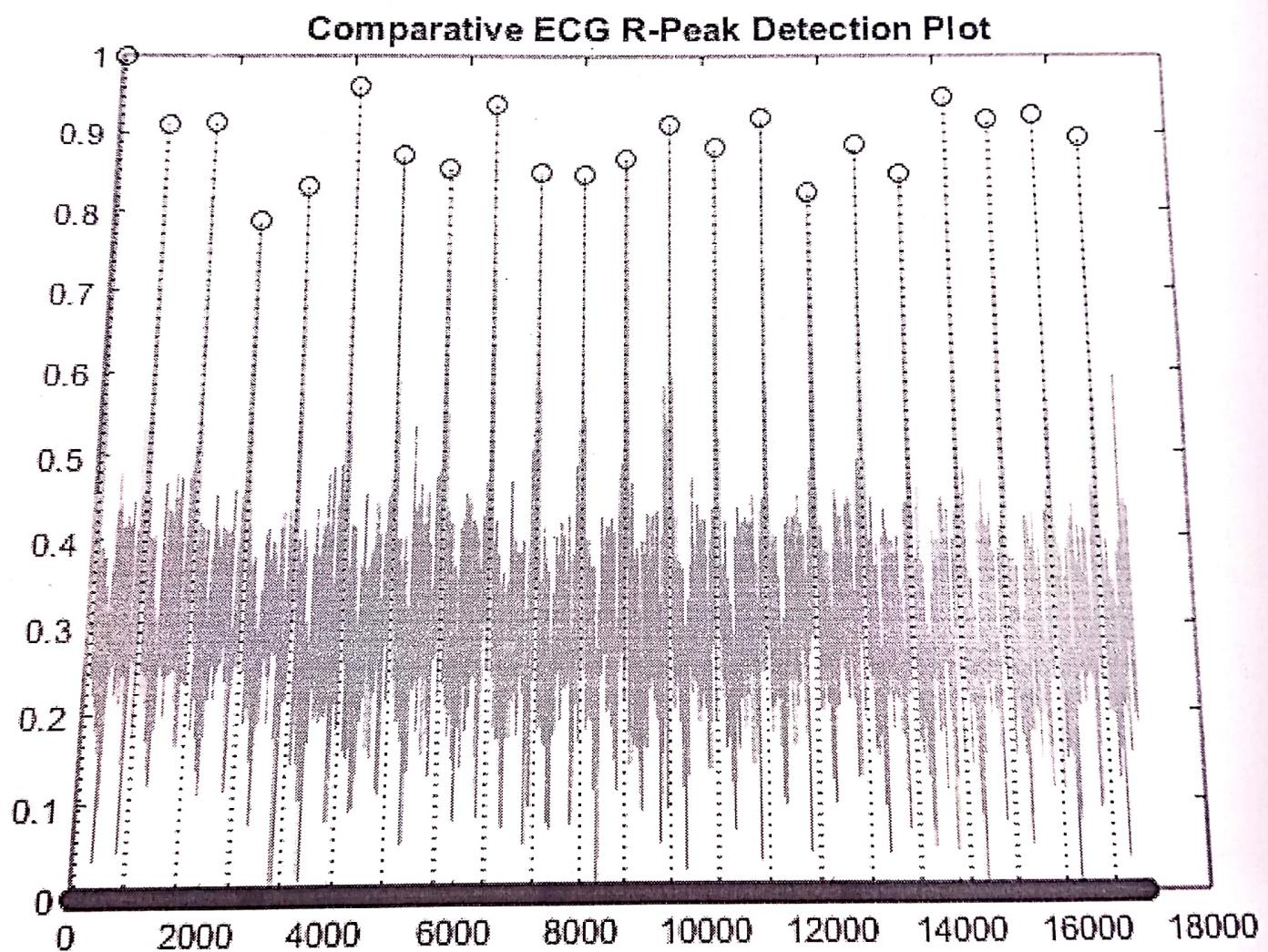
Steps for detection of Heart Rate

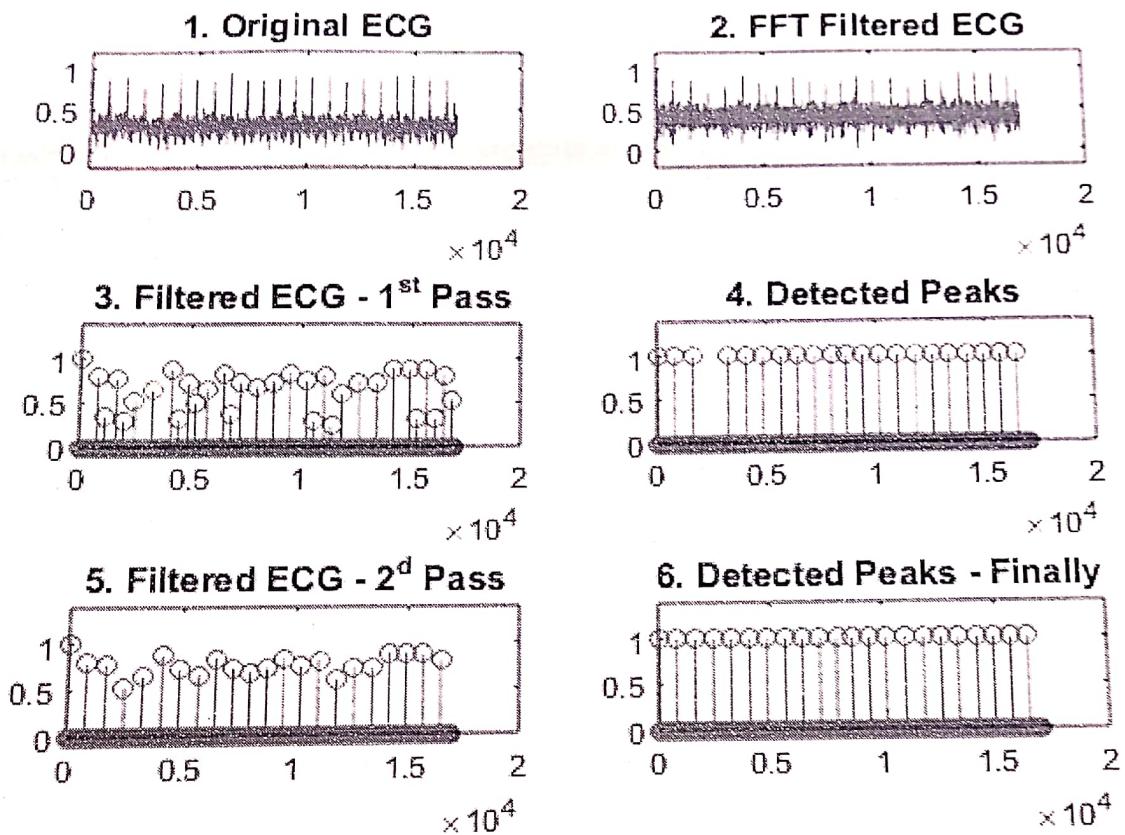
$$\text{Heart Beat Rate} = 60 * \text{sampling rate} / (\text{R-R interval})$$



Results

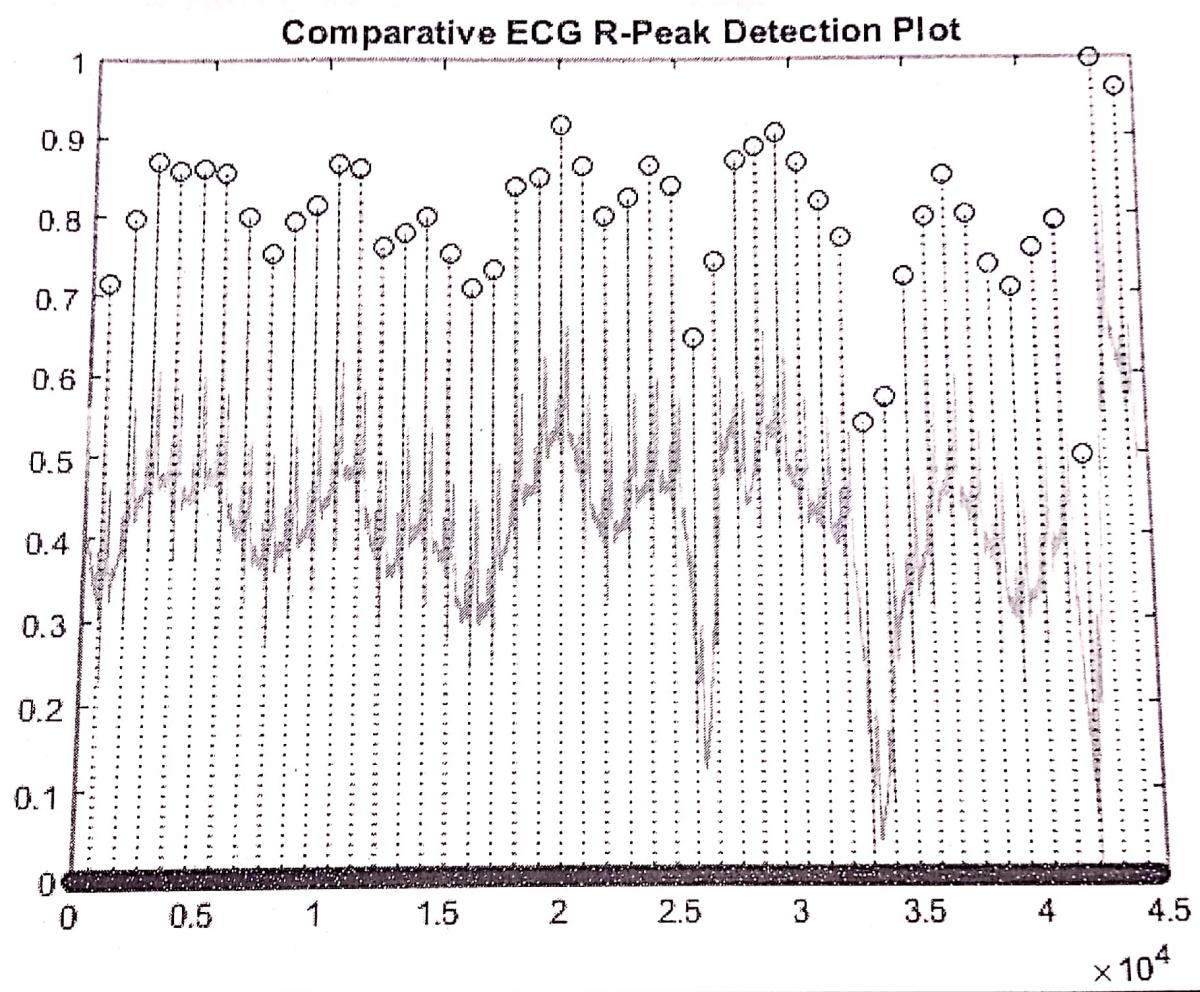
On the input data 1, our code detects the R peaks in the signals

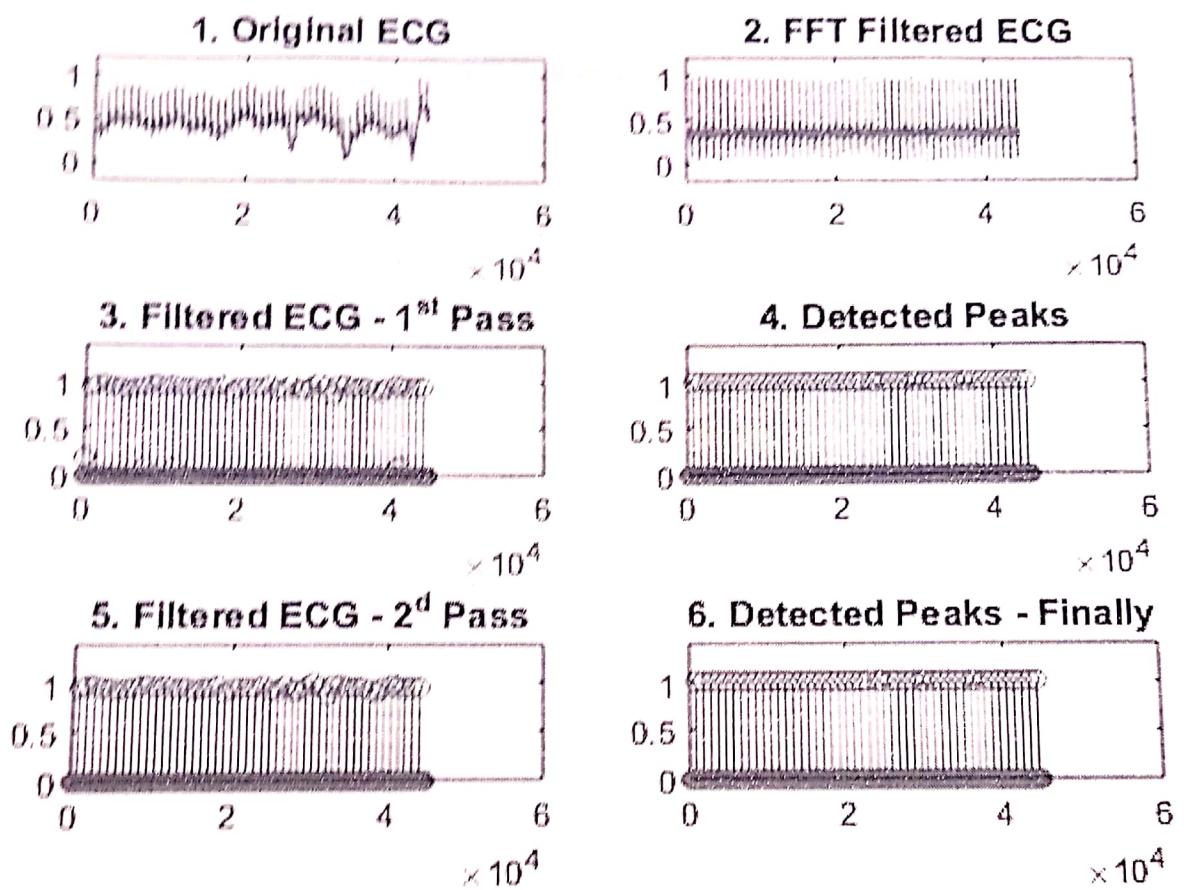




The average heart rate calculated = Average Heart Rate = 64.8768

On the input data 2, our code detects the R peaks in the signals





The average heart rate calculated = Average Heart Rate= 80.3996

Conclusion

The ECG signal can be used as a reliable indicator of heart diseases. The most important factor in determining whether an automatic ECG diagnosis system is successful or not, is the accuracy of event detection. The accuracy of the tools depends on several factors, such as the size and quality of the training set, the efficient extracted feature set and also the parameters chosen to represent the input. In this report, we have performed the detection of R Peaks only and calculation of the Heart Rate by calculating the average distances between the R peaks. In the next part we shall continue by calculating the area under ST segment and the slope of the QRS complex to determine different myocardial diseases.

References

- [1] J. Pan, W. J. Tompkins, "A real time QRS detection algorithm," *IEEE Trans. Biomed. Eng.*, vol. 32, pp. 230–236, 1985.
- [2] Y.C. Yeha, and W. J. Wang, "QRS complexes detection for ECG signal The Difference Operation Method (DOM)," *Computer methods and programs in biomedicine*, vol. 9, pp. 245–254, 2008.
- [3] P.de Chazal, M.O. Duyer, and R.B. Reilly, "Automatic classification of heartbeat using ECG morphology and heart beat interval features," *IEEE Trans. Biomed. Eng.* vol. 51, pp. 1196-1206, 2004.
- [4] T.Ince, S. Kiranyaz, and M. Gabbouj, "A generic and robust system for automated patient-specific classification of ECG signals," *IEEE Trans. Biomed. Eng.* vol. 56, pp. 1415-1426, 2009.
- [5] W. Jiang and S. G. Kong, "Block-based neural networks for personalized ECG signal classification," *IEEE Trans. Neural Netw.*, vol. 18, no. 6, pp. 1750–1761, Nov. 2007.
- [6] Y. Hu, S. Palreddy, and W. J. Tompkins, "A patient-adaptable ECG beat classifier using a mixture of experts approach," *IEEE Trans. Biomed. Eng.*, vol. 44, no. 9, pp. 891–900, Sep. 1997.
- [7] Practical Hints to Clinical Electrocardiography by C.R. Maiti and N. Goswami Published by New Central Book Agency
- [8] Outline of Electrocardiography by H. Harold Freidman Published by McGraw-Hill Book Company.
- [9] Biomedical Signal Analysis, A case study approach by Rangaraj M. Rangayyan Published by John Wiley and Sons.