1.Abstract

We collected ECG waveforms and created a database of the diseases. We have considered one normal and eight abnormal waveforms. The noises seen in ECG waveform are simulated and added to the signal. Digital filters are implemented to suppress the noises. The QRS parameters such as R amplitude, R time, QRS width are computed.

2.Introduction

Computer can be used to make quicker diagnosis and treatment free from subjective errors. Computer provides physician information in a clearer form and saves his time from repetitive and routine calculations. Also provides storage of patients' data. Computer not only reduces time required for interpretation of ECG but also ensure better reliability. Many times it is also possible to increase diagnosis potential of ECG.

Computer can be used to find out minimum or maximum values of different parameters. They can be used to identify P waves, QRS complex, T waves and from this data nature of rhythm can be tracked. We selected this topic as it is of interest due to recent advancements going on in the Biomedical field. We have implemented software part using Digital Signal Processing and C/C++ Language, which are familiar to us.

3.Electrocardiography

3.1. Cardiac Cycle

3.1.1:

The general behavior of the heart is as a pump used to force the blood through the cardiovascular system. The heart lies obliquely across the chest. The mature heart is built upon a collagenous 'skeleton' in the shape of a fibrotendious ring, which is located at the atrioventricular junction. The ring acts as a base for heart and contains the tricuspid, mistral, aortic and pulmonary valves grouped beneath the sternum. The apex of the heart is formed by the left ventricle (LV) and posterior surface is formed mainly by the left atrium into which open four pulmonary veins. The anterior surface is formed by the right ventricle (RV) and the right atrium (RA). The inferior surface of the heart and the pericardium rest on the central tandem of the diaphragm. Pericardium is the fibrous sac in which the heart is enclosed.

3.1.2 Mechanical Events of the Cardiac Cycle:

The atria and the ventricles contract in sequence. The cardiac cycle has four phases:

a) The right atrium receives deoxygenated blood from upper and lower part of the body through superior and inferior vena cava. When the right atrium is full it contracts (systole) that causes the opening of the

right atrioventricular valve (AV valve) and blood rushes into right ventricle.

b) When the right ventricle becomes full the right AV valve closes and right ventricle contracts causing opening of pulmonary valve and blood enters the lungs via the pulmonary trunk where it gets oxygen.

c) The oxygenated blood then enters into the left atrium of the heart via the pulmonary veins. When the left atrium gets full, the left AV valve opens and blood rushes into the left ventricle.

d) When the left ventricle is full, the left AV valve closes and the blood then rushes into the aorta via the aortic orifice. This oxygenated blood is then distributed to the rest of the body via the aorta.

3.1.3 The Cardiac Electrical System:

The heartbeat is initialized by a special electrical system situated within the walls of the heart, composed of modified muscle cells. The cardiac electrical system consists of:

3.1.3.1 The Sino-Atrial Node or Pacemaker:

The node is composed of small myocytes with an electrically unstable cell membrane. As a result of their unstable resting membrane potential, human nodal cells generate an action potential roughly every one second. This excites the adjacent atrial work cells and a wave of depolarization then spreads across the two atria, passing from cell to cell at a rate of approximately 1 m/s and initiating atrial systole.

3.1.3.2 Atrioventricular Node:

After passing down the atrial septum, the electrical impulse reaches the atrioventricular node. The AV node marks the start of the electrical connection between the atria and the ventricles. The impulse is delayed in the node for approximately 0.1s (at resting heart rate) owing to the complex circuitry of the cells of the node and their small diameter (2-3 micrometer) which reduces the conduction velocity to only 0.5m/s. the resulting delay is important because it allows atria sufficient time to contract before the ventricles are activated.

3.1.3.3 The main bundle (bundle of His) and its branches:

A bundle of fast conducting muscle fibers, called the bundle of His, next conveys the electrical impulse from the AV node into the fibrous upper part of the interventricular septum. Here the bundle turns forward and runs along the crest of the muscular septum, giving off the 'left-bundle branch' really comprises two sets of fibres-one anterior and one posterior.

These course down the left side of the septum to supply the left ventricle. The remaining bundle, the right bundle branch, runs down the right side of the septum and supplies the right ventricle. The bundle fibres are wide; fast conducting myocytes arranged in a regular end-to-end fashion. They terminate in an extensive network of large fibres in the sub-endocardium and are called Purkinje fibres. The

Purkinje fibres are the widest cells in the heart and their large diameter (40-80 micrometer) endows them with a high conduction velocity (3-5 m/s). Their role is to distribute the electrical impulse rapidly to the endocardial work cells. From the endocardium the impulse spreads from work cell to work cell at approximately 0.5-1 m/s and excites the entire ventricular wall. The function of the conduction system is thus to excite the ventricular mass as near simultaneously as possible.

3.1.4 Transmission of Excitation:

The spread of electrical excitation from the SA node into the atria, conduction system and ventricles is mediated by local electrical currents acting ahead of the action potential. In the 'active' depolarized region, the exterior of the cell membrane is negatively charged with respect to the interior, while in the resting zone ahead it is positively charged. The two regions are connected by a conducting medium; the extra cellular fluid, so positive charge flows from outside of the resting membrane, depolarizing it. An intracellular current flows in the opposite direction along the cell axis and depolarizes the inside of the membrane. The process is in fact the discharging of a capacitor, namely the lipid cell membrane.

When the resting membrane has been depolarized to threshold it generates an action potential and the entire process moves on, and since the membrane to the rear is refractory, excitation progresses unidirectionally. The rate of conduction is greater in wider cells such

as Purkinje fibres because they have a lower axial resistance. It is also greater in cells with large rapid rising action potentials, because these create bigger propagating currents. Since nodal cells have only small slow-rising action potentials and therefore small propagating currents, conduction is more easily blocked in nodal tissue.

3.2 Features of ECG signal

3.2.1 Introduction:

Each and every cell of the myocardium generates minute electrical voltage. This occurs in two phases, once during electrical discharge of the cells depolarization and later during recovery called repolarization. The sum total of electric voltage generated by all cells at any particular moment is called resultant vector. As the heart is activated sequentially the resultant vector changes from moment till the cells are depolarized and later repolarised. The body is a good conductor of electricity so the electrical activity of the heart can be recorded on the body surface. When two electrodes-one positive or exploring electrodes and other negative or indifferent electrode are applied on the body surface, it forms an electrical axis called 'lead' on which the resultant vectors are recorded. Twelve such combinations have been selected which form the twelve standard leads of the routine electrocardiogram. This enables an analysis of the electrical activity from twelve different directions.

3.2.2 Normal Activation and Waveform:

Atria form one electrical unit while ventricles form another. Impulse generated from the sinus node activates the atria first. The impulse then conducts through the AV node to activate the ventricles. Spread of electrical activity in the atria is from cell to cell while spread in the bundle branches is via bundle branches and Purkinje system to the endocardium. The electrical activity spreads from endocardium to epicardium. The entire process of ventricular depolarization is completed in 80 ms.

The electrical waveform is produced by sequential atrial and ventricular depolarization and depolarization and consists of PQRST components.

P represents atrial depolarization

QRS represents ventricular depolarization

- Q-First negative deflection
- R-Following upright deflection
- S-Negative terminal event

T represents ventricular depolarization.

Atrial repolarization wave is buried within QRS complex and is usually not seen.

3.2.3 Standard Electrical Leads:

The twelve standard leads used to record the electrocardiogram consist of 3 bipolar limb leads, 3 augmented unipolar limb leads and 6 unipolar precordial leads.

3.2.3.1 Bipolar limb leads:

They are formed by connecting right arm (RA), left arm (LA) and left leg (LL). The electrodes are applied usually just above the wrists and ankle.

Lead 1: Formed between RA (-ve) and LA (+ ve)

Lead 2: Formed between RA (-ve) and LL (+ve)

Lead 3: Formed between LA (-ve) and LL (+ve)

3.2.3.2 Unipolar limb leads:

They are constructed with a positive electrode on one of the limbs and a negative electrode applied to all three limb leads is formed by joining together to form an indifferent electrode of zero potential. The unipolar limb leads are

Lead a VR: Positive electrode on right arm

Lead a VL: Positive electrode on left arm

Lead a VF: Positive electrode on left leg

3.2.3.3 Precordial leads:

Electrical forces do not exist in the frontal plane only. They occur in three planes or dimensions (i.e. in space) Precordial leads are formed to show the horizontal components of spatial vectors. They are called unipolar leads, as indifferent electrode is a zero potential electrode. Their position is located as shown.

Lead V1: Fourth intercostals space at the right sternal border

Lead V2: Fourth intercostals space at the left sternal border

Lead V3: Equidistant between V2 and V4

Lead V4: Fifth intercostals space in the mid-clavicular line

All subsequent leads are taken in the same horizontal line as V4.

Lead V5: In the anterior axillary line

Lead V6: Mid-axillary line

3.2.4 ECG Paper:

The paper upon which the ECG is recorded is ruled in lines one mm both horizontally and vertically. Five lines in both directions complete one block. The vertical axis represents voltage. With normal standardization, each 1mm represents 0.1mV. The horizontal axis represents time with normal speed, 1mm represents 0.04s i.e. each 5mm represents 0.2s and in one minute the ECG paper moves by 300 thick lines or 1500mm.

3.2.5 Normal Electrocardiogram:

The basic ECG waveform consists of three recognizable deflections. The deflections are termed as 'P wave, 'QRS complex ' and 'T wave'.

3.2.5.1: P Waves:

The P wave represents the spread of electrical activation through the atrial myocardium. In the normal ECG it is a small, smooth, rounded deflection preceding the QRS complex. A P wave is formed when right depolarization starts and terminates before left atrial depolarization termination. In normal circumstances atrial depolarization begins as soon as depolarization of the SA node spreads to activate the adjacent right atrial myocardium. Depolarization then spreads simultaneously in all available directions through the right atrial myocardium. The direction in which the greatest amount of atrial myocardium is available determines the direction in which the right atrial component of P wave is best seen. This is usually towards lead 2 and away from lead V1. The first part of the left atrial myocardium to be depolarized is that point which is on the shortest route of depolarization from the SA node.

From this point depolarization spreads in all available through the left atrial myocardium. The direction in which the greatest amount of atrial myocardium is available determines the direction in which the left atrial component of P wave is best seen. This is usually also towards lead 2 but is away from lead V1.

3.2.5.2 QRS Complex:

Formation of QRS complex:

The QRS complex represents the spread of electrical activation through the ventricular myocardium. It is usually, but not always, the largest deflection of the ECG. It is always spiky in shape. The QRS complex is the electrical manifestation at the body surface of the ventricular myocardial depolarization. Ventricular activation begins on the left side of interventricular septum. It then spreads from the left to the right within the septum and later, from endocardium to epicardium in the free walls of the two ventricles. The full sequence of ventricular depolarization can be simplified into three phases, viz.

1. Depolarization of the interventricular septum.
2. Depolarization of the free wall of the right ventricle.
3. Depolarization of the free wall of the left ventricle.

QRS nomenclature:

All sharp pointed deflections resulting from electrical activation of the ventricles are called 'QRS complex' whether they start a positive or a negative deflection and whether they have one, two, three or more recognizable deflections within them. The presence and relative size of the several possible components of the QRS complex may be indicated by a convention using combination of letters q, r, s, Q, R, S. The rules of the convention are as follows:

The first positive or up going wave is labeled as r or R.
Any second positive wave is labeled as r ‘or R’.
A negative wave (i.e. one descending below the base line) is labeled as s or S if follows a r or R wave.
A negative wave is labeled as q or Q if it precedes r or R (in which case it must inevitably also be the first wave to occur).
Any wave, which is entirely negative, is labeled as ‘qs’ or ‘QS.’
Large deflections are labeled with an appropriate uppercase letter.
Small deflections are labeled with an appropriate lower case letter.

Manifestation of QRS complex in leads:

Lets us assume the direction of ventricular depolarization is in the direction represented by the arrow. If eight leads are positioned, the QRS complex would appear as shown Leads 3 and 4 are at right angles to the direction of propagation, and hence show no deflection. Leads 1 and 2 are along the line of propagation and thus record maximum positive and negative deflections respectively electrodes at 5 and 6 will see positive deflection of (identical) intermediate size while electrodes 7 and 8 will see negative deflection of intermediate size. Thus, despite the fact that the eight electrodes are looking at the same wave they see very different things because of their differing orientation.

3.2.5.3 T wave:

The T wave represents the electrical recovery of the ventricular myocardium. This must inevitably follow electrical activation and must be accomplished before any repeat electrical activation is possible A T wave follows each QRS complex and is separated from it by an interval which is constant in any given ECG.

3.2.5.4 Ta wave:

The atrial repolarization is called the 'atrial T wave' or Ta wave. It is normally a shallow, smooth, negative wave, which, since it occurs at the same time as the much larger QRS complex, and is normally totally obscured by the latter. The Ta wave is often mistaken to be a S-T segment depression. A careful inspection reveals that the depression begins before the QRS complex. It therefore cannot be a S-T depression.

3.2.5.5 U wave:

The U wave is a small rounded, upright wave occurring immediately at the end of the T wave. It is part of the repolarization process. The U wave is normally 5-25% of the height of the preceding T wave. Its exact genesis is still uncertain.

3.2.5.6 The Iso-electric line:

It is horizontal level of recording at a time when there is no cardiac activity, i.e. in the T-P interval.

3.2.6 Standards of normal ECG:

P wave:

1. It should not exceed 0.12s in duration.
2. It's height should not exceed 25mm in lead 2.
3. Any negative component visible in lead VI should not have a greater area than that of the positive component.

QRS Complex:

1. R wave in lead aVL must not exceed 13mm.
2. R wave in lead aVF must not exceed 20mm.
3. Any Q wave present in leads aVL, aVF, 1,2 must not have a depth greater than one-fourth the height of the ensuing R wave and must not have a duration equal to or in excess of 0.04s.

T wave:

Normality of T waves in the limb leads is analyzed as follows:

1. Using soft criteria:

When QRS is upright, T wave should upright. When QRS is negative, T wave should be negative. When QRS is close to zero, T wave should small, but may be positive or negative.

2. Using reliable criteria:

The angle between mean frontal plane QRS axis and the mean frontal plane T axis must not exceed 45 degrees.

3. In the presence of QS complexes or abnormal Q waves in leads 1,2,3 and aVF, negative T waves in these leads are abnormal despite failure to fulfill the soft or reliable criteria as mentioned above.

U wave:

1 The normal U wave is upright in all leads in which the T wave is upright. It should also be upright in the right precordial leads even if the T waves are inverted here.

2.Its average amplitude is less than 0.5mm. The U wave is normally 5-25% of the height of the preceding T wave. Hence it tends to be the largest in V2 and V3 where it may occasionally reach 2mm in height.

3. It is definitely abnormal when it is taller than preceding T wave.

S-T segment:

The S-T segment in the precordial leads must not deviate from the iso-electric line by more than +1mm or -1mm.

3.2.7 Standard Intervals:

PR interval:

It is defined as the measure of the total transmission from the beginning of the atrial myocardial depolarization to the beginning of the ventricular myocardial depolarization.

Criteria for normality:

1.PR interval is 0.11s or less.
2.Total QRS duration is 0.11s or more.

QT interval:

QT interval is the time interval from the first recognizable part of the QRS complex to the final recognizable part of the T wave in the same lead.

Ventricular activation time (VAT):

It is the time interval between the starting q wave with the peak of R wave. It can only be measured in leads showing a ‘qR’ type of QRS complex.
Criteria for normality:
It should not exceed 0.04s.

3.3 Electrodes

3.3.1 Introduction:

Transducers are defined as devices capable of converting signals from one form of energy to another, without loading the source. The bioelectric potentials generated in the body are ionic potentials, produced by the ionic current flow. Efficient measurement of these

ionic potentials requires that they be converted into electronic potentials before they can be measured by conventional methods. Devices that convert ionic potentials into electronic potentials are called electrodes.

3.3.2 Electrode theory:

The interface of metallic ions on solution with their associated metals results in an electrical potential that is called the electrode potential. This potential is the result of the difference in diffusion rates of ions into and out of the metal. Equilibrium is produced by the formation of a layer of charge at the interface.

Another source of an electrode potential is the unequal exchange of ions across a membrane that is semi-permeable to a given ion when the membrane separates liquid solutions with different concentrations of that ion. The equation relating the potential across the membrane and the two concentrations of the ion is the ‘Nernst’ equation. In electrodes used for the measurement of bioelectric potentials, the electrode potential occurs at the surface of a metal and an electrolyte. It is impossible to measure the absolute electrode potential of a single electrode, for measurement of the potential across the electrode and its ionic solution would require that another metallic interface be placed inside the solution. Therefore all electrode potentials are given as relative values and must be stated in relation to some reference. By international agreement, the normal hydrogen electrode was chosen

as the reference standard and arbitrarily an electrode potential of zero volts.

3.3.3 Types of electrodes:

A wide variety of electrodes can be used to measure bioelectric events but nearly all can be classified as belonging to one of three basic types:

1. Microelectrodes: Electrodes used to measure bioelectric near or within a single cell.
2. Skin Surface Electrodes: Electrodes used to measure ECG, EEG and EMG potentials from the surface of the skin. These are discussed further in the next section.
3. Needle electrodes: Electrodes used to penetrate the skin to record EEG potentials from a local region of the brain or EMG from a specific group of muscles.

All three types of biopotential electrodes have the metal-electrolyte interface described in the earlier section. In each case, an electrode potential is developed across the interface, proportional to the exchange of ions between he metal and the electrolytes of the body. The double layer of charge at the interface acts as a capacitor. Thus, the equivalent circuit of a biopotential electrode in contact with a body consists of a voltage in series with a resistance capacitor network.

3.3.4 Electrode Characteristics:

The resistance-capacitance networks shown in figs. 4.2 and 4.3 represent the impedance of the electrodes (one of their most important characteristics) as fixed values of resistance and capacitance. Unfortunately, this impedance is not constant, but frequency dependant because of the presence of the capacitance. Further, both electrode potential and impedance are valued by polarization. Size and type of the electrode are also important in determining the electrode impedance. The larger surface electrodes have impedances of 2 to 10 k, whereas small needle electrodes and microelectrodes have much higher impedances. For best results in reading and recording the potentials measured by the electrodes, the input importance of the amplifier must be several times that of the electrodes.

Since measurement of bioelectric potentials requires the use of two electrodes, the voltage measured is really the difference between the instantaneous potentials of the two electrodes, as shown in the figure. If the electrodes are of the same type, the difference is usually small and depends essentially on the actual difference of ionic potential between the two points on the body from which measurements are being taken. If the two electrodes are different, however, they may produce a significant dc voltage that can cause current to flow through both electrodes as well as through the input circuit of the amplifier to which they are connected. This de voltage is called the electrode offset voltage. The resulting current is often, wrongly, interpreted as a

true physiological event. Even two electrodes of the same material may produce a small electrode offset voltage.

In addition to electrode offset voltage, experiments have shown that the chemical activity taking place within an electrode can cause voltage fluctuations to occur without any physiological input. Such variations may appear as noise on a bioelectric signal. This noise can be reduced by proper choice of materials or, in most cases, by special treatment like electrolytic coating of electrodes to improve stability. It has been found that, electrochemically; the silver-silver chloride electrode is very stable. This type of electrode is prepared by electrolytic coating a piece of pure silver with silver chloride.

3.3.5 Skin Surface Electrodes:

These are also known as Body surface electrodes. These are found in many sizes and forms. Although any type of surface electrode can be used to sense ECG, EEG or EMG potentials, the larger electrodes are usually associated with the ECG where localization of electrodes is not important, unlike the other two.

The earliest biopotential measurements used immersion electrodes, which were merely buckets of saline into which the patient placed the hands and feet one bucket for each extremity. This had problems of maintenance, spillage and inconvenience of position. A great improvement over the immersion electrodes was the plate electrodes. Originally separated from the subject's skin by cotton or felt pads soaked in a strong saline solution, later versions used a conductive

electrolyte jelly or paste. The metal is allowed to contact the skin through this thin coating. Plate electrodes of this type are still used today. Another fairly old type of electrode still in use today is the suction cup electrode. This is especially used as a unipolar lead in ECG.

Both these electrodes suffer from sensitivity to movement. Even the slightest movement changes the thickness of the thin film of electrolyte between the metal and skin and thus causes variance in electrode potential and impedance. In many cases, the potential changes are so severe that they completely block the bioelectric potentials the electrodes attempt to measure. Floating electrodes remove this problem. To eliminate the need for cleaning and caring of the electrodes after each use, disposable electrodes have been introduced. These are of floating type with simple snap connectors. Primarily intended for ECG monitoring. These can be used for EEG and EMG.

3.4 Signal Characteristics:

Given below are parameters for major biomedical signals in terms of frequency content and amplitude.

3.5 Abnormalities:

The four categories of diseases are considered

1.Heart blocks:

a. RBBB

b. 1st degree AV block

2.Rhythms:

a. Sinus Tachycardia

b. Sinus Bradycardia

c. Sinus Arrhythmias

3.Myocardial Infarcts:

a. Anterio lateral wall myocardial infarct

b. Inferior wall myocardial infarct

4.Left Ventricular Hypertrophy

Symptoms:

Normal ECG

The heart rate of a normal person is 72 per min. & the range is 60-120 per minute.

Rhythm: regular

P wave:	amplitude	duration
	about 0.25mv	0.12 sec.

PR interval 0.12- 0.2Sec

QRS Complex 0.04 –0.10 Sec.

ST Segment is isoelectric.

T wave is usually upright except in lead aVR and V1.

QT interval: - The normal Qt interval is 0.32-0.45.

U wave: Normally U wave is absent or it may be just present. Its amplitude & duration are less than that of the T wave.

Abnormal ECG

1. **Heart blocks:**

A. Right Bundle Branch Block:

1. A wide slurred QRS Complex with rsR pattern in leads V1 and V2 and a wide S wave in leads I, V5 and V6. Q waves are absent.

2. QRS Complex is wide more than 0.12s.
3. ST depression & T wave inversion may be present in leads V1 & V2.

B. 1st Degree AV block:

Delay in Conduction of impulse through AV node. This results in prolongation of RR interval to above 0.2 seconds
Rhythm is regular & no beat is dropped.

2. Rhythms:

A. Sinus Tachycardia:

Cardiac rate > 100 times/min

RR is less than 15 small squares with normal PQRST Complexes occurring at regular intervals.

B. Sinus Bradycardia:

Cardiac SA node discharges < 60-times/ min Pulse rate less than 60/min
RR interval is more than 25 small squares with normal PQRST Complexes occurring at regular intervals

C. Sinus arrhythmia:

It is alternate period of Tachycardia & Bradycardia, which occur due to irregular discharge of the SA node associated with phase of respiration.

Tachycardia occurs towards the end of inspiration and Bradycardia occurs towards the end of the expiration.
PQRST Complexes are normal but occur irregularly in relation to phase of respiration so that PR interval varies.

3.Myocardial Infarct:

There are two types:

A) Anteriolateral wall myocardial infarct.

a. ST elevation found in lead 2, 3, avF.
b. ST depression in leads V2-V6 & T inversion.

B) Inferior wall myocardial infarct.

ST elevation found in leads V2-V6 & T inversion in leads 2,3,avF.

There are three stages of myocardial infarct:

i. Initial stage: - ST elevation and T inversion found.
ii. Developing stage: - No inversion of T found.
iii. Chronic stage: - Q wave amplitude > ¼(R wave amplitude).

4. Left Ventricular Hypertrophy:

ST – T Charges – Without digitalis

With digitalis

QRS interval 0.09sec or more

Causes of LVH: -

1) Hypertension
2) Coronary artery disease.
3) Mitral insufficiency.
4) Aortic Valvular disease.
5) Congenital heart disease: patent ductus arteriosus, Co arctation of aorta, tricuspid atresia.
6) Cardio myopathies.

4. Software development:

4.1 Simulation of ECG signal:

The ECG data samples are taken at the rate of 250 samples/second. The amplitude scale is 0.1 mV/unit. A positive potential is represented by a negative number and vice-versa. This is done for plotting the waveform on the graphics screen.

The ECG waveform is photocopied, enlarged and is sampled using transparent graph paper. The value of ECG signal for each instant is noted. These data points are then entered in the data file using a computer program ‘Database.cpp’. This program asks for the total number of samples in one cycle of the waveform and asks for the data points. Before the data entry, the filename is to be specified. The program itself writes the data points into the file mentioned. This procedure is adopted for all waveforms i.e. standard as well as abnormal signals. This is shown in the figure.

4.2 Noise in ECG:

The QRS detection is difficult not only because of physiological variability of QRS complex, but also due to the noise that can be

present in the ECG. Typical noises present are already mentioned in the previous section.

4.2.1 Characteristics of Noise:

1. Power the interference:

It consists of 50 Hz fundamental sinusoidal and its harmonics. It may have amplitude up to 50% of peak to peak of ECG signal.

2. Electrode contact noise:

It is a transient interference caused by loss of contact between the electrode and skin of the patient, which in turn disconnects the measurement system from the subject. This type of noise can be modeled as a randomly occurring rapid base line step transition that decays exponentially to the base line.

Duration - 1 second

Frequency - 50 Hz

3. Motion artifacts:

These are transient (not step) baseline changes caused by change in the electric skin impedance. As electrodes are directly connected to the amplifier that sees this impedance change as different source impedance and hence output of the amplifier changes as motion artifacts.

Its amplitude may be up to 500% of peak-to-peak ECG amplitude.

4. Muscle movement noise:

Muscle movement of the subject causes mV potentials and these are recorded along with actual ECG. The signal resulting from muscle movement can be assumed to be transient burst of zero-mean band-limited Gaussian noise. Its typical parameters are:

Duration - 50 ms

Frequency content - 0 to 10 KHz

Amplitude - up to 10% of peak of ECG signal

5. Base line drift:

This can be due to respiration of the subject. This type of noise can be represented as a sinusoidal component at the frequency of respiration that is added to the ECG signal. Amplitude of the signal must be variable.

Typical parameters:

Amplitude variation: up to 15% peak to peak of ECG signal

Base line variation: 0.15 Hz to 0.3 Hz

6. Noise generated by electronic devices used in signal processing:

A QRS detection algorithm cannot correct this type of noise. The input amplifier gets saturated and no signal can reach the detector. In this case an alarm must be present to alert the ECG technician to take corrective action.

7. Electro surgical noise:

This type of noise can completely destroy the ECG and can be represented by large amplitude (randomly varying) sinusoid with frequency approximately between 100 KHz to 1 MHz.

Typical parameters:
Amplitude: up to 200 % of peak to peak of ECG signal amplitude
Frequency contents: 100 KHz to 1 Mhz
Duration: 1 to 10 seconds

4.3 Simulation of Noise:

Out of various types of noise discussed, four noise signals are simulated.

4.3.1 Power line interference:

This kind of noise is always present when the system is connected to the main's source. [Power line frequency = 50 Hz]. Noise is simulated using sine function in 'C' programming language with randomly varying amplitude as: random (10) sin (2*PI*50*t/250). Sampling rate used is 250 samples per second.

4.3.2 Muscle movement noise:

This kind of noise is simulated as - random (8)sin (2*PI*200*t/500)
The noise amplitude varies between zero to 8.

4.3.3 Base line drift OR base line wander:

This noise is simulated as10*sin (PI*t/500). The frequency of sinusoid is kept to 0.25 Hz and maximum amplitude is kept at 0.2 mV.

4.3.4 Composite noise:

This noise is simulated using two different noise signals. These are power line interference and base line drift (low frequency noise). High frequency noise is purposefully not added, as its addition will not be seen due to power line interference noise. Otherwise it can also be added.

Other noises are not simulated specifically because electro surgical noise and instrumentation noise, both of these noises are similar to muscle movement noise. Similarly the motion artifact is much like the base line drift and therefore it is not simulated.

Corrupted ECG signal is obtained by adding noise sample to the ECG sample points.

4.4 Noise Filtering:

The noise added ECG i.e. Corrupted ECG signal is filtered to obtain the actual ECG. This noise filtering is done using Digital Signal Processing techniques.

4.4.1 Digital Signal Processing: (DSP):

DSP provides an alternative method for processing the analog signal. To perform the processing digitally, there is a need for an interface between the analog signal and the digital processor. The interface is called an analog to digital converter. The output of the A/D converter is a digital signal that is appropriate as an input to the digital processor. Here, digital processor is computer, programmed to perform filtering operation on the input signal.

As most of the practical interest signals e.g. Speech, biological signals, seismic signals, radar signals, etc are analog, to process them by digital means, first they are converted to the digital form. This conversion of a continuous-time signal into a discrete-time signal is obtained by taking samples of the continuous time signal at discrete instants. Therefore, if Xa (t) is the input to the sampler, the output is Xa (nT) = X (n), where T is called the sampling interval. The reciprocal of T is called sampling frequency or a sampling rate. Sampling rate should be selected properly. If the sampling period is too large then the upper frequency gets reflected into the lower frequency. This phenomenon is called aliasing.

The basics of processing an analog signal in digital domain are supported by Shannon's theorem. The Shannon's theorem states that, if X (t) is a band limited signal with X (w) = 0; for |w| < Wm, then Xa (t) the analog signal is uniquely defined by its samples X (nt), if Ws > 2*Wm; where Wm = a band limited frequency

Ws = 2*PI/T = sampling frequency

The maximum significant frequency content of an electrocardiogram does not exceed 100 Hz hence, in accordance with the sampling theorem, sampling is performed at a rate if 250 samples per second, which is more than the contents of an ECG signal.

4.5 Digital Filters:

Filters are a particularly important class of linear time invariant systems. The response of the digital filter to an arbitrary excitation can be expressed in terms of the impulse response of the filter.
If the response of the system to unit sample sequence ä (n) is h (n), then as per convolution sum, the response y (n) of the system to an input x (n) of the system to an input x (n) can be expressed as

$$y(n) = \sum_{k=-} x(k) * h(n-k)$$

Thus a linear time invariant system can be completely characterized in terms of its impulse response h (n). If unit sample response is of finite duration, it is referred as finite impulse response system (FIR) and if it is of an infinite duration, it is referred as infinite duration, it is referred as infinite duration impulse response system (IIR).

The causal linear time-invariant FIR system can be described as follows:
For FIR filter: h (n) = 0; n<0 & n> = M

$$=>y(n) = \sum_{k=0}^{M-1} x(k) * h(n-k)$$

FIR systems are nonrecursive whereas IIR filter systems are recursive and their response depends upon the input as well as on the output of the system. The causal linear time invariant IIR system can be described as:

$$=>y(n) = \sum_{k=0} x(k) * h(n-k)$$

FIR filters are all zero systems with poles at z=0 in z-plane and IIR filters are pole-zero systems. FIR filter can be designed to have a linear phase characteristics and it is inherently stable as its poles lie inside unit circle in z-plane. IIR filter can be unstable if its poles are outside the unit circle in z-plane. Because of its linear phase characteristics, in FIR filters the phase distortion is minimized which is essential in biomedical signal processing to preserve certain characteristics of the signal. Here FIR filter is used.

The design techniques for FIR filters are based on directly approximating the desired frequency response of the discrete-time system. The simplest method of FIR filter design is called the window

method. This method generally begins with an ideal desired frequency response that can be represented as:

$$Hd(e^{jw}) = \sum_{n=-\infty} hd[n] * e^{-jw}$$

Where hd [n] is the corresponding impulse response sequence, which can be expressed in terms of Hd (e) as:

$$Hd[n] = \int_{-n}^{n} (1/2 * PI)\, Hd(e^{jw})\, e^{jwn}\, dw$$

Many idealised systems are defined by piecewise constant or piecewise functional frequency response with discontinuities at the boundaries between bands. As a result, they have impulse responses that are noncausal and infinitely long. The most straightforward approach to obtain a causal FIR approximation to such systems is to truncate the ideal response. The simplest way to obtain a causal FIR filter from hd [n] is to definite a new system with impulse response h [n] given by

$$h[n] = hd[n]; \quad 0 <= n <= M$$
$$= 0; \text{ otherwise}$$

More generally, we can represent h [n] as the product of the desired impulse response and a finite duration window w [n] i.e.

$$h[n] = hd[n] * w[n]$$

4.5.1 Some commonly used windows are:

Rectangular:

w [n] =1; 0<=n<=M

=0; otherwise

Bartlett (triangular):

w [n] =2 *n/M; 0<=n<=M/2

= 2 -2*n/M; M/2<=n<=M

= 0; otherwise

Hanning:

w [n] = 0.5 - 0.5 * cos (2*PI*n/M): 0 < = n<=M

= 0: otherwise

Hamming:

w [n] = 0.54 - 0.46 * cos (2*PI*n/M); 0<=n<=M

= 0; otherwise

Blackman:

w [n] = 0.42-0.5* cos (2*PI*n/M) + 0.08* cos (4*PI*n/M); 0<=n<= M

= 0; otherwise

In practice the window function will produce the side lobes along with the main lobe. These side lobes are undesired and should be reduced. Otherwise they give rise to Gibbs oscillation in amplitude

response of the filter. If the order of the filter increases then the amplitude of main lobe increases and amplitude of side lobe decreases, but the width of main lobe decreases and that of side lobe increases such that the area under each lobe is constant. Tapering the window smoothly to zero at each end can moderate Gibbs oscillation. Therefore the trade off between the main lobe width and side lobe area is required. Here,
Blackman's window is selected as it gives maximum side lobe attenuation.

4.6 FIR Filter Design:

The steps followed are:

- Obtain the impulse response h [n] of the filter from frequency response H (e^{jw}).
- Define the required specifications such as lower frequency of transition region, upper frequency of transition region, stop band frequency, pass band frequency, sampling frequency.
- The transition width is the frequency range in which the filter characteristics move from pass band to stop band or vice-versa. If there are more than one transition region, minimum of all such widths is used.

By using the formula for transition width for the selected window function i.e. (=12*PI/M), find the order of the filter and the center of the symmetry as (M-1)/2.

- Calculate corner frequency as Wc=2*PI*(fl-fh)/(2*fs) where

fl=lower transition frequency

fh=higher transition frequency

fs=sampling frequency

- System response h [n] is obtained by multiplying filter response with samples of window function.

  h [n]=hd [n]*w [n]

- Finally the output y [n] of the filter to the input x [n] is computed as

  y [n] = x [n]*hd [n].

Now, convolution in time domain is equivalent to multiplication in frequency domain. Therefore convolution is computed using DFT as: First compute the DFT of filter coefficients h [n] using DFT procedure described later in this chapter, then compute DFT of corrupted ECG signal x [n] using DFT. Multiply both DFT and then compute IDFT of the resultant to obtain filtered ECG.

4.7 Determination of filter coefficients h [n]:

Coefficients of the filter are computed using the steps described in the previous section.

4.7.1 Low Pass Filter:

Frequency response of low pass linear phase FIR filter is

$$Hd(w) = e^{-jw(M-1)/2};\ 0 <= |w| <= Wc$$

= 0; otherwise

Delay of (M-1)/2 units is incorporated into Hd (w) in anticipation of forcing the filter to be of length M. The corresponding units sample response is obtained as:

$$hd[n] = \int_{-wc}^{wc} (1/2 * PI) * e^{jw(n-(M-1)/2)}\, dw.$$

Equation 1: hd [n] = [sin (wc*(n- (M-1)/2)] / (PI*(n- (M-1)/2));
n (M -1)/2

By Shannon's theorem sampling frequency should be greater than the maximum frequency content in the signal to be sampled. Considering noise we take fs = 500 Hz. As required ECG signal frequency is in the range of zero to 120 Hz, the frequency above 150 Hz is not allowed to pass.

Specifications:
Pass band: 0 to 100 Hz.
Stop band: 120 & above.

Blackman window w [n] function is selected as it gives maximum attenuation for side lobe.
Transition width (TW) = 12*PI*(150-120)/500 = 0.12*PI
For Blackman's window: TW = 12*PI/N

Therefore order of filter N = 12*PI/TW =100

For odd symmetry take higher order odd value, Therefore N = 101.

Center of symmetry = (N -1)/2 = 50.

Corner frequency (wc) = 2*PI*(150 +120)/ (2*fs) = 0.54*PI.

In equation 1 the required values calculated as above are substituted.

For n = (N-1)/2, h [n] is calculate as h [n] = wc/PI =0.54

Sample value calculated for h[0] from equation 1 is

h [0] = sin (0.54*PI*(0-50))/PI*(0-50))

= 0

4.7.2 High Pass Filter:

Frequency response of high pass filter is given by

Hd (w) = 0; 0<= | w| < = Wc

$= e^{-jw\,(M-1)/2}$; wc <=|w| <=PI

Corresponding unit sample response is obtained as

$$hd[n] = \frac{1}{2\pi}\int_{-\pi}^{\pi} Hd(w)\, e^{jwn}\, dw.$$

Equation 2. Hd [n] = [sin (PI*(n- (M-1)/2))- sin (Wc*(n- (M-1)/2))]/(PI*(n-(M-1)/2));

n (M-1)/2

Specification:

Sampling frequency fs: By Shannon's theorem sampling frequency should be greater than the maximum frequency content of signal to be the signal to be sampled which is about 120 Hz. In this case noise frequency is lower than ECG signal frequency, therefore,

fs = 250Hz.

As required ECG signal frequency is in the range of zero to 120 Hz, the frequency below 0.5 Hz. is not allowed to pass.

Pass band = 2.5 Hz and above

Stop band = 0 to 0.5 Hz.

For Blackman's window transition width TW = 12*PI /N.

Also, TW = 2*PI*(0.5-2.5)/250 = 0.016 *PI

Therefore, N = 12*PI/W =750,

We take higher order i.e. = 751

Center of symmetry (N-1)/2 =375

Corner frequency = Wc = 2*PI*(0.5 + 2.5)/(2*fs) = 0.012 *PI

Find the system response h [n] =hd [n] * w [n],

For n = (N-1)/2, h [n] = 1 - Wc/PI = 0.988

Sample value is calculated for n =0 as,

h [0] = [sin (PI*(0-375)) - sin (0.012 *PI*(0-375))]/ (PI*(0-375))

= 0.0008488

4.7.3 Band Reject Filter:

Frequency response of band reject filter is given by,

Hd (w) =e^{-jw}; |w| < Wc 1

= e^{-jw}; |w| > Wc2

= 0; otherwise

Corresponding impulse response is given by,

$$h[n] = \int_{-\pi}^{-wc2} (1/(2*PI))*Hd(w)*e^{-jwn}\,dw + \int_{-wc1}^{wc1} (1/(2*PI))*Hd(w)*e^{-jwn}\,dw + \int_{wc2}^{\pi} (1/(2*PI))*Hd(w)*e^{-jwn}\,dw$$

h [n] =[sin (PI*(n-alpha)] + sin (Wc1*(n-alpha)) - sin (Wc2*(n-alpha))]/(PI *(n-alpha0)

Where, alpha = (M-1)/2.

Specifications:

Sampling frequency fs: By Shannon's theorem sampling frequency should be greater than the maximum frequency content in the signal to

be sampled which is about 120 Hz. In this case noise frequency is lower than the signal frequency. Therefore, fs = 250 Hz.
As the required frequency range is in the range of zero to 120 Hz, the frequency between 49 Hz. to 51Hz is not allowed to pass.

Lower pass band: 40 to 49 Hz.
Upper pass band: 51 to 60 Hz.
Stop band: 49 to 51 Hz.

Lower transition width = 49 -40 = 9
Upper transition width = 60 -51 = 9

Transition width = 2*PI*9/250 = 0.072 *PI
For Blackman's window TW = 12*PI/N
Therefore, the order of the filter, N = 12*PI/TW =167
Center of symmetry = (N-1)/2 = 83
Lower corner frequency Wc 1 = 2* PI*(40 + 49)/(2*fs) =0.356*PI
Upper corner frequency Wc2 = 2*PI*(51+60)/(2*fs) =0.444*PI
Find the system response hd [n] = h [n]*w [n]
From equation 2 we get sample value for n=0 as,
h[0] = [sin(PI*(0-83)) + sin (0.356*PI*(0-83)) - sin (0.444*PI*(0-83))] /(PI*(0-83))
= 0.00551
For n = (M-1)/2, h [n] = Wc/PI = 0.8

4.8 Important Frequency Domain Characteristics of Some Window Functions:

The different window function characteristics are as shown in table.

4.9 Discrete Fourier Transform:

The discrete Fourier transform (DFT) plays an important role in the analysis, design and implementation of discrete-time signal processing algorithms and systems.

The DFT of a finite length sequence of length N is,

Equation1: $$X[k] = \sum_{n=0}^{N-1} (1/N)* X[k]* (W_N)^{kn}, n=0,1,2 \ldots N-1$$

Where $W_N = e^{-j(2PI)/N}$

The inverse discrete Fourier transform is given by,

Equation 2: $$x[n] = \sum_{k=0}^{N-1} (1/N)* X[k]* (W_N)^{-nk}; n=0,1,2 \ldots N-1$$

Since equations differ only in the sign of the exponent of (W_N) AND in the scale factor (1/N), a discussion of computational procedure for equation 1 applies with straightforward modifications to 2.

4.10 QRS Detection:

QRS detection is difficult not only because of the physiological variability of the QRS complex but also because of the various types of noise that can be present in the ECG signal. The various types of noise present are already discussed in the previous sections. Generally following steps are followed for QRS detection.

- Linear Filtering
- Nonlinear Transformation
- Decision rule

Out of these linear filtering has already been discussed. Various steps used in QRS detection are

- Differentiation
- Squarer
- Moving window integration
- Parameter detection

4.10.1 Differentiation:

An ideal differentiator has a frequency response that is linearly proportional to frequency. Its frequency response is given by:

Hd (w) =jw; -PI<= w<= PI

Corresponding unit sample response is

$$hd[n] = \int_{-\delta}^{\delta} (1/(2* PI)* Hd(w)*e^{jw}\, dw$$

$$= \int_{-\pi}^{\pi} (1/(2*PI)* jw * e^{jw} \, dw$$

hd [n] = cos (PI*N)/N; n< > 0

hd [0] = 0

The ideal differentiator has an antisymmetric unit sample response.ie.hd [n] =hd [-n] Now

$H [z] = h [nT]*w [nT]*z^{-n}$

Here H [z] is calculated for N =5 to get five point derivative symmetrical about n =0, from n = -2 to n =2

$H [z] = h [nT]* w [nT]*z^{-n}$

Where w [nT] is a rectangle window,

w [n] =1; 0< = n <= M

= 0; otherwise

=> $H [z] =(1/(2*T))*[z^{-2} -2*z^{-1}+2* z^{1}-z^{2}]$

Therefore, y [n] = (1/(2*T))*(x [n-2] -2*x[n-1] + 2*x[n+1] - x[n+2])

4.10.2 Non Linear Transformation:

Non-linear transformation is the squaring of the differentiated signal. Non-linear transformation intensifies the amplitude of R wave, as compared to the amplitude of T wave. Otherwise T wave may be taken as R wave, if amplitude of T wave is compared to R wave.

Squaring is done as follows:

$y[n] = (x[n])^2$

4.10.3 Moving window integration:

The differentiated signal provides information only about slope of R wave. The purpose of moving window integration is to obtain the width of QRS complex in addition to slope of R wave. But this can also be found using zero detection technique as explained in the next section.

4.10.4 Detection of Parameters:

- R wave detection:

R wave is detected by applying amplitude threshold to the ECG signal. Initially threshold is kept to zero, then signal sample is compared with it. If the signal sample is greater than the current threshold then the threshold is changed to the current signal sample. This procedure is carried out till the maximum value is obtained and the corresponding time is also noted.

- S wave detection:

S wave is detected by applying amplitude threshold to the ECG signal. Initially the threshold is kept to zero, then the signal sample is compared with it. If the signal sample is lower than the current threshold then the threshold to the current signal sample. This

procedure is carried out till the lower maxima is obtained and the corresponding time is also noted.

- Q wave detection:

For Q wave detection, search back technique is used by applying amplitude threshold to the ECG signal. Initially the threshold is kept to zero. The search is carried out from time of R wave. Same procedure is adopted as in S wave. The lower point is taken as Q wave and corresponding time is recorded as time of Q wave.

- Width of QRS complex:

Width of QRS complex is simply found by taking the difference between time of end of S wave and the start time of Q wave. The time of end of the S wave is found by moving towards the right from the S-wave is found by moving towards the right from S-time detecting zero crossing. Similarly for start of Q time, we move left from Q time and find the zero crossing.

4.11 Mouse

The mouse driver is implemented using INT 33H of the BIOS STD function .The BIOS is a rich set of library having many required functions for handling the various Mouse event like Mouse_Enabling, Mouse ON/OFF, Mouse Displaying ON/OFF. Mouse control rate

(Mickeys), We can also change the size, shape and color of the mouse pointer. But it requires the graphics mode to be in graphics mode, which is also a option available. Mouse_CLICKING Mouse_TRACKIING can also be implemented using various functions. The above shows e.g. used in c language to check for mouse **LEFT click**.

```
int buttons,x,y;
regs.x.ax=3;
int86(0x33,&regs,&regs);
x=regs.x.bx;
if(x==0){
return(0);
}
if(x==1)
{ return(1);}
```

Mouse which was invented by XEROX company is now very popular and used for Graphical User Interface, which we have implemented and is possible because of the BIOS mouse function independent of type of mouse i.e. PS2/Serial/BUS.

5.Project Work details

5.1 Block Diagram

5.1.1 Introduction:

In the present project work, one standard and eight abnormalities are simulated. Further processing is done to detect the QRS complex from the ECG signal.

Work done is as per the block diagram shown.

5.1.2 Simulation of ECG signal:

Database for standard and abnormal ECG is generated by using software, by defining the points for

ECG waveform. The database is a linear array of 250 samples per second.

Abnormalities generated have already been discussed.

5.1.3 Noise simulation:

Various types of noise may corrupt ECG.

For example:

- Power line interference

- Electrode contact noise
- Base line drift or base wander
- Muscle artifacts
- Muscle movement
- Instrumentation noise generated by electronic devices used in processing
- Electro surgical noise source present in ECG.

Here, there noise sources and one composite of power line interference and base wander noise is simulated.

5.1.4 Corrupted ECG:

Addition of noise to the ECG signal gives corrupted ECG.

5.1.5 QRS detection:

Detection of QRS is done using the QRS detection algorithm discussed in the forthcoming sections.

5.1.6 Computation of parameters & output:

Varies ECG parameters are found out & the result is displayed.

5.2 Algorithms

1.Database.cpp:

1. Display the Banner.
2. Display the first menu (Data Entry Menu) and ask user for his choice.
3. If choice is to ‘Enter input points’ goto 4 .If choice is for saving to disk goto 5. If choice is for quit, exit the program.
4. Display banner, show the ‘Add ECG signal menu’. If user choice is for ‘Add new signal’ goto 6.If user choice is for ‘Review points’ goto 10.For other choice goto 3.
5. Ask user for name of file to be saved and create a file with that name and goto 3.
6. Display banner. Create a file named ‘Default.dat’ and display, ask and take from user the information about ‘Name of Disease’, ‘Age of person’.
7. Ask user for number of samples for a particular lead. Then ask him to enter data points.
8. Repeat the procedure in 7 until the data points for each lead are taken. Then display a message indicating everything is done and save file default.dat to the disc.
9. Return back to 4.
10. Display banner. If user choice is for ‘Review points’, display the Name, Age, Disease from ‘default.dat’. Now ask user for his choice to see a particular lead and display array of particular lead. Return back to 4 as per the user choice.

2.Main.cpp:

1. Initialize graphics engine, initilise and show mouse pointer on the screen. Open ‘default.dat’ in binary input mode.
2. Show main menu and check status of input device by going to 11. If user choice is ‘File’ menu, clear screen, display the dat files from the current directory and ask the user for his choice of file and return to main menu.
3. If user choice is ‘Next menu’ goto 5 else goto 2.
4. If user choice is ‘Exit’, come out of the program, turn off the mouse curser, turn off mouse, disable the graphics engine and return back to operating system.
5. Refresh the screen, display the ‘Next menu’ and check the status of input device. If user selection is to simulate goto 6. If user selection is ‘Lead selection’ goto 7. If user selection is ‘Noise’ goto 8. If user selection is ‘Filter’ goto 9. If user selection is ‘Main menu’ goto 2. If user selection is ‘Detect QRS’ goto 10.
6. Fill the array with data according to the lead chosen by the user else take the default lead as V6. If user has chosen a particular noise, add the noise to the original data array. Now if user has selected a filter pass the array through the filter algorithm, multiply by scaling factor, adjust zero position as per the screen mode (resolution chosen is 640x480). Then plot each point and draw lines to join them. Goto 5.
7. Clear the screen, ask user for his choice of lead to be seen and change the value of lead parameter. Goto 5.
8. Clear the screen, ask user for his choice of noise to be simulated and change noise parameter. Goto 5.

9. Clear the screen, ask user for his choice of filter and change the filter parameter to decide the type of filter. Goto 5.
10. Clear the screen; display the R wave amplitude, R time and QRS width, as per the QRS algorithm and goto 5.
11. Monitor the mouse position, if it is on the known area, display the note on the screen, else blanken the part of screen. Also monitor keyboard for any known keys and do the action as per the key. If there is a mouse left click over a particular area do action as per menu.

3.Differntiation:

1.t=4

2.xr [0]=(2*dis [1]-dis [2])/(2*t)

3.xr [1]=(-2*dis [0]+2*dis [2]-dis [3])/(2*t)

4.For I=2 to 228 do following in steps of 1:

xr [i]=(-dis [I-2]-2*dis [I-1]+2*dis [I+1]+dis [I+2])/(2*t)

5.Call function to plot differentiated signal.

6.Close graphics screen.

7.Return to calling function.

4.Transform:

1.For I=2 to 228 do the following in steps of 1:

$$xi[I] = -(xr[I])^2$$

2.Call the function and plot squared waveform from data points.

3. Close the graphics screen.

4. Return to the calling function.

5.Filter:

1.Display the type of filter to be used i.e. Low pass, High pass, Band reject and composite.

2.Blackman windows is used ,whose formula is

$$W[i] = 0.42 - 0.5\cos(2*Pi*i/M) + 0.08\cos(4*Pi*i/M)$$

3.If selection is low pass GOTO 4.If selection is Band Reject GOTO 5 ,If high pass GOTO6 ,if composite then GOTO 7 and for no filter GOTO 9.

4. Calculate the filter coefficients according to cut off frequency using BLACKMAN window. GOTO 8.

5. Calculate the filter coefficients according to cut off frequency using BLACKMAN window. GOTO 8.

6. Calculate the filter coefficients according to cut off frequency using BLACKMAN window. GOTO 8.

7.Calculate the filter coefficients for band reject filter and convolve, then find the coefficients for high pass filter and GOTO 8.

8.Find the convolution of the array using DFT – IDFT technique with the filter coefficients, and store result in array.

9.Terminate the sub-loop.

6.Noise generation:

1.Display the types of noise to be simulated

2. If selection is “Muscle movement Noise” GOTO 3,If selection is “Power line interference” GOTO 4,If selection is “Baseline Drift”, GOTO 5,If selection is “Composite Noise” GOTO 6 and if selection is “No Noise” GOTO 8.

3.Calculate the noise according to Frequency and amplitude and store

Noise [i]= random (6)*sin (2*Pi*200*i/500) and GOTO 7.

4. Calculate the noise according to Frequency and amplitude and store

Noise [i]= random (10)*sin (2*Pi*i/5) and GOTO 7.

5. Calculate the noise according to Frequency and amplitude and store

Noise [i]= 10*sin (Pi*i/500) and GOTO 7.

6. Calculate the noise according to Frequency and amplitude and store

Noise [i]= random (10)*sin (2*Pi*i/5) + 10*sin (Pi*i/500) and GOTO 7

7. Add noise to the ECG array and GOTO 8.

8. Terminate the sub-loop.

7.QRS Detection:

1. Find the MAX value in the array and multiply it with the scaling factor, to give R-amplitude.

2.Find the corresponding sample no for the max value and also multiply it with the scaling factor to give R-time.

3.After Differentiating and Squaring (transforming) QRS width is calculated using following steps:

a. Find the sample point for which amplitude become zero on the both sides of R-Time which gives Q-time and S-time samples

b. The difference between the S-time and Q-time samples is multiplied with scaling factor to give QRS width.

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