Simulation and Study of Cardiac Disorders

Anjali J. Deshmukh
Associate. Professor, Dept. of Electronics
Shri Shivaji College
Akola (MS), India
ajaydesh@rediffmail.com

Yogendra B. Gandole
Principal & HOD, Dept. of Electronics
Adarsh Mahavidyalaya
Dhamangaon Rly (MS), India
ygandole@gmail.com

Abstract— The examination of the ECG has been comprehensively used for diagnosing many cardiac diseases.The growing health concerns, especially for cardiac disorders reflect on the need of developing a simple inexpensive and portable ECG system. In the present work, a simple ECG simulator module has been developed using LabVIEW that displays ECG wave of various cardiac disorders related sinus and nonsinus arrhythmias. The ECG wave is recorded and analyzed using LabVIEW software. The better analysis of the ECG can help doctors to give the appropriate care to the patients and also helps to avoid various severe situations that may arise.

Keywords- *ECG; Cardiac disorder; Heart Rate; arrhythmia; LabVIEW*

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I. INTRODUCTION

ECG is an important biomedical parameter and is used clinically in diagnosing various diseases and conditions associated with the heart. Cardiovascular diseases (CVD) are a disease that involves the heart or blood vessels. Most countries face high and increasing rates of cardiovascular disease. Each year, heart disease kills almost 2.6 million people which constitute 54.1% of all CVD deaths in India by 2020. Cardiovascular diseases are the world's largest killers, claiming 17.1 million lives a year [1]. Cardiac healthcare is the fastest growing market as cardiovascular disease is the leading cause of death in the world. Among the various medical or healthcare information, ECG is best way to measure and diagnose abnormal conditions of the heart. It is a painless, inexpensive and measuring quantity and thus ECG has become one of the most preferable vital in the area of healthcare.

The state of cardiac heart is generally reflected in the shape of ECG waveform and heart rate. ECG, if properly analyzed, can provide information regarding various arrhythmia diseases related to heart. Clinical observation of ECG can take long hours and can be very tedious. Moreover, visual analysis cannot be relied upon and the possibility of the analyst missing the vital information is high. Hence, computer based analysis and classification of heart diseases can be very helpful in diagnosis.

The Electrocardiogram (ECG) provides the valuable information regarding the cardiovascular diseases. ECG is a test that measures the electrical activity of the heart. The morphology and heart rate reflects the cardiac health of human heart beat. It is a non invasive 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.

II. NORMAL ECG

The electrical wave is due to depolarization and re polarization of Na+ and k-ions in the blood. Amplitude and duration of PQRST waves correspond to electrical power fluctuation in entire heart. An ECG signal is therefore presented by using a graph, where the y-axis represents voltage and the x-axis represents time. Any abnormalities in the heart rate can be monitored by analyzing the graphs. The R-R interval is referred as the interval from the peak of one QRS complex to the peak of the next in an electrocardiogram as shown in figure1. The R wave is usually chosen to do this because it is the tallest and most conspicuous. In most rhythms, the R-to-R interval will be the same as the P-to-P distance, or the distance between any two analogous points on consecutive beats.

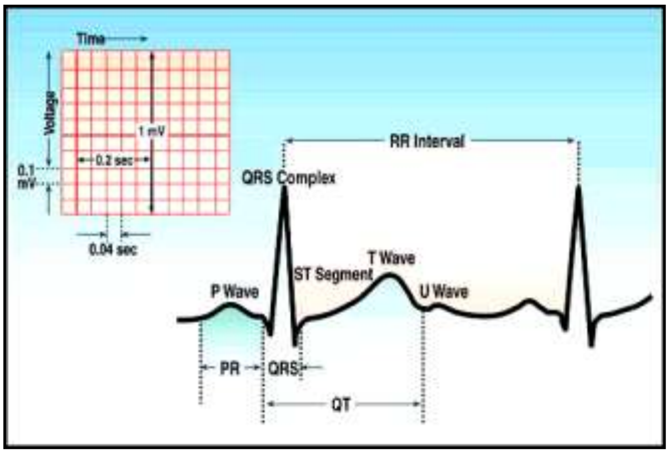

Figure 1 ECG waves and intervals [2]

Normally the frequency range of an ECG signal is 0.05– 100 Hz and its dynamic range – of 1–10 mV. The ECG signal is characterized by five peaks and valleys labeled by the letters P, Q, R, S, T. In some cases we also use another peak called U. The performance of ECG analyzing system depends mainly on the accurate and reliable detection of the QRS complex, as well as T and P-waves. The detection of the QRS complex is the most important task in automatic ECG signal analysis. Once the QRS complex has been identified a more detailed examination of ECG signal including the heart rate, the ST segment *etc.* can be performed [3].

Standard values of normal ECG is shown in table 1.

Parameters	Amplitude (mv)	Parameters	Duration (Sec)
P-Wave	0.25	P-R Interval	0.12 to 0.20
R-Wave	1.60	Q-T Interval	0.35 to 0.44
Q-Wave	25% of R-wave	S-T Segment	0.05 to 0.15
		P-Wave interval	0.11
T-Wave	0.1 to 0.5	QRS-interval	0.09
U-Wave	May be or may not be exists		
Heart Rate	60 to 100 bpm		

Table 1: Standard values Normal ECG Waveform [4]

III. MATERIAL AND METHOD

Normal ECG done in clinical setting allows monitoring and recording but gives no analytical results. Available data analysis algorithms are complicated, as they do not implement transparent decision procedure The better analysis of the ECG can help doctors to give the appropriate care to the patients and also helps to avoid various severe situations that may arise.

The growing health concerns, especially for cardiac disorders reflect on the need of developing a simple inexpensive and portable ECG system. In the present work, a simple ECG simulator module has been developed using LabVIEW-11 that displays ECG wave of various cardiac disorders related sinus and nonsinus arrhythmias. The ECG wave is recorded and analyzed using LabVIEW software.

IV. LABVIEW - A GRAPHICAL PROGRAMMING

The software package LabVIEW (Laboratory Virtual Instrument Engineering Workbench) is a commercial product from National Instruments and runs on several host machines (PC, Macintosh, or Sun workstations). LabVIEW is a powerful graphical development environment for signal acquisition, measurement analysis, and data presentation, giving the flexibility of a programming language without the complexity of traditional development tools.

LabVIEW is a graphical programming language that uses icons instead of lines of text to create programs. Unlike text based programming language, LabVIEW uses the data flow programming, where the flow of data determines execution. The flexibility, modular nature and ease to use programming possible with LabVIEW, makes it less complex [5]. LabVIEW is a graphical programming environment which has become widespread throughout research labs, academia and industry. It is powerful and versatile analysis and instrumentation software for measurement and automation [6]. Since the LabVIEW is software oriented, it offers more flexibility than standard laboratory instruments. Because of their appearance and operation imitates the physical instruments, the LabVIEW programs/codes are called virtual instruments (VIs). LabVIEW is designed to facilitate data collection and analysis, as well as offers numerous display options. With data collection, analysis and display combined in a flexible programming environment, the desktop computer functions as a dedicated measurement device. The LabVIEW contains a comprehensive set of VIs and function for acquiring, displaying, and storing the data, as well as the tools since it will support users to troubleshoot the code [7].

LabVIEW has been developed as an environment for the design of virtual instruments (VI). It uses symbols, terminology and formats that are familiar to technicians, scientists, and engineers. LabVIEW is programmed to act as an interface, helping pieces of hardware "communicate" with each other. Moreover, LabVIEW offers built-in libraries that allow the user to work over the internet and use different programming formats and systems.[8].

V. LITRETURE REVIEW

Various contributions have been made in literature regarding detection and classification of ECG Arrhythmias. Most of them use either time or frequency domain representation of the ECG waveforms, on the basis of which many specific features are defined, allowing the recognition between the beats belonging to different classes.

A fahoum *et.al,* [9] has analyzed the work dealing with classification problem of four different arrhythmias: NSR – normal sinus rhythm, AF-atrial fibrillation, ventricular fibrillation(VT)and ventricular tachycardia(VT), RPS. Nonlinear dynamical behavior of the ECG is used to identify the cardiac arrhythmias. This algorithm shows that sensitivity and specificity are within range of 87.7-100%. The classification accuracy is 100% for VF arrhythmia.

P. G. Patel *et.al,* [10] studied the Pen Tompkins Algorithm, efficient method for ECG Signal Analysis which is simple and has good accuracy and less computation time. For analysis the ECG signals from MIT database are used. The peak detection is very important in diagnosis arrhythmia which is proved as tachycardia, bradycardia, asystole, second degree AV block. The results show that from detected QRS peaks, arrhythmias which are based on increase or decrease in the number of QRS peak, absence of QRS peak can be diagnosed

V Mahesh *et.al,* [11] has studied the discrete wavelet transform, heart rate variability and logistic model tree. This LMT classifier to classify 11 different arrhythmia and results obtained 98% accuracy.

BekirKarhket *et. al,* [12] carried out artificial Neural network of ECG signal analyzed in the time domain thus corresponding arrhythmias are determined by using ANN, around 95% result is achieved for identification of arrhythmia.

Sarkalehet *et. al,* [13] has done the discrete wavelet transform and neural networks with DWT is used for processing ECG recording and extracting some arrhythmia and neural network perform classification task. This method is 96.5% accuracy.

VI. THE APPLICATION AREAS OF ECG DIAGNOSIS

Heart disease is a general term for a number of different diseases which affect the heart such as the left ventricular hypertrophy (LVH), right ventricular hypertrophy (RVH), myocardial ischemia, myocardial infarction and bundle branch block. Heart disease is one of the leading causes of death in the world.

The main application of the ECG to cardiological diagnosis includes the following as shown in Figure 2[14].

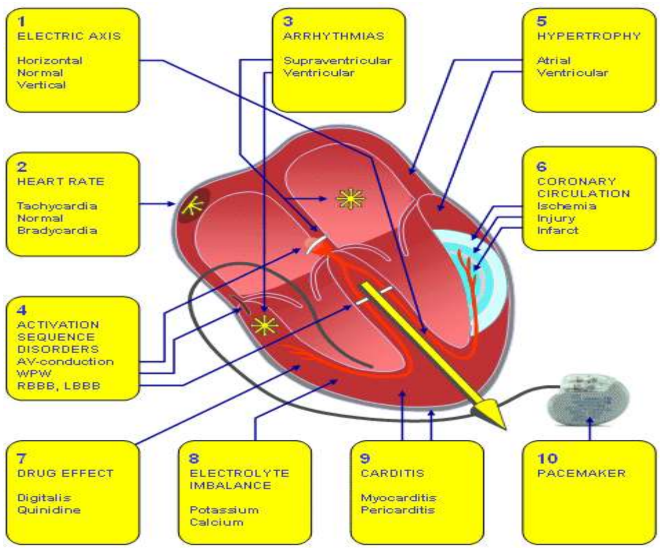

Figure 2 Applications of the ECG to cardiological Diagnosis[15]

A. *Supraventricular rhythms*

Cardiac rhythms may be divided into two categories:

i) Supraventricular (above the ventricles) and

ii) Ventricular rhythms.

The origin of supraventricular rhythms (a single pulse or a continuous rhythm) is in the atria or AV junction, and the activation proceeds to the ventricles along the conduction system in a normal way.

B. *Normal sinus rhythm (NSR)*

The normal rhythm of the heart where there is no disease or disorder in the morphology of ECG signal is called Normal sinus rhythm (NSR). The heart rate of NSR is generally characterized by 60 to 100 beats per minute. The regularity of the R-R interval varies slightly with the breathing cycle.

- Impulses originate at SA node at normal Rate
- All complexes are normal, evenly spaced, Heart rate 60-100bpm

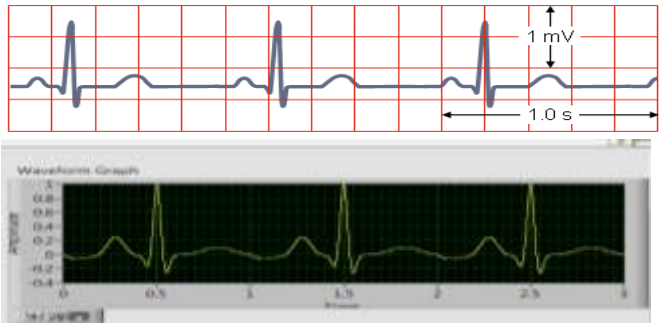

Figure 3 Normal sinus rhythm (Theoretical and Simulated)

C.Sinus atrial rhythm

This type of arrhythmia arises from the SA node of heart. As the electrical impulse is generated from the normal pacemaker, the characteristic feature of these arrhythmias is that P wave morphology of the ECG is normal. These arrhythmias are the following types: Sinus bradycardia, Sinus *tachycardia* and Sinus arrhythmia, etc.

I). Sinus bradycardia

If the heart rate is too slow then this is known as bradycardia and this can adversely affect vital organs. Impulses originate at SA node at slow Rate

- All complexes are normal, evenly spaced, Heart rate <60bpm
- This may be a consequence of increased vagal or parasympathetic tone

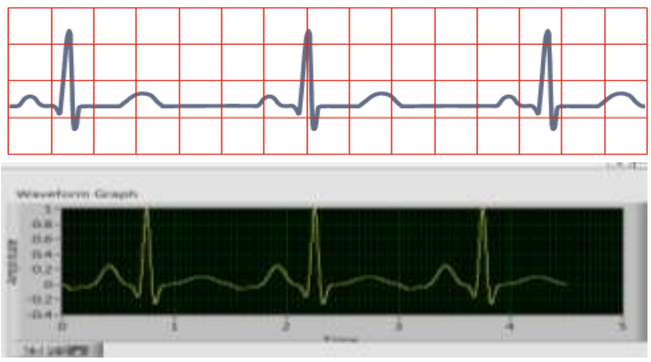

Figure 4 Sinus bradycardia

II). Sinus tachycardia

When the heart rate increases above 100 beats per minute, the rhythm is known as sinus tachycardia. This is not an

ISSN: 2321-8169
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arrhythmia but a normal response of the heart which demand for higher blood circulation. When the heart rate is too fast, the ventricles are not completely filled before contraction for which pumping efficiency drops, adversely affecting perfusion.

- Impulses originate at SA node at rapid Rate
- All complexes are normal, evenly spaced, Heart rate >100bpm
- It occurs most often as a physiological response to physical exercise or psychical stress, but may also result from congestive heart failure.

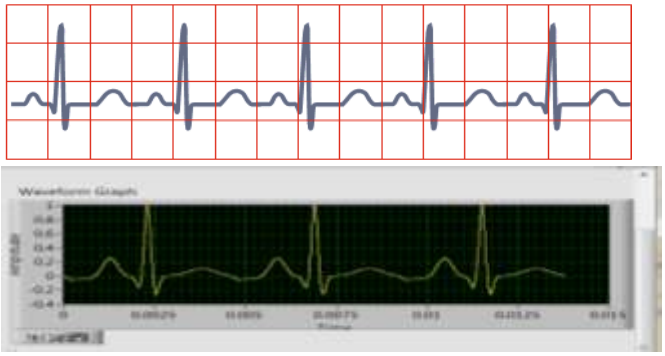

Figure 5 Sinus tachycardia

III). Sinus arrhythmia

- Impulses originate at SA node at varying Rate
- All complexes are normal, rhythm is irregular
- Longest RR interval exceeds shortest > o.16 sec.

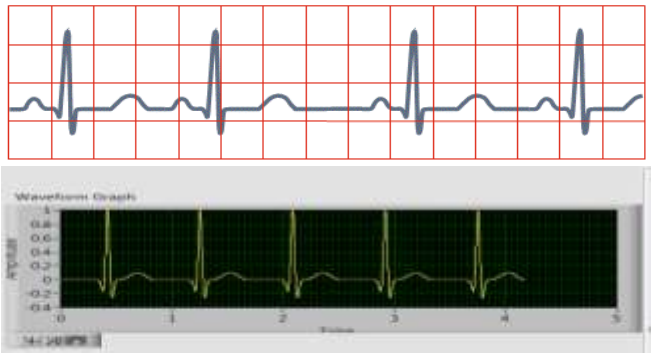

Figure 6 Sinus arrhythmia

D. Nonsinus atrial rhythm

The origin of atrial contraction may be located somewhere else in the atria other than the sinus node. If it is located close to the AV node, the atrial depolarization occurs in a direction that is opposite the normal one. In the ECG the P-wave has opposite polarity. These arrhythmias types are given bellow;

I). Wandering pacemaker

Impulses originates from varying points in atria or wander. Consequently, the P-waves will vary in polarity, and the PQ-interval will also vary.

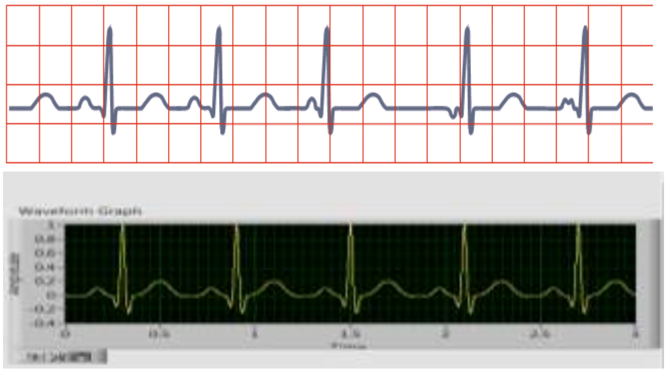

Figure 7 Wandering pacemaker

II). Atrial flutter

When the heart rate is sufficiently elevated so that the isoelectric interval between the end of T and beginning of P disappears, the arrhythmia is called atrial flutter. In atrial flutter, the atrial rate is very fast, ranging from 240 to 360 per minute. The abnormal P-waves occur regularly and so quickly that they take morphology of saw-tooth waveform which is called flutter (F) waves.

- Impulses travel in circular course in atria
- Rapid fluter waves, ventricular response irregular
- The frequency of these fluctuations is between 220 and 300/min.

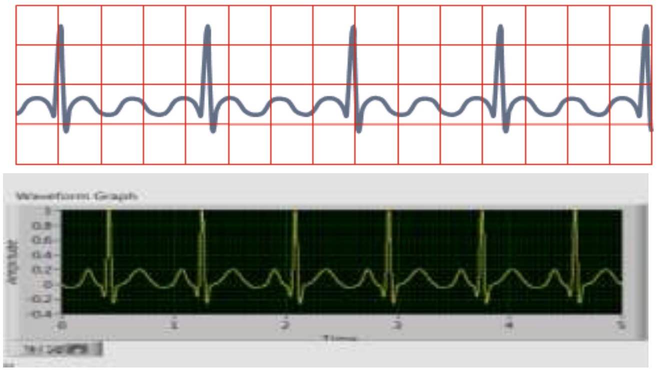

Figure 8 Atrial flutter

III). Atrial fibrillation

The atrial rate exceeds 350 beats per minute in this type of arrhythmias. This arrhythmia occurs because of uncoordinated activation and contraction of different parts of the atria. The higher atria rate and uncoordinated contraction leads to ineffective pumping of blood into the ventricles. Atrial fibrillation may be intermittent, occurring in paroxysms (short bursts) or chronic

- Impulses have chaotic,random pathwayes in atria
- Baseline irregular, ventricularresponse irregular

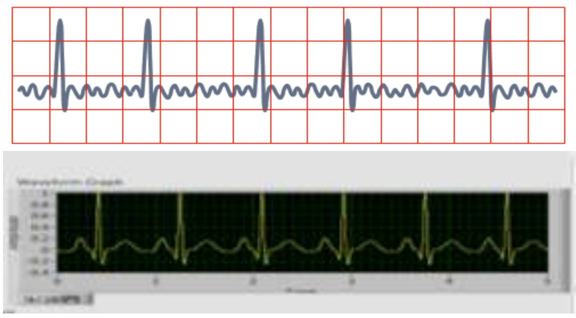

Figure 9 Atrial fibrillation

IV). Junctional rhythm

Junctional arrhythmias are originated within the AV junction in the form of the impulse comprising the AV node and it's Bundle. The abnormal in P wave morphology occurs because of these arrhythmias .The polarity of the abnormal P-wave would be opposite to that of the normal sinus P-wave since depolarization is propagated in the opposite direction – from the AV node towards the atria.

If the heart rate is slow (40-55/min), the QRS-complex is normal, the P-waves are possibly not seen and then the origin of the cardiac rhythm is in the AV node. Because the origin is in the junction between atria and ventricles, this is called junctional rhythm.

- Impulses originate at AV node with retrograde and antegrade direction
- P-wave is often inverted, may be under or after QRS-complex
- Heart rate is low

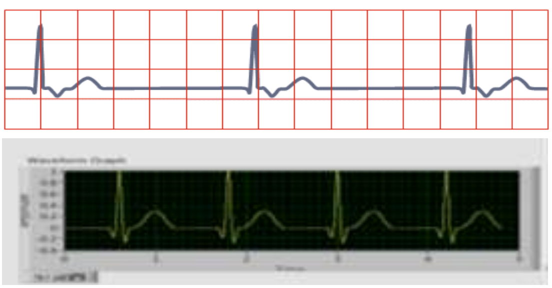

Figure 10 Junctional rhythm

VII. Coclusion

The information obtained from an Electrocardiogram can be used to discover different types of heart diseases. The automatic detection of ECG waves is important to cardiac disease diagnosis. Presently, many Cardiologists face difficulty in making a correct diagnosis for ECG arrhythmia diseases. In addition to this also conventional technique of visual analysis is more complicated and requires experience and time. Clinical observation of ECG can take long hours and can be very tedious. Moreover, visual analysis cannot be relied upon and the possibility of the analyst missing the vital information is high. Hence, computer based analysis and classification of Arrhythmia diseases can be very helpful in diagnosis.

As studied from existing literature ECG arrhythmias accuracy are about 90 to 98% as well as detection algorithms are more complicated, but because of flexibility, modular nature and ease to use programming possible with LabVIEW, makes it less complex and more reliable. Thus with the help of LabVIEW software a simple ECG simulator module has been developed that displays ECG wave of various cardiac disorders related sinus and nonsinus arrhythmias as shown in figure 3 to 10. The ECG wave is recorded and analyzed using LabVIEW software is more accurate and helpful for better analysis of ECG. Thus software makes the system cost efficient and can be utilized as a test bench for the study of ECG signals with more interactive and simplicity.

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