International Journal of Science and Healthcare Research
Vol.3; Issue: 4; Oct.-Dec. 2018
Website: www.ijshr.com
Original Research Article *ISSN: 2455-7587*

Detection and Classification of Heart Defects

Priyanka Mayapur

Dept. Of Electronics and Communications Engineering, Agnel Institute of Technology and Design, Assagao, Goa, India

ABSTRACT

Heart Defects are immensely threatful to human beings and can cause death. Improvements in diagnosis and treatment tools are welcome by the medical community and have proven to be one of the most useful diagnostic tools for heart patients, one of it to be mentioned would be the Electrocardiogram. Traditional technique of visual analysis of ECG is complicated for doctors, time consuming and requires expertise. Hence, computer based classification and detection of diseases can be immensely useful in diagnostics.

This project has been inspired by the need to find an efficient method for ECG signal analysis and classification which is simple yet has good accuracy and less computation time. It deals with the study and analysis of ECG signal processing by means of MATLAB tool effectively for classification and detection of heart defects using Lead-II Configuration.

Study of ECG signal includes reading and plotting of the ECG signal, acquisition of real time ECG data, ECG signal filtering and processing, feature extraction and detection of certain parameters, decoding, comparison, classification of the required features.

In this thesis, we first find out the characteristics to classify a normal ECG and then pass any random signal to check whether the features or the values determined fall within the specified range with the ones characterized to be a normal ECG. If it does, then we classify it as normal ECG else we classify it as an abnormal ECG using Lead-II Configuration.

***Keywords*:** Electrocardiogram, ECG Processing, Classification, Lead-II Configuration, Heart Defects, Matlab.

1. INTRODUCTION

Heart is known to be the most significant organ of the human body that beats in rhythm to pump the blood in circulation through the body which results in making the action potentials responsible for the mechanical events within the heart that generates a certain sequence of electrical events. Due to contraction and relaxation of the muscle tissue of the heart, electrical activation begins by the movements of ions which constitute current throughout the body giving rise to potential differences in millivolts. [1-3] An ECG or EKG (Electrocardiogram) records these potential differences' using electrodes attached to the surface of the skin and measures the electrical activity of the heart recorded by a device external to the body over the amount of time.

It has been known since 1856 that the heart muscle produces electrical activity and subsequently that it can be measured to provide functional status and diagnostic information about the condition of an individual's heart. Since the required measurements are very low in magnitude, noise can have a great impact on measurements.

The ECG analysis is performed by using signal processing. Signal processing being the enabling technology encompasses the fundamental theory, applications, algorithms, and implementations of processing or transferring information contained in many different physical, symbolic or abstract formats broadly designated as signals. [4,5] The modification and processing is used to maximize the details of information extraction and further analysis. The ECG technique is implemented with software to perform a various operations like reading, decoding and recording a data depending on the

computing platforms. Then the waveform is used to find the rate of heart beat, heart rate, heart rate variability and any disease which are affected by the heart.

2. HISTORICAL BACKGROUND OF ECG AND CLINICAL INTERPRETATION OF ECG PARAMETERS

ECG or EKG is basically an abbreviation for the word electrocardiogram (derived from the Greek electro for electric, cardio for heart, and graph for "to write") and the German word electrocardiogram.

In 1901 the device used by Willem Einthoven he invented while working in Leiden, Netherlands, the string galvanometer proved to be much more sensitive than both the capillary electrometer used by Waller and the string galvanometer that had been invented separately by the French engineer Clement Ader in 1897. [6]

Earlier Einthoven's subjects would immerse each of their limbs into containers of salt solutions from which the ECG was recorded. The letters assigned by Einthoven to the various deflections that described the electrocardiographic features of a number of cardiovascular disorders were P, Q, R, S, and T. Einthoven was awarded the Nobel Prize in Medicine for his discovery in 1924. Though the basic principles of that era are still in use today, over the years many advances in electrocardiography have been made.

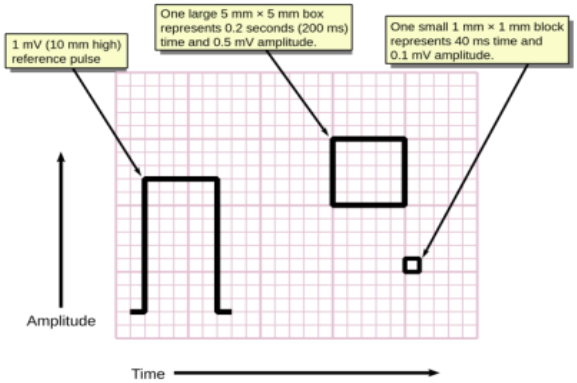


Figure 1: An ECG Graph Paper Measurement

The study of the ECG signal is extensively used for identification and analysis of irregularities and heart diseases. Each portion of the heartbeat produces a totally different deflection on the ECG that represents a realistic and graphic record of the direction and magnitude of the electrical activity of the heart. [7]

The sinus (Sino-atrial node) node located near the entrance of the superior vena cava vein, acts as a generator of the sinus rhythm that produces the heart frequency at about 60-100 cycles per minute. This activation is then propagated to the right and left atria muscle tissues. There is a delay at the atrioventricular node, to allow the ventricles to fill with blood from atrial contraction. This is then followed by the depolarization propagating to the ventricles through the Bundle of His which spreads along the Purkinje fibers. This in turn activates the ventricles that contract and pump blood to the aorta and to the rest of the body. Finally, depolarization occurs followed by repolarization and this cycle is repeated. [8]

A Normal ECG waveform tracing (in Lead-II) has a characteristic shape and features as mentioned in the table.

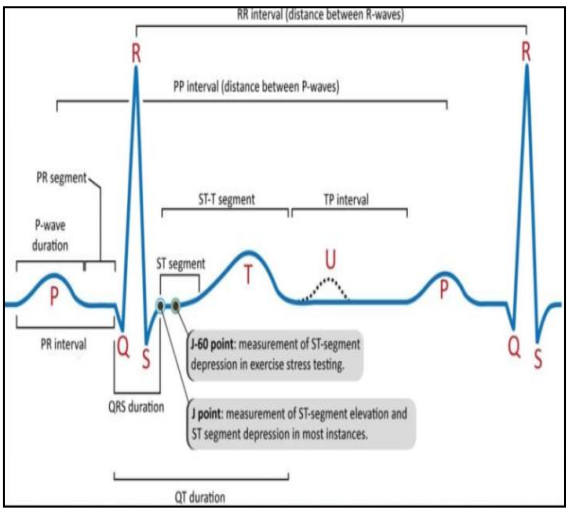


Figure 2: A General ECG Waveform

The table 1 shows the ECG features and descriptions.

Table 1: ECG Features and their Description

FEATURE	DESCRIPTION
P WAVE	P-waves represent atrial depolarization.
P-R SEGMENT OR PQ SEGMENT	The PR or PQ segment is the flat, usually isoelectric segment between the end of the P wave and the start of the QRS complex. This segment represents the time the impulse takes to reach the ventricles from the sinus node.
P-R INTERVAL OR PQ INTERVAL	The time taken for electrical activity to move between the atria and ventricles is represented by this interval.
Q WAVE	The normal Q wave represents septal depolarization and is any initial downward deflection after the P wave.
R WAVE	The R wave represents early ventricular depolarisation and is normally the easiest waveform to identify on the ECG.
R-R INTERVAL	The RR-interval begins at the peak of one R wave and ends at the peak of the next R wave and represents the time between two QRS complexes.
S WAVE	The first negative deflection after the R wave represents the S wave indicating the late ventricular depolarization.
QRS COMPLEX	The depolarization of the ventricles is represented by the QRS Complex.
QT INTERVAL	It represents the time taken for the ventricles to depolarize and then repolarize.
ST SEGMENT	The isoelectric line that represents the time between depolarization and repolarization of the ventricles (i.e. contraction) represents the ST segment.
J-POINT	The J point is the junction between the termination of the QRS complex and the beginning of the ST segment.
T WAVE.	The T-wave represents ventricular repolarization.
T-P INTERVAL	The isoelectric interval on the electrocardiogram (ECG) is TP segment that represents the time when the heart muscle cells are electrically silent.
T-Q INTERVAL	Termed as the diastolic interval through the ECG.
U WAVE	Uwaves represent re-polarization of the Purkinje fibers that indicates the last remnants of the ventricular repolarization. Generally it is 0.05mV and has duration of 0.1s.

3. THE LEAD-II CONFIGURATION

Under the expert guidance of the doctors and after lots of literature review, it was seen that Lead II is the most preferred monitoring lead of choice for continuous ECG monitoring. Mostly monitors show one lead at a time, so it is necessary to choose a lead that gives as much information as possible. The most commonly used lead is Lead II which measures the potential difference between the right arm and left leg electrode. Since its appearance in 1910 with Willem Einthoven's invention of the electrocardiograph, Lead II has traditionally been the most commonly used monitoring lead.

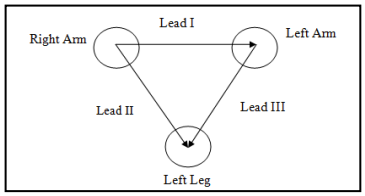


Figure 3: The Einthoven's Triangle

Paramedics are trained how to interpret rhythms in lead II and have traditional exams wherein they have established a paradigm of lead II monitoring in patients. The placement of electrodes for Lead-II configuration is located near the apex of the heart due to its best view. It is the most useful lead for detecting cardiac arrhythmias as it lies close to the cardiac axis (the overall direction of electrical movement) and allows the best view of P and R waves.

4. ARRHYTHMIA AND IRREGULATIES OF THE HEART

In the morphology of ECG signal where the normal rhythm of the heart represents no disease or disorder is called Normal sinus rhythm (NSR). ECG arrhythmia can be defined as a condition in which the electrical activity of the heart is irregular and can cause heartbeat to be slow or fast. The heart rate of NSR is generally defined by 60 to 100 beats per minute in a normal resting person. [2]

Arrhythmia could be of many types and can be classified with respect to three factors:

- Regularity (Regularly, Irregular and Irregularly, Irregular)
- Rate (Abnormal Heart Rhythms)
- Origin (Supraventricular and Ventricular)

If a resting heart beats at a rate of 100 or more beats per minute in an average adult, this would represent abnormal rapid beating of the heart defined as Tachycardia resulting in a drop of pumping efficiency, adversely affecting perfusion.

Bradycardia is defined as a resting heart rate below 60 beats per minute and can adversely affect vital organs.

Arrhythmia can take place in a healthy heart having minimal consequence, but may also indicate a serious problem that leads to stroke or sudden cardiac death, scarring of heart tissue or change of heart structure or heart blocks or premature beats. Depending upon the type of symptom the arrhythmia would be classified. [6] Being one of the leading causes of death, cardiac arrhythmia can be treated if detected on time. [9]

5. THE FLOW DIAGRAM

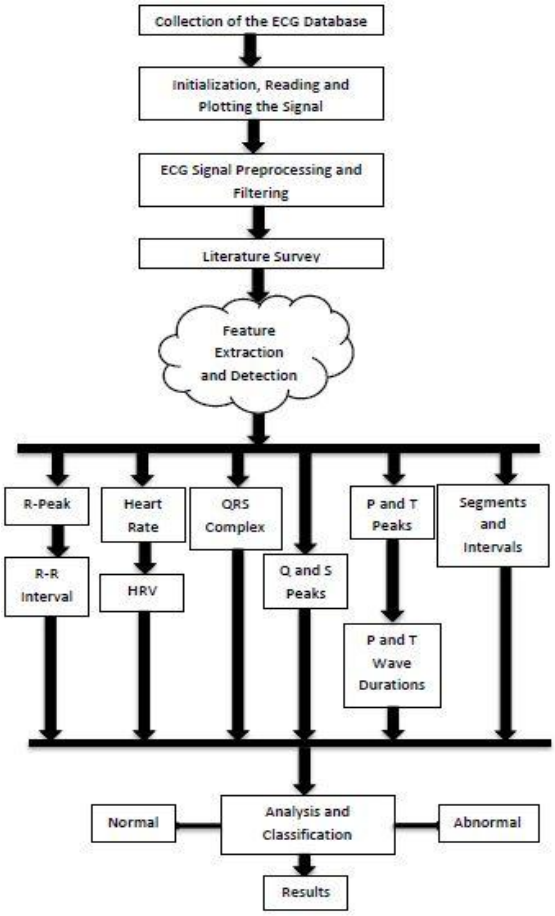


Figure 4: Flow Diagram for ECG Signal Analysis and Classification

6. WORK DONE METHODOLOGY

A. COLLECTION OF ECG DATABASE

One of the most important parts of Signal Processing is the collection of the ECG database. Our databases were collected from a variety of places which were in four different formats. To start off with, we selected MIT-BIH Arrhythmia Database Directory of ECG signals from PhysioNet.

ECG signals from MIT-BIH Database are described by- a text header file (.hea), a binary file (.dat), a binary annotation file (.atr) and (.mat) a mat lab file. In the mat lab file, data is available in terms of a row matrix suitable to be loaded in MATLAB software for further signal analysis. This was then followed by collecting ECG samples from UCI, then ECG Simulator that produces normal Lead-II waveforms and ECG Machines from the laboratory and hospitals. The different ECG Signal formats we worked with were .mat, .csv, .xml, .dat or .txt.

B. INITIALIZATION STEP

Our Project has been implemented using the multipurpose tool i.e. the MATLAB Environment. [14] In order to process a particular ECG Signal, it first needs to be read, i.e. loaded and plotted in Matlab. It is always good to smooth the reading data before plotting by removing the base and gain, i.e.

$$Yi = \frac{Yi - Base}{Gain} \qquad (1)$$

Where Yi= ECG Sample
Base= Baseline Value
Gain= Gain Factor

Depending upon the various formats, some signals could be plotted directly (.mat) and some required conversion from one format to the required format ((.csv, .xml, .dat or .txt) to .mat) by choosing the appropriate frequency and threshold along with re-dimensioning of the variable matrix.

C. ECG SIGNAL PREPROCESSING

Noise and artifacts such as Power Line Interference, Electrode Contact Noise, Motion Artifact, Muscle Contractions, Baseline Wander and Instrumentation Noise can contaminate the recorded ECG signal and manifest can similar characteristics as the ECG signal itself within the frequency band of interest. [10] Processing of the raw ECG signal is done in order to extract the useful information from the noisy ECG signals and could be roughly divided into two stages of functionality: [11]

a) Pre-Processing
b) Feature Extraction

In the preprocessing stage, the noise is removed or suppressed using specific filters in order to extract the required information from the signal and for noise reduction. This if required could be then followed by normalization that serves to prevent parasitic influence of variation of the input signal. Specifically Amplitude Normalization could be done where in each sample of signal is divided from max of absolute value of signal in order to limit signal dynamic range from -1 to 1, i.e.

$$\boldsymbol{Variable} = \frac{\boldsymbol{xi}}{\boldsymbol{max}\,(|\boldsymbol{x}|)} \quad (2)$$

Where xi= ECG Sample at a point
x= ECG Sample

The .mat format signal could be directly plotted in Matlab using a specific command. Considering the .csv and .dat format signals, Conversion and Zero Phase Filtering were done in order to plot it. In case of the .xml format signal, the same procedure was carried out in order to plot the signal which represented all the 12 Lead Configurations followed by extracting the required signal configuration needed to work on (Lead-II).

D. FEATURE EXTRACTION AND DETECTION

The feature extraction stage is used to extract diagnostic information from the ECG signal.

An ECG Signal is the combination of various Peaks, Waves, Valleys, Segments, Intervals, Complexes and Points. The respective amplitude, location and duration of these peaks carry very crucial information about the functioning of the heart.

Therefore, in order to classify an ECG signal as Normal or Abnormal, the very first step would be to identify these attributes and store the values in specific variables.

i. R-Peak Detection

- A peak is a local maximum determined by observing the signal when it changes direction within a predefined time interval.
- Since R is considered to have the *largest* amplitude and is the sharpest component with respect to all the other *peaks in a Normal Lead-II ECG Signal, this was used as the main criteria to identify the R Peaks.*
- *Initially a particular threshold was set adaptively for the detection of the local maxima and local minima.*
- The local minima with absolute amplitude larger than a threshold are detected as R peaks.
- Once the amplitudes were obtained, *the temporal locations were estimated followed by its durations.*

ii. R-R Interval

- This was then followed by calculating the R-R Interval using the R-Spike Detection Method which is basically calculating the interval between one R-Spike and the next R-Spike (successive R's).
- R-R Interval helps us detect the Heart rate and the Cycle Length Variability.

iii. Heart Rate

The number of times a person's *heart beats* per minute is known as *Heart rate* or pulse. Depending upon the individual, body size, age, *heart* conditions, whether the person is sitting or moving, medication use and even air or temperature, the heart rate could vary.

Normal range at rest is between 60-100 BPM. Once the R peaks are detected and the R-R Interval is found out, the heartbeats, thus the heart rate can be obtained.

- Number of R peaks=Number of Cycles=Number of Beats
- Number of Heart Beats per minute= Heart Rate (BPM)
- Initially the mean value of the R-R Interval is calculated and then this duration is then divided into 60. The resulting equation would be:

$$\boldsymbol{Rate} = \frac{\boldsymbol{60}}{\boldsymbol{R{-}R\ Interval\ (Avg)}} \quad (3)$$

iv. Heart Rate Variability (HRV):

The physiological phenomenon of variation in the time interval between heartbeats is termed as *Heart rate variability* (*HRV*). It measures the variation in the *beat*-to-*beat* interval. It is a sign of the flexibility of the heart and measurements have been shown to be able to predict a likelihood of diseases occurring in the future.

In order to find out the HRV, the following steps were followed:

- Detect the maximum and the minimum value from the R-R Interval vector.
- The mean value (average) of the R-R Interval is calculated.
- Calculate the HRVmax by subtracting the mean value of R-R Interval from the HRVmax and then dividing the entire value by the R-R interval (average).
- Calculate the HRVmin by subtracting the mean value of R-R Interval from the HRVmin and then dividing the entire value by the R-R interval (average).

Then we calculate the HRV using the equation,

$$\boldsymbol{HRV = (HRVmax - HRVmin) * 100} (4)$$

v. QRS Complex Detection using Pan Tompkins Algorithm

Detection of the QRS Complex was done using the Pan Tompkins Algorithm:

- First the ECG signal is filtered using a band pass filter which is composed of cascaded low-pass and high-pass filter for the purpose of removal of noise, baseline and interference.
- After filtering, the filtered signal is differentiated in order to get the slope information and to highlight the QRS Complex.
- This is then followed by squaring the signal which makes all the signal values positive, thus amplifying the output of the previous stage in a non-linear manner.
- In the next step, moving window integration was done in order to obtain the waveform feature information calculated from the formula,

$$\boldsymbol{y(nT) = \left(\frac{1}{N}\right)[x(nt - (N-1)T + x(nT - (N-2)T + \cdots . + x(nT)]} (5)$$

- where N represents the number of samples in the width of the integration windowand T is the sampling period. [12, 13]
- After moving window integration, thresholding of the obtained signal is done. If a peak exceeds the threshold during the first step of analysis, it is classified as a QRS peak (Complex).
- This is then followed by calculating the Area under the QRS Complex in order to calculate the work done by the heart (not mandatory).

vi. Q and S Peak Point Detection

- Q wave is detected as the first local minimum from the left of the positive R wave. The Q wave is judged to be missing, if the minimum cannot be detected.
- S wave is detected as the first local minimum from the right of the positive R wave. The S wave is judged to be missing, if the minimum cannot be detected.
- Then, the start and end of Q, R and S waves were found out.
- This was then followed by finding out the Duration of the QRS Complex.

vii. P and T Peak Point Detection

- The QRS region is considered as the reference for finding the P and T waves. The left side of the QRS region consists of P wave and the right side consists of T wave.
- Using the Moving Window Integration technique along with the Threshold Detection method, we were able to detect the P and the T peak points in the ECG signal. Once the amplitudes were obtained, *the locations were estimated.*
- The offset and onset of the P wave are detected as the two consecutive local maxima from the left of the Q wave.

- The first and second local maxima from the right of the S wave are detected as the onset and offset of the T wave.
- Once the onsets and offsets were found, *P and T wave durations were calculated.*

viii. The R to P Ratio

- First check whether the R peak is greater than P peak.
- Then compute the R to P ratio by using,

$$\frac{R}{P} = \frac{R\ Peak\ (Amplitude)}{P\ Peak\ (Amplitude)} \quad (6)$$

ix. *Segments and Interval Detection*

- *Since the waveform boundaries are detected, the onset and offset of every wave is known.*
- *This feature could be used to calculate the various segments and intervals that make up the ECG.*
- The segments calculated were PR or PQ Segment and ST Segment.
- The intervals calculated were PR or PQ Interval, QRS interval and TP Interval.

7. ANALYSIS AND CLASSIFICATION

Since all the characteristics and features were detected and calculated for a particular signal, we can now apply the same procedure to all the collected signals (more than 80 samples) and analyze them based on the measurements and values and the specific range obtained in order to classify them as Normal and Abnormal ECG Signals. This was then followed by evaluating the kind of irregularity, variation or any defect observed in the ECG Signal, i.e. if the person is suffering from any arrhythmia or any other heart defect could be found out.

8. RESULTS, CLASSIFICATION AND DISCUSSION

The results, classification and the specific range are discussed and shown below.

Table 2: ECG Signal Features and their Respective Values

FEATURES	VALUES	
General Factors	Values	
Heart Rate	60-100 bpm*	
R-R Interval	0.6*s to 1.2*s	
Heart Rate Variability	+/-10%* to +/-30%*	
R to P Ratio	3* to 12*	
Waves	Amplitude(mV)	Duration(s)
P Wave	0.1*-0.35*	0.07*-0.12*
Q Wave	0.1*-0.3*	<0.04*
R Wave	0.8*-1.5*	0.035*-0.09*
S Wave	0.5*-0.9*	0.03*-0.05*
T Wave	0.15*-0.6*	0.1*-0.250*
Segments/Intervals	Duration(s)	
PQ or PR Segment	0.04*-0.12*	
PQ or PR Interval	0.1*-0.2*	
QRS Complex	0.06*-0.12*	
ST Segment	0.07*-0.12*	
QT Interval	0.320*-0.450*	
TP Segment	<0.420*	

- *These obtained values in the table are calculated manually as well as using specific algorithms through computer processing in Matlab by analyzing more than 80 samples and is verified by doing a lot of literature review and is approved by the doctors.
- The entered values in the table above are the average values of more than 80 samples after processing.

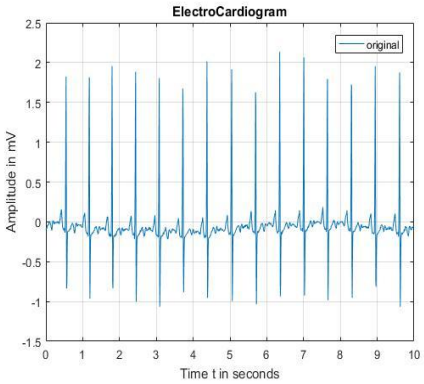
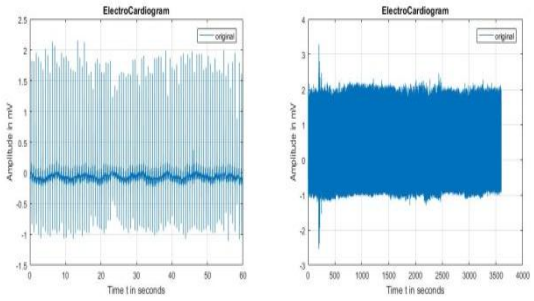


Figure 5: An Original ECG Signal (10 sec) (Normal)



(a) **(b)**

Figure 6: ECG Signals (a) 60 sec and (b)3600 sec (Normal)

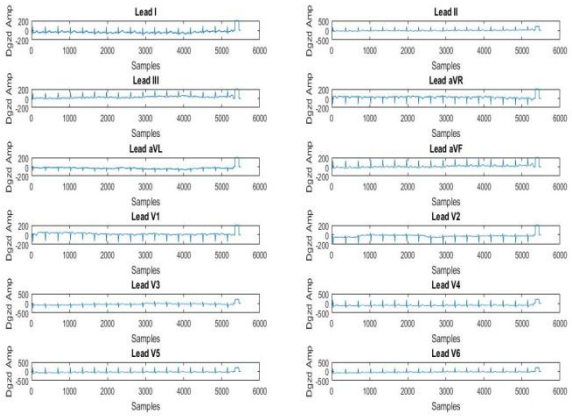
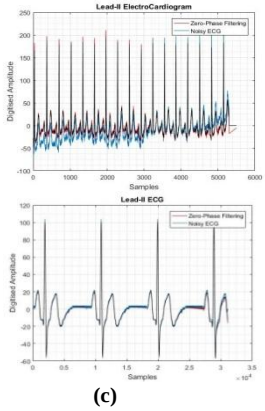


Figure 7: Plotting of 12 Lead Configuration ECG Signal from the .xml format to .mat signal



(c) (d)

Figure 8: Zero Phase FilteringofExtracted Lead-II ECG Signalto (.mat) from (c)(.xml) and (d) (.csv)

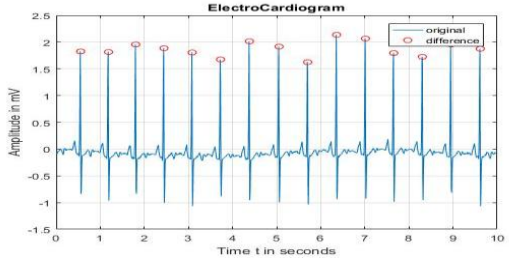


Fig 9: Detection of R Peaks

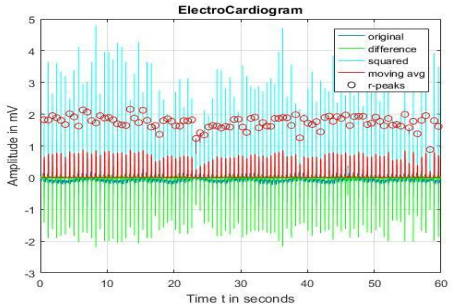


Figure 10: Detection of QRS Complex and its area using Pan Tompkins Algorithm

The estimated area under the QRS Complex is found to be 4.24 mVps.

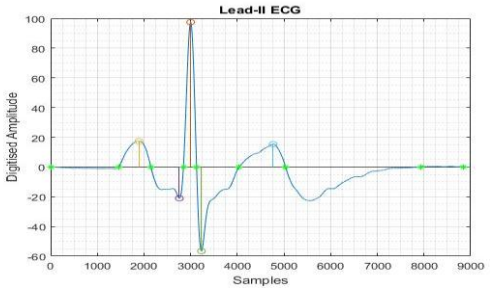


Figure 11: Detection of Peak Points and Locations; P, Q, R, S,T Waves

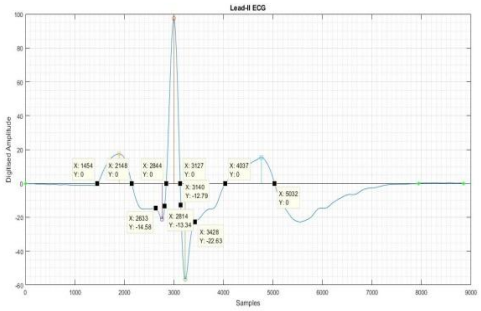


Figure 12: Detection of Various Segments and Intervals

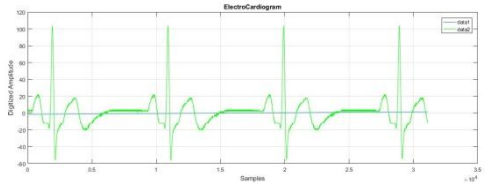


Figure 13: Plotted Waveform of the Arrhythmia Signal (Bradycardia)

The ECG Analysis after processing 10 signals of similar kind states that it has a Regular Rhythm and all values of the Waves, Segments and Intervals fall within the normal range but the rate observed in such signals fall below 60 BPM. The Rate observed in Fig. 13is below 60 BPM that is 47 BPM, which is not within the normal range. This represents BRADYCARDIA.

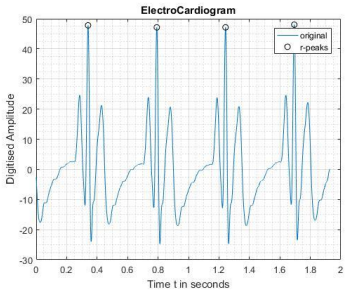


Figure 14: Plotted Waveform of the Arrhythmia Signal (Tachycardia)

The ECG Analysis after processing 10 signals of similar kind states that it has a Regular Rhythm and all values of the Waves, Segments and Intervals fall within

the normal range but the rate observed in such signals lie above 60 BPM. The Rate observed in Fig. 14 is above 60 BPM that is 133 BPM, which is not within the normal range. This represents TACHYCARDIA.

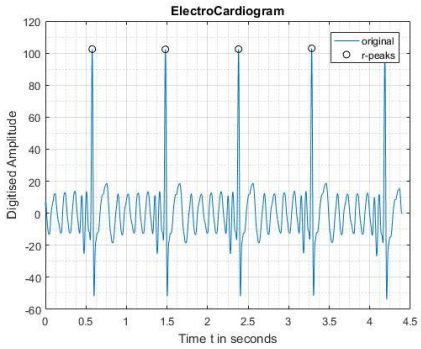


Figure 15: Plotted Waveform of the Arrhythmia Signal

The ECG Analysis after processing 10 signals of similar kind states that it does not have a Regular Rhythm and few of the Waves, Segments and Intervals are either absent or immeasurable. The Rate observed in Fig. 15 is 67 BPM. This represents an ABNORMAL ECG Signal. Since few features are indiscernible along with a Chaotic Rhythm and the QRS Complex duration is 0.0842 s, from the literature review, it can be concluded that this could represent ATRIAL FIBRILLATION.

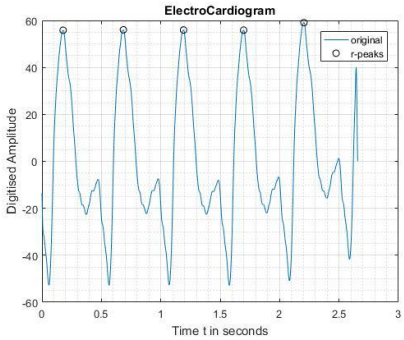


Figure 16: Plotted Waveform of the Arrhythmia Signal

The ECG Analysis after processing 10 signals of similar kind states that it does not have a Regular Rhythm and few of the Waves, Segments and Intervals are either absent or immeasurable. The Rate observed in Fig. 16 is 118 BPM. This represents an ABNORMAL ECG Signal. Since few features are indiscernible and the QRS Complex duration is 0.5296 s, which is wide and bizarre and from the literature review, it can be concluded that this could represent VENTRICULAR TACHYCARDIA.

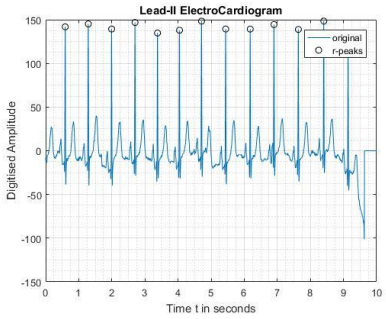


Figure 17: Plotted Waveform of the Arrhythmia Signal

The ECG Analysis after processing 10 signals of similar kind states that it does have a Regular Rhythm and the Waves, Segments and Intervals are measurable. The Rate observed in Fig. 17 is 84 BPM. It has a bifurcated P Wave, it can be concluded that this could represent P MITRALE. This represents an ABNORMAL ECG Signal.

These results were obtained at the time of writing the paper while further recording, processing and analyzing were in progress. In consultation with the cardiologists and after a lot of processing and analyzing, it was seen that Lead-II Configuration ECG can detect Arrhythmias, P Mitrale and P Pulmonale. ECG Signals from normal subjects as well subjects suffering from heart defects were acquired and based on processing, the ECG Signals were analyzed (more than 80 samples) and classified as NORMAL and ABNORMAL ECG Signals.

9. DISCUSSION

Biomedical signals are non-stationary signals whose analysis requires better time and frequency resolution. Such analysis includes de-noising, filtering, normalizing, squaring, averaging, encoding, decoding, compressing, decompressing, de-interleaving, constructing, reconstructing and comparing.

The work has been done in the area of feature extraction, decoding, filtering, detection and arrhythmia classification. The results obtained from our project cannot be immediately applied to the population.

Many of our subjects suffered from a combination of heart defects.

10. CONCLUSION

Classification and Detection of the heart defects using Lead-II configuration requires many more samples. Future research heading in this direction is necessary with a larger sample size in order to accurately pinpoint the various heart defects individually.

11. FUTURE SCOPE

ECG is a form of biomedical waveform that provides a lot of necessary information to the physicians. The research work carried out has the ability to work in real time as well as offline environment for detection of arrhythmias. Any further research heading in this direction needs a large sample of data in order to accurately classify and detect the heart defects using Lead-II configuration individually. As the microprocessor and its parent semiconductor technology continue to evolve, the resulting devices will stimulate development of many new types of medical instruments.

Work is needed to be done on the hardware for successful implementation of the method devised. Moreover the work can be further improved by developing disease diagnostic clinical applications with the assistance of encoding, decoding, compression and decompression schemes for ECG. Research can be extended on developing the logic to detect and analyze more number of arrhythmias or diseases which can be detected using Lead-II configuration. It can be made more compact with latest technology.

The detailed parameters of such signals can be studied for the purpose of training or generating a robust ECG classifier. With a larger database of heart defects at different stages will make the analysis more full proof. To come up with still simpler methods for ECG signal Analysis, a lot of research needs to be done on the properties. Modification of enhancement can be done using more evolved techniques. Hence our future work will be dedicated to an improved feature classification and maybe location.

ACKNOWLEDGEMENT

We were really privileged to be guided by several doctors and technicians along with our college of Agnel Institute of Technology and Design. Thanks are also addressed to the field team and to the anonymous reviewers as well.

REFERENCES

1. Rajan Chaudhary, Anand Prakash, Chandan Gupta, Comparison of Different ECG Signals on MATLAB, International Journal of Electronics and Computer Science Engineering, IJECSE, Volume2, Number 2.
2. S.T. Sanamdikar, Dr.S.T.Hamde, Dr. V.G. Asutkar, A Literature Review on Arrhythmia Analysis of ECG Signal, International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056 Volume: 02 Issue: 03, June-2015.
3. A Khorovets, What Is An Electrocardiogram (ECG)?, The Internet Journal of Advanced Nursing Practice Volume 4 Number 2, 1999.
4. Rob Theriault, Cardiac Dysrhythmia Interpretation.
5. Biology, Preliminary Volume 1, The Dynamic Science, Units 1 and 2, CTI Reviews.
6. Anand Kumar Joshi, ArunTomar, MangeshTomar, A Review Paper on Analysis of Electrocardiograph (ECG) Signal for the Detection of Arrhythmia Abnormalities, International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering (IJAREEIE),Vol. 3, Issue 10, October 2014, ISSN: 2278 8875.
7. Vandana Verma, Sagar Singh Rathore, Detection of Characteristic Points of ECG Signal, International Journal of Innovative Research in Computer and Communication Engineering, Vol. 3, Issue 11, November 2015.
8. S. Thulasi Prasad, S. Varadarajan, Analysis of ST-Segment Abnormalities in ECG using Signal Block Averaging Technique, International Journal of Advanced Research

in Computer and Communication Engineering, Vol. 4, Issue 2, February 2015, ISSN: 2278-1021.

9. Mr. Vyankatesh S. Thorat, Dr. Suresh D. Shirbahadurkar, Mrs. Vaishali V. Thorat, Study and Literature Survey for Classification of Cardiac Arrhythmia With Respect to ECG and HRV Signal, International Journal of Advanced Research in Computer and Communication Engineering, Vol. 5, Issue 4, April 2016.
10. M. K. Islam, A. N. M. M. Haque, G. Tangim, T. Ahammad, M. R. H. Khondokar, Member, IACSIT, Study and Analysis of ECG Signal Using MATLAB LABVIEW as Effective Tools, International Journal of Computer and Electrical Engineering, Vol. 4, No. 3, June 2012.
11. Durgesh Kumar Ojha, Monica Subashini, Analysis of Electrocardiograph (ECG) Signal for the Detection of Abnormalities Using MATLAB, World Academy of Science, Engineering and Technology International Journal of Medical, Health, Biomedical, Bioengineering and Pharmaceutical Engineering Vol.8, No: 2, 2014.
12. Kritika Bawa, PoojaSabherwal, R-Peak Detection by Modified Pan-Tompkins Algorithm, International Journal of Advancements in Research & Technology, Volume 3, Issue 5, May-2014.
13. Jiapu Pan, Willis J. Tompkins, Senior Member, A Real-Time QRS Detection Algorithm, IEEE Transactions On Biomedical Engineering, Vol. BME32, No. 3, March 1985.
14. Signal Processing Toolbox, For Use with MATLAB, Users Guide Version 5.

How to cite this article: Mayapur P. Detection and classification of heart defects. International Journal of Science & Healthcare Research. 2018; 3(4): 286-296.

******