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Framework for Arrhythmia Identification using Real Time ECG Signals

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***Abstract*—Abnormal heartbeats or Cardiac arrhythmia denotes a dangerous condition of irregular electrical activity in the heart. Arrhythmia is the disease affecting 30 million people worldwide. There is need of introducing a method of real time Arrhythmia detection from low cost hardware. This article focuses on for the Arrhythmia identification using electrocardiogram (ECG) signals. The Electrocardiogram (ECG) signals are having small amplitude of about 1mv but carry a lot of noise. This paper is about a framework design to build, evaluate, and create a system that can record a patient's ECG in real time and measure the heartrate and irregular rhythm of the heartbeats. The framework further performs Arrhythmia detection. The process of acquiring the ECG is done using electrodes connected to PC/laptop having Matlab software. Filtering, describing, and evaluating the Electrocardiogram (ECG) data are further steps in the process of classifying heartbeats into Tachycardia, Bradycardia or Arrhythmias. RT interval, RR interval, and QRS complex are the features that were calculated. Tachycardia, Bradycardia, and the "normal state" are examples of various cardiac arrhythmias that cause changes in heart rate. The threshold is chosen in accordance with algorithm, and ECG signal peaks. The patient's anomaly is identified in accordance with the feature extraction algorithm and thresholding.**

***Index Terms*—Matlab, Arduino IDE, AD8232, Arduino UNO Microcontroller (based on ATmega328P), RT, interval, RR interval, QRS complex, Tachycardia, Bradycardia, Normal condition, Threshold.**

I. INTRODUCTION

Around 30 million people worldwide are affected by heart related diseases. From the data of WHO (World Health Organization), due to heart and cardiovascular diseases India has lost 237 billion dollars in the years between 2005 to 2015. In accordance with the Global Burden of Disease report, published in September 2017, India had lost 1.7 million people due to cardiovascular disease.

The electrocardiogram is an important resource for doctors to diagnose a patient's health condition. The rate at which the heart conducts electrical impulses is referred to as cardiac conduction. An ECG waveform can be used to extract features such as the rate and regularity of heartbeats, chambers positions, heart damages if any, as well as the effects of drugs and devices used to control the heart. The heart is a muscle with a unique electrical conduction system. Cardiac Arrhythmia is a term used to describe a classification of disorders that cause the heart to beat irregularly, slowly, or too quickly. Arrhythmias are classified into several types, such as

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bradycardia (slow heartbeat). Tachycardia is characterized by a rapid heartbeat. Fibrillation is another name for it.

The heart rate is calculated in terms of pulse. Heart rate means heart beats per minute. It differs from one person to the next. A person's heart rate is shown as a waveform on the Electrocardiogram (ECG). The electrocardiogram (ECG) is an important resource for physicians who need information to diagnose a patient's health condition and pathology. Electrocardiogram (ECG) is one of the medical devices that looks for any heart disease or heart abnormalities. A healthy person's heart rate fluctuates between 60 and 100 beats per minute. When the heartbeat is very fast in the range above 100, it is called Tachycardia. And when the heartbeat is less than 60 it is called Bradycardia.

The Arrhythmia can affect anyone who is healthy, normal and free from other heart diseases. Arrhythmia can affect several types of symptoms. When there is Arrhythmia condition the heart is not working well this causes the symptoms like Chest pain, shortness of breath, and temporary inability to breathe, symptoms of high blood pressure, diabetes, and other medical conditions. In other medical cases like High cholesterol, heart disease. It may increase the chance of heart problems that can lead to arrhythmias.

The tabular form of risk factors causing the various types of heart diseases are as follows:

TABLE I. RISK FACTORS AND HEART DISEASES

Sr. No.	Risk Factors	Types of heart diseases
1.	Hypertension	Arrhythmia
2.	High cholesterol	Heart valve disease
3.	Stress	Heart Failure
4.	Smoking	Acute myocardial infarction
5.	Physical Inactivity	Coronary Artery disease
6.	Diabetics	Cardiomyopathy
7.	Obesity	Pericardial disease

The human heart is the pump like biological structure and is one of the important organs of vital importance. The heart health and diseases are always has been significant research area. Following graphs show the worldwide occurrences of the heart diseases such as arrhythmia for developing countries and developed countries. Both The graphs are having scale of the scale on Y-axis is as mortality per 10,000 and on X-axis years is considered.

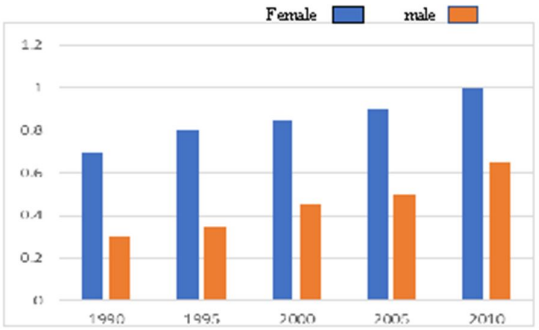

Figure.1. Arrhythmia cases found in worldwide population in developing countries

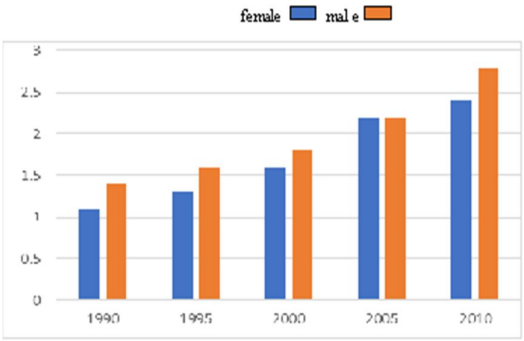

Figure.2 Arrhythmia cases found in worldwide population in developed countries

II. LITERATURE SURVEY

Yan sun et al, [1] In his article, proposed a function for wave detection in ECG that realizes the use of singularity detector-based multiscale morphological derivative (MMD). The article demonstrates the advanced MMD method that exhibits suitable potential for computerized ECG signal evaluation and the popularity of cardiovascular arrhythmias. Thakor et al [2] submitted a work on Noise Cancellation and Arrhythmia Detection by removing various types of noise using numerous adaptive clear-out techniques. The adaptive filter out minimises the suggest-squared errors. Preeti Raman et al [3], Have shown that the phase of heart disease based on ECG analysis is eliminated through the use of data mining techniques. The range of extracurricular activities was reduce using a PCA (key feature test) and compiled using a set of FCM rules (Fuzzy C Means) identified

with the help of the use of SVM (Vector auxiliary machine) for class purpose with 90% accuracy. Vijayavanan et al [4] An automatic class of ECG signs for coronary heart disorder prognosis proposed with the aid of the author said that morphological characteristics should be retrieved in in order to differentiate between normal and arrhythmic ECG signals impacted (weird) categories. In their example, they employed Probabilistic neural community (PNN), a modelling method used to document the spread of the category's characteristic vectors. Arumugam and colleagues [5] The authors of the study Detection of Cardiac Arrhythmia from ECG Warnings offered a summary of several methodologies utilised in the function extraction and classification of ECG alerts. This investigation discovered that the wavelet transform is utilised to extract functions, and the SVM classifier is used to categorise bio alerts. because to its high category accuracy Yan Sun, Kap Luk Chan, and Shankar Muthu Krishnan, among others [6]. The Multi-scale Morphological Derivative (MMD) transform-based singularity detector, which utilised for the identification of fiducial spots in ECG signals, was used to recognise characteristic waves in ECG signals, according to a study report published by the authors. The new MMD approach showed promising results for automated ECG signal processing and cardiovascular arrhythmia detection. Mr. Vyankatesh S. Thorat, Dr. Suresh D. Shirbahadurkar, Mrs. Vaishali V. Thorat et al [7] investigated real-time detection utilising 180 ECG data [60 atrial fibrillation, 60 ventricular fibrillation, and 60 ventricular tachycardia]. The suggested technique has excellent detection accuracy (up to 100 percent) and is ECG characteristic wave recognition computed quick. Cardiac arrhythmias can occur as a result of consistent or periodic heart rhythm abnormalities. Recurrent arrhythmic episodes (also known as cardiac dysrhythmia or irregular heartbeats) are present, as is erroneous beat detection due to poor signal quality.

Prof. A N Jadhav et al [8] and V. S. Waydande The authors of the study on cardiac telemonitoring system made an effort to aid and save cardiac patients by developing a system that allows real-time transmission of a patient's ECG to be diagnosed by an experienced cardiologist via wireless means. It aids cardiac patients in receiving medical attention in an emergency. It may also be used to send ECG signals on a regular basis to warn the concerned doctor or other medical personnel for patients who have been discharged from the hospital or those who have been kept on observation. One of the most significant advantages of this system's ECG monitoring This technique recognises significant emergency situations before they become harmful. Sharma A and Bhardwaj K, 2015 et al [9], developed a technique for discriminating between normal and abnormal ECGs based on neural pattern recognition. ECG classification encompasses a variety of methodologies and procedures that have improved performance and accuracy in the study of cardiac disorders. The Artificial Neural Network is used to detect regular and irregular ECG's. The authors, Sathya R and Akilandeswari K, 2015 et al [10], wanted to Classification utilising all retrieved characteristics results in anomalies being misclassified. As a result, feature selection is a key notion in distinguishing normal and pathological cardiac behaviour. The classification is done in Matlab using on the MIT-BIH Arrhythmia dataset.

III. METHODOLOGY

Cardiac Arrhythmia indicates the state of abnormal electrical activity of the heart that threatens human life. Processing, Filtering and extracting features from the electrocardiogram (ECG) signal. Further analysis of the extracted features is done. hence the processed signal is used for classification of heartbeats according to different Arrhythmia conditions.

Step 1. Pre-processing of data

The calculated features are: RT interval, RR interval, QRS complex. The heart rate changes observed for cardiac arrhythmias are as follows: Tachycardia, Bradycardia. Except for these two cardiac arrhythmias, the Normal state is observed. The preliminary data processing step includes steps for signal, signal measurement, R-peak detection, splitting, and finally removing noise from the output element. The extracted components are segregated into the next processing phase for arrhythmia detection once the previous data processing processes have been completed. Finally, in the final stage of processing, the removed factor is categorised based on the arrhythmia detection stage.

Step 2. To import the data from MIT-BIH Database into Matlab function

The first step is to import data from the MIT-BIH website into Matlab. In this case, we use the load() function in Matlab In this case, we have to add the path of that database to the function

Step 3. To remove Noise or distortion using Savitzky–Golay filter is used in Matlab for smoothing.

In Matlab, this filter is used to smooth. The next stage in data processing is to remove the noise and compare the data to the behaviour of each sensor. Medical data, such as an ECG signal, might appear in a range of sounds based on the natural surroundings, which can influence its accuracy. To acquire trustworthy signal data without

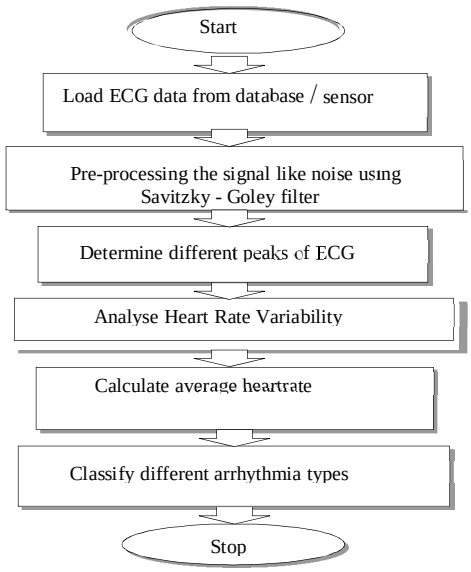

Figure.3 Flowchart of Methodology used

distortion or early loss of information, we must first eliminate this noise before eliminating the ECG signal components.

The Savitzky-Golay filter is a digital filter that can smooth a variety of digital data points., hence increasing data accuracy without diminishing signal bias. Convolution is performed by adding sequential selections of neighbouring polynomial data points in the form of linear squares.

Step 4. QRS complex Detection

Each heartbeat is composed of a sequence of electrical impulses produced by the heart, and they demonstrate the timing of the electrical impulses produced by the heart in a single beat. Each arrhythmia alters one or more of these waves. Different arrhythmias can be recognised by recognising and quantifying these changes. The QRS complex, which combines the Q, R, and S waves to form one big wave of a typical pulse, is the most critical element of the heartbeat. We acquired R points that make up the highest QRS complex for a single pulse at this level of our research, as each heartbeat has a single QRS complex. We will be able to transform a huge ECG signal file into using these points. units in the next step through the splitting process.

To extract the peaks from the waves, we utilised the findpeaks() method. It is critical to precisely calculate the R-points of the ECG signal since this allows us to detect the pulse, which has a significant impact on the final findings of detecting cardiac arrhythmia. To do so, we must eliminate the waveform's edges in order to appropriately identify all of the peaks. To eliminate the margins in this example, we utilised a random function(). T-QRS-P waves make up the cardiac signal loop.

The ECG signal contains useful clinical information at the distances and amplitudes determined by its waves.

Step 5. Heart Rate Variability Analysis

We may evaluate the characteristics in additional ways after deleting them using complicated QRS detection. For example, we may use the R-R intermediate signal to do a heart rate (HRV) analysis to determine the status of the heart and neurological system.

Step 6. Identification and Graphical representation of Arrhythmia's in Matlab The ECG data is processed using Wavelet Transforms' built-in function to determine rate of heart. The typical heart rate ranges from 60 to 100 beats per minute. A lower level is referred to be bradycardia (tired heart), while a greater level is referred to as tachycardia. If the cycles are not evenly spaced, arrhythmia may be suspected, If the PR interval is longer than 0.2 seconds. The following is an equation for estimating heart rate:

$$\text{Heart Rate} = (1/\text{RR INTERVAL per Second}) * 60 \quad ..(1)$$

ECG analysis after processing the same type of signals indicates Normal Rhythm and all Wave, Phase and Interval values are detected in such signals has plummeted below 60 BPM, although being within the typical range. The heart rate is under 60 beats per minute., which is outside of the usual range. BRADYCARDIA is represented by this.

ECG analysis after processing the same type of signals indicates it is Normal Rhythm and while all Waves, Sectors, and Intervals values are within normal limits, the level seen in such signals surpasses 60 BPM. The heart rate is above 60 beats per minute, which is not within the usual range. Tachycardia is represented by this.
We use Matlab sites to view all the information obtained from the ECG signal. The structure will create an image representation in Matlab and will be used to display the waves and peaks of the listed Signals.

IV. BLOCK DIAGRAM

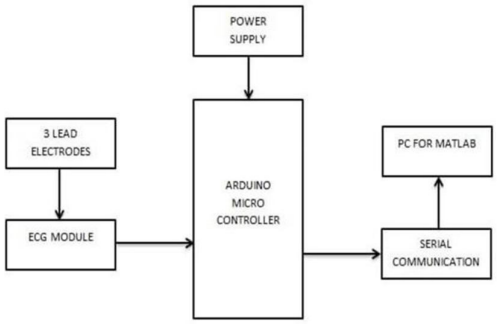

Figure 4: Block diagram of a system

V. FEATURES EXTRACTION

As presented in the previous topic, signal normalization and character extraction Tests were performed using MATLAB software. This step was necessary to use a modular and complete algorithm that can perform from signal windowing to feature extraction for training with a learning machine, Arrhythmias reference is from the MIT-BIH database. At the base are 48 samples from different subjects, each with a duration of approximately 30 minutes and random windows of different types of arrhythmias. For each sample, it is possible to perform the extraction of several types of files, four types were analysed. signal extraction with a band in a .mat file (MLII potential derived from type V2); extracting information from the full signal in an .info file; extracting essential patient health information into a file header; finally, extracting the details of each signal period along with the arrhythmia types - from professional cardiologists' assessments - in a .txt file. With the signal samples it was possible to perform the normalization and subtraction of the 3 suggested arrhythmias with some steps performed in MATLAB on each of the samples:

1. The first step consisted of loading each of the ECG signals, subtracting the electrical values in amplitude and time in addition to frequency, number of samples, and total signal duration.
2. Next, the signal annotation file was read, capturing the periods and times of the arrhythmia samples selected for extraction in a vector object.
3. With each of the specific periods of the arrhythmias, it was possible to perform the windowing of the QRS portion of each wave, capturing a previous time interval and after the arrhythmia time sample extracted in the previous step.
4. After subtracting the signal in amplitude and time in a windowing vector object, each subtracted QRS signal is plotted, except when there is no arrhythmia, called normal Sine Rhythm (N).
5. Splitting signal windows into vector objects, decomposing each windowed signal into time-varying frequency components with Maximum Overlapping Discrete Wavelet Transform (MODWT) and Inverse Maximum Overlapping Discrete Wavelet (IMODWT) at Scale 3 - Functions available through Wavelet MATLAB software toolbox.
6. After extracting the modulated and filtered signal with the Discrete Wavelet Transform, the amplitude and time of the peaks of the windowed signal are extracted via the Find peaks function of the Signal Processing Toolbox.
7. After removing the peaks in a vector object, plotting each signal with its corresponding peaks, except in the absence of arrhythmia
8. Perform feature extraction with amplitude and time data extracted from a vector object, capturing the amplitude value of the last peak of the signal, the R-R time difference between the last and first peak (middle

peak is not characterized). as peak R) and the peak velocity of wave R (the division between the peak amplitude and the R-R time period).

9. To finish off the extraction process, combine the three previously used extra features with patient-informative features from each sample header: gender, age, and drug administration. When combined, the extraction of these six feature sets is performed along with the arrhythmia type in a file, and each row of the file is populated with each sample period found for the selected arrhythmia. These presented steps were performed for each of the files and for all arrhythmias, in addition to extracting features from a healthy signal (N). After extraction, the arrhythmia features were organized in MATLAB into a single file used for each training classifier.

Flowchart for MATLAB program is as follows:

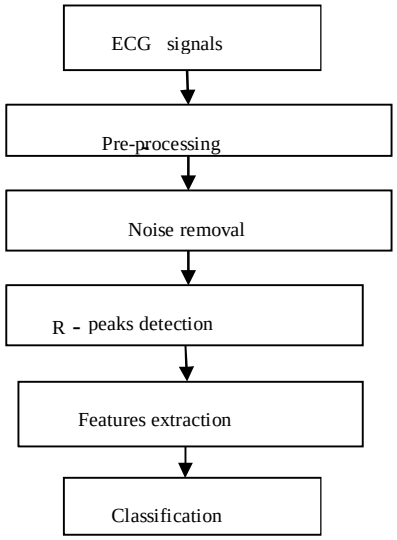

Figure 5: Flowchart of program

VI. SYSTEM DESIGN

Our proposed work entails designing, analysing, and developing a system capable of capturing a real-time ECG signal from a person and transmitting the data/signal to a processing device such as a laptop or PC. The suggested approach extracts ECG signals from a dataset (MIT-BIH).

The proposed work involves the collecting of ECG data using electrodes and connection to a PC/Laptop using MATLAB, followed by the detection of different arrhythmias (abnormal heartbeat).

The suggested System for Arrhythmia Detection in ECG Signals must meet the following parameters.

1. The system which is designed is capable of capturing real-time ECG signals through the human body and dataset values.
2. The system which is designed must be capable of recognising and categorising various forms of arrhythmias
3. The system which is designed is capable of determining severity.
4. The system which is designed is capable of calculating the time duration between two pulses.

The following components are chosen based on the system requirement.

Hardware used

a) ECG Module AD8232
b) ARDUINO UNO R3 Microcontroller
c) Serial USB to TTL converter
d) Arduino programming cable

Software used

a) MATLAB IDE R2013A.

Arduino IDE V1.8.19

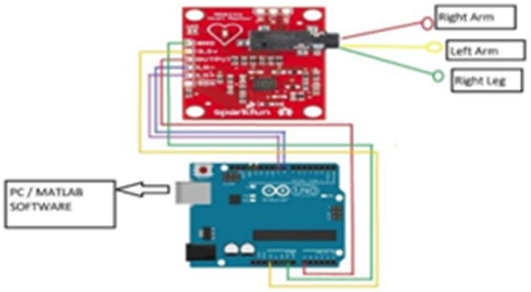

Figure 6: Interfacing of ECG module AD8232 Arduino microcontroller Diagram With

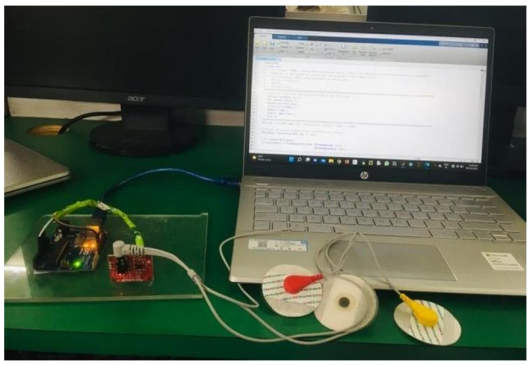

Figure 7: Hardware interfacing to pc/laptop

Figure 8: Hardware implementation

1. ECG MODULE AD8232

This sensor is interfaced with microcontroller. The AD8232 is a little chip that monitors the heart's electrical activity. An ECG, or electrocardiogram, can be used to record this electrical activity. Electrocardiography is used to assist in the diagnosis of various cardiac diseases.

2. ARDUINO UNO R3 MICRO-CONTROLLER

Arduino Uno microcontroller is interfaced with pc/laptop. It has inbuilt TTL (Transistor Transistor Logic) and Analog to Digital converter which converts the ECG analog signal into digital signal.

3. ARDUINO PROGRAMMING CABLE

For connecting an ARDUINO microcontroller to a laptop or PC programming cable is required.

4. MATLAB IDE (R2013A)

MATLAB is used for signal processing of ECG for example: to extract the mathematical values of the detected peaks.

5. ARDUINO IDE V1.8.19

In this Software (IDE) is code was written and uploaded to the board.

VII. Test and Results

The system is capable of detecting/ identifying the various types of Arrhythmias.

1.The first stage is used to distinguish a normal or abnormal ECG.

2.The second stage is used to distinguish the different types of arrhythmias found in the ECG signal.

The proposed system extracts features of real time ECG signal and can classify it to be normal or Irregular ECG signals.

Case 1: **Tachycardia detected**

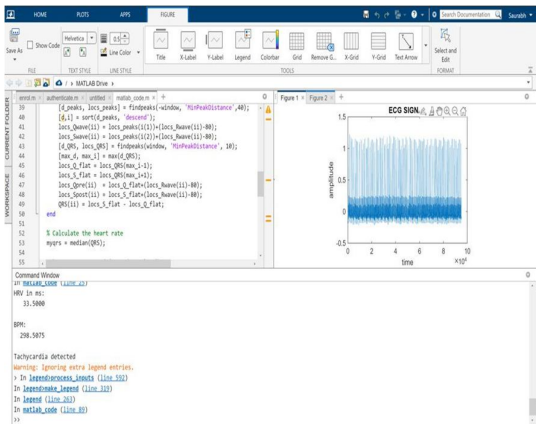

Figure 9: Tachycardia Detection

The figure above shows value of 298,5075 beats per minute. The Heart Rate Variability (HRV) for the above waveform is 33.5 milliseconds (ms). The waveform has an R-R interval of shorter than 0.6 seconds. From this data, the proposed system identifies TACHYCARDIA condition of heart based on MIT-BIH arrhythmia database. Using our proposed setup, we have taken readings of 50 persons and found that Arrhythmia is not proportional to age and effort/activity level.

Case 2: No Arrhythmia detected

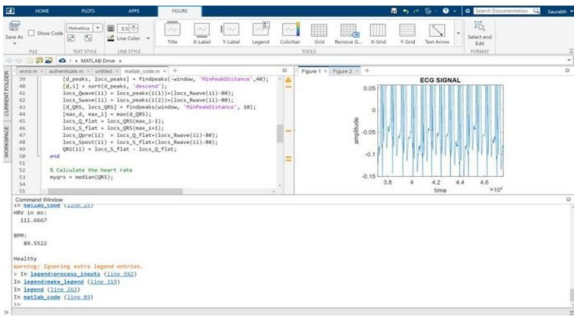

Figure 10: No Arrhythmia detection

The above figure shows 89,552 beats per minute and Heart Rate Variability (HRV) is 111.667 milliseconds (ms). From this data, the proposed system identifies NO ARRHYTHMIA condition of heart based on MIT-BIH arrhythmia database. Thus this case is about healthy person's ECG signal.

Case 3: Bradycardia detected

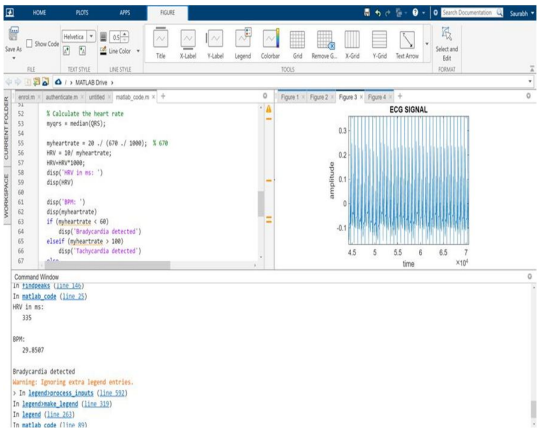

Figure 11: Bradycardia detection

The above figure shows 29,8507 beats per minute and Heart Rate Variability (HRV) is 335 milliseconds (m s). From this data, the proposed system identifies BRADYCARDIA condition of heart based on MIT-BIH arrhythmia database. In this condition it is observed that a person having bradycardia is having slower heartbeat i.e. below 60 BPM.

Case 4: Real Time ECG Waveform

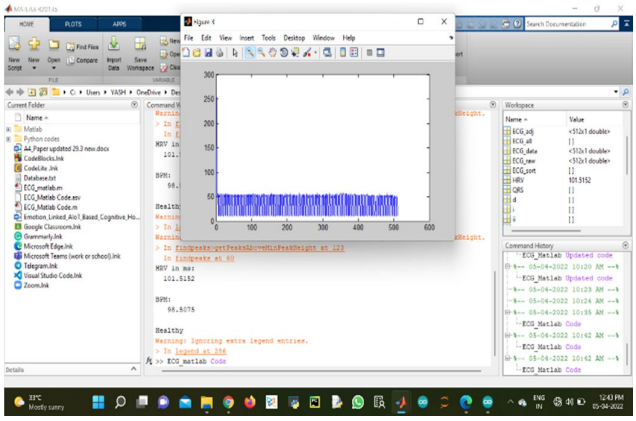

Figure 12: Real-time ECG Waveform

Figure 12 shows a real time ECG signal captured on the fly for a random person. The proposed system captures Real Time ECG signal with the help of AD 8232 ECG sensor. We have observed that the heart rate is 98.5075 beats per minutes (BPM) and the Heart Rate Variability reading is having 101.5152 milliseconds (m s) value. The proposed system identifies the persons heart condition as Healthy.

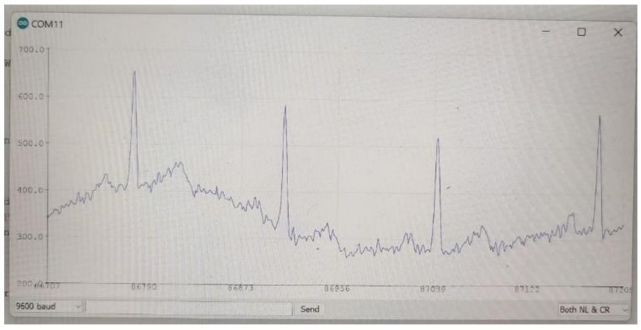

Figure 13: Output waveform captured for healthy person

Above figure shows Real-time Waveform generated for healthy person with normal heartbeat rhythm.
Following table shows various types of Arrhythmias detected with proposed framework.

Value in BPM	Condition	Remark
298.5057	Tachycardia	It is a medical term for heart rate greater than 100 beats per minute
89.5522	Healthy	The normal Heartrate for adults is in the range of 60-100 beats per minute.
29.8507	Bradycardia	It is a medical term in which heartrate is slow usually lower than 60 beats per minute.

Figure 14: classification of Arrhythmias as per obtained Results

VIII. CONCLUSION

This Paper provides a better ECG waveform observed in MATLAB we also calculated real-time ECG waveforms and waveforms generated using database, thus we observed various types of arrhythmias. The detection and calculation of Heart Arrhythmia was made successfully considering all aspects. All the required parameters of R peaks, P, QRS, T, U components are and used to detect heart abnormalities. Many persistent heart problems can be detected due to a person's ECG deficiency just by counting. heart rate but also the above

parameters. The normal ECG signal conditions are considered and compared with the human ECG to assess whether a person has normal or abnormal heartbeat or heart rate. Hence a complete analysis and diagnosis of cardiac arrhythmia is performed.

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