Development of Graphical User Interface to Classify Cardiac Abnormalities using ECG Signal

Sharanya S*, Sridhar PA, Suresh MP, Poorana Mary Monisha W, Tharadevi R
Department of Electronics and Instrumentation Engineering, SRM Institute of Science and Technology, Kancheepuram-603203, India,

Article History:
Received on: 07.03.2019
Revised on: 18.06.2019
Accepted on: 23.06.2019

Keywords:
Artifacts, Cardiac Arrhythmia, Electrocardiogram (ECG), Graphical User Interface (GUI)

ABSTRACT
Analysis of Electrocardiogram (ECG) signal can lead to better detection of cardiac arrhythmia. The important steps involved in the ECG signal analysis include acquisition of data, pre-processing of signal to remove artefacts, feature extraction of attributes and finally identifying abnormalities. This work proposes an efficient implementation of the R-R interval-based ECG classification technique for detecting abnormalities in heart functioning. ECG signals from an online database (PhysioNet.org) was analysed after noise removal for R-R interval, as R peak has the maximum prominent amplitude in ECG wave. Deviation in the R-R interval values obtained from unhealthy was observed and compared with healthy subjects. This observation of cardiac activity can be visualised in our developed Graphical User Interface (GUI). The GUI platform requires only the input of the ECG signal that is to be analysed for abnormalities, which can provide the clinician with the result of cardiac abnormality classification and can help in diagnosis.

INTRODUCTION
Electrocardiogram (ECG or EKG) is the process of recording the electrical activity of a human heart over a period using electrodes placed on the skin. ECG signal does not have a fixed shape, but the repetitive way of the self-similar form (Tara et al., 2017). The signs may be an indicator of disease or even warning about impending disease if the self-similarity is not uniform. Such indication may happen frequently or randomly in time scale (Gupta et al., 2010). However, analysis of irregular data set is time-consuming and challenging task, as heart is one of the most important body organs and is responsible for pumping blood in cardiovascular systems, if heart has gone out of its natural rhythm, blood circulation cycle is affected, and this can result in severe risks for the individuals (Subramanian et al., 2016). Hence, reliable and protective diagnosis of cardiac abnormalities is vital. One way for on-time diagnosis of these cardiac arrhythmias is analysing electrical activities of the heart using electrocardiography (ECG) signals. Minor changes cannot be visualized in ECG signals in the early stages of abnormality. Hence, data has to be analysed for identifying and classifying the arrhythmic condition.

The electrical activity of heart records each contraction and a graphical display of heart rate and a series of initial measurements to diagnose different heart change abnormalities (Belgacem et al., 2011). As ECG signals have similar morphological feature, through processing and analysing these morphological features, lots of heart diseases could be diagnosed and engineered with the help of GUI, hence reduces the critical evaluation strain of a medical expert. Such assistive mechanism should be highly re-
liable and accurate that aids the clinician in proper diagnosis and treatment of the condition. One of the pathologic changes which are diagnosable by ECG signals is arrhythmia, a condition where the heart beats with abnormal or irregular rhythm. An arrhythmia is a factor threatening the life, diagnosis of disorders in patients in ICU is vital.

Hence, analysis of ECG signals and diagnosis of abnormalities is useful and can also help clinical staffs in the absence of doctors and can also help doctors in the way of decision-making, diagnosis and respond quickly in an emergency.

In order to design an efficient system for diagnosis of cardiac arrhythmias from ECG signals, it is necessary to extract appropriate features of these signals. ECG signals have PQRST components, and each part has its own amplitude and time interval for a healthy heart (Sengupta et al., 2014). In feature extraction, the change in time interval and amplitude of attributes are taken to distinguish between normal and abnormal heart signal.

In the proposed method, the input ECG signal is taken from the MIT-BIH arrhythmia database (R-R interval) (5 records). (Subramanian et al., 2016) have worked with the abnormal ECG signal from PhysioNet.org, an online database - (i)The MIT-BIH Normal Sinus Rhythm Database (ii)The MIT-BIH arrhythmia Database (P and T amplitude) (iii)The Intra-cardiac Atrial Fibrillation Database) (Subramanian et al., 2016).

(a) Data acquisition
Irregular heartbeat or the change in the rhythm of the heartbeat is known as an arrhythmia, which can be classified by their origin and heart rate (George and Mohammed, 2013). Some of the arrhythmias and their identification process are shown in the Table 1.

In the proposed method, the input ECG signal is taken from the MIT-BIH arrhythmia database (R-R interval) (5 records). (Subramanian et al., 2016) have worked with the abnormal ECG signal from PhysioNet.org, an online database - (i)The MIT-BIH Normal Sinus Rhythm Database (ii)The MIT-BIH arrhythmia Database (P and T amplitude) (iii)The Intra-cardiac Atrial Fibrillation Database) (Subramanian et al., 2016).

(b) Data Pre-Processing
Data pre-processing involves noise removal technique. Various types of noise in the ECG signal and their range are shown in Table 2:

In the research article (Marie and Alfi, 2014) many methods for noise removal are discussed, few are summarized here. Different filters are used for different noise removal technique, and noise removal can be done in Time and Frequency Domain. Frequency domain can be used only for a specific application. Hence, frequency domain-based approach for noise removal is preferred. Baseline drift (low-frequency noise) affects the shape of the signal that can be removed using Moving Average filter which is a simple Low Pass FIR (Finite Impulse Response) Filter (George and Mohammed, 2013). Power line interference, Baseline wander, and motion artefacts that are always embedded with the raw ECG signal can be removed, and QRS complex can be detected using bandpass filter (Tara et al., 2017).

In the proposed Method, Fast Fourier transform (FFT) is used to remove Baseline Drift of frequency greater than 1 Hz and Power line Interference of frequency range 50Hz or 60Hz. The Fourier transform can process out random artefacts and uncover the frequencies.

(c) Feature Extraction
Feature Extraction involves detection of attributes and their ranges in the signal. The attributes were taken according to the different needs and application. In the proposed method, the R-R interval is

MATERIALS AND METHODS
The proposed system has four stages (i) ECG Data acquisition (ii) Data Pre-Processing (iii) ECG Feature Extraction (iv) Development of GUI.

Figure 1: Standard ECG signal and its attributes

MATLAB is an interactive environment and high-level language used for visualization, numerical computation and programming. Using MATLAB, we can analyse & classify data, develop algorithms, and create models and applications (Tara et al., 2017). It is used in the computation of complex mathematical calculation, pictorial representation of the signals in terms of plots. We can also analyse the signal behaviour using MATLAB (Gupta et al., 2010).

Graphical User Interface (GUI) is a system which is accessible to people of all levels of knowledge, from an absolute beginner to an advanced developer (Özbal and Keskin, 2017). This work has developed a GUI with the purpose of ECG signal processing using R-R duration detection and to aid the doctors for a better diagnosis of cardiac abnormalities (George and Mohammed, 2013).
Table 1: Different arrhythmia and their identification process

<table>
<thead>
<tr>
<th>S.No</th>
<th>Nature of arrhythmia</th>
<th>Identification process</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Bradycardia</td>
<td>When the R-R interval and the average R-R interval is more significant than 1.5sec and 1.2sec, respectively.</td>
</tr>
<tr>
<td>2.</td>
<td>Tachycardia</td>
<td>When average R-R interval less than 0.5sec.</td>
</tr>
<tr>
<td>3.</td>
<td>Asystole</td>
<td>When there is no R wave for more than 1.6sec and lack of QRS complex.</td>
</tr>
<tr>
<td>4.</td>
<td>Ventricular fibrillation</td>
<td>When there is a change in the QRS complex often.</td>
</tr>
<tr>
<td>5.</td>
<td>Skipped beat</td>
<td>When the R-R interval is approximately equal to twice the previous average R-R interval.</td>
</tr>
<tr>
<td>6.</td>
<td>Pre-mature ventricular contraction (PVC)</td>
<td>The QRS width is more extensive, and the T wave is the other way, and furthermore, there is no P wave.</td>
</tr>
<tr>
<td>7.</td>
<td>R on T phenomenon</td>
<td>When there is no way of detecting T wave that is R wave is riding on T wave.</td>
</tr>
<tr>
<td>8.</td>
<td>Trigeminy</td>
<td>When a regular beat is followed by two pre-mature beats and a full compensatory pause.</td>
</tr>
<tr>
<td></td>
<td>Interpolated PVC</td>
<td>When the pre-matured beats that are not followed</td>
</tr>
</tbody>
</table>

Table 2: Different type of noise and their frequency range

<table>
<thead>
<tr>
<th>S.No</th>
<th>Type of Noise</th>
<th>Frequency Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Baseline Drift or Baseline Wander</td>
<td>greater than 1.0 Hz</td>
</tr>
<tr>
<td>2.</td>
<td>Power line Interference</td>
<td>50 or 60 Hz</td>
</tr>
<tr>
<td>3.</td>
<td>Electromyogram (EMG) Noise</td>
<td>5 to 50Hz</td>
</tr>
<tr>
<td>4.</td>
<td>Noise due to respiration</td>
<td>0.12 to 0.5 Hz</td>
</tr>
</tbody>
</table>

measured from the input signal. R peak is a high amplitude attribute compared to other attributes and there is an evident difference in R-R interval of particular abnormal signal (Sengupta et al., 2014). In the proposed method, R-R intervals are detected using ecgdemowinmax (ECG Feature Extractor Toolbox) for both normal and abnormal signal. Window functions are used since their analytic expression, and they guarantee zero at the edges of the window. Steps involved in feature extraction are:

1. Removal of Low-frequency components using FFT
2. Windowed filter is used to find local maxima
3. Small values are removed, and significant values are stored
4. Step 2 and three are repeated for the given time duration of the signal

(d)Development of GUI

GUI is developed using MATLAB to load ECG signal and to test for normal and abnormal ECG signal using the calculated R-R interval. GUI framework has push buttons to load the input signal. Steps involved in each stage of GUI are:

1. Loading input signal
2. An input signal is filtered using FFT
3. R-Peak detection using ECG Feature Extractor Toolbox.

R-R plot (Time vs R-R interval) for the calculated R-R interval

RESULTS AND DISCUSSION

The results of each stage of the process are as follows: Figure 2 represents the input ECG signal.
loaded from the MIT-BIH arrhythmia database. Raw ECG signal is obtained with noise. Figure 3 represents the raw ECG signal is filtered by removing baseline drift and power line interference. Fast Fourier Transform is used to remove the mentioned noise. Figure 4 represents the R-R peak detection of the signal using ECG Feature Extractor Toolbox. Figure 5 represents the R-R plot for the processed ECG signal as time (X-axis) Vs RR interval (Y-axis). Figure 6 shows the developed GUI. GUI represents the entire interface which includes a user-friendly environment for the process of

a. Input ECG signal upon clicking the load signal
b. ECG noise filtering
c. R peak detection
d. RR interval plot

Figure 2: Raw input of ECG signal

Figure 3: FFT filtered ECG signal

RR interval is calculated for the obtained normal and abnormal signals from them, and the average of it is calculated and tabulated as below.

Figure 7 shows the bar graph to show the difference between the normal and abnormal displayed by rep-

<table>
<thead>
<tr>
<th>Subject</th>
<th>The average value of Abnormal R-R interval (sec)</th>
<th>The average value of Normal R-R Interval (secs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.882</td>
<td>0.977</td>
</tr>
<tr>
<td>2</td>
<td>0.946</td>
<td>0.930</td>
</tr>
<tr>
<td>3</td>
<td>0.860</td>
<td>0.888</td>
</tr>
<tr>
<td>4</td>
<td>0.942</td>
<td>0.930</td>
</tr>
<tr>
<td>5</td>
<td>0.930</td>
<td>0.992</td>
</tr>
</tbody>
</table>

Table 3: The R-R interval calculated for the normal and abnormal signal
CONCLUSION

Today, the process of ECG signal analysis is one of the most prominent topics in the research of bio signals. Therefore, this project has been developed to analyze the ECG signal using the R-R interval of normal and abnormal signal. The proposed method is, and it is capable of classifying ECG arrhythmia. The results obtained from the project showed that the proposed method has higher accuracy and speed of diagnosing heart diseases compared to other methods. The work can be further developed by using fractal features in ECG. ECG signals can be analyzed for a more profound understanding with creative techniques and can also be used for predicting rather than classifying abnormality. Moreover, fractal features are proved for ECG signals. As the method provides a proper diagnosis method for heart disease, it can be used by specialists to diagnose the types of different heart diseases.

REFERENCES


