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Asystole and Atrial fibrillation Arrhythmia Classification of ECG signals

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ABSTRACT: The heart is one of the important parts of any human being. The heart produces electrical signals, normally called Electrocardiogram (ECG) signal. The analysis of ECG signals plays an important role for detecting different cardiac arrhythmias. Asystole is the absence of ventricular contractions of a lethal heart arrhythmia. Atrial fibrillation is the most common cardiac disease and is associated with other cardiac complications. The aim of this study is to classify normal and abnormal ECG signals.

KEYWORDS: Electrocardiogram (ECG), QRS complex, Asystole, Atrial fibrillation, Heart rate

I. INTRODUCTION

ECG signal plays an important role in the primary diagnosis, prognosis and survival analysis of heart diseases. The ECG signal contains an important amount of information that can be exploited in different manners. It allows for the analysis of anatomic and physiologic aspects of the whole cardiac muscle. In the present scenario, cardiovascular diseases have proved to be one of the major causes of casualties. There is strongly established that a pre-monitoring and a pre diagnostic of these cardiac arrhythmias by using an ECG tool can lead to avoidance of such casualties caused by arrhythmia. Arrhythmia is defined as any sort of disorder that takes place in normal rhythm of heart. Some arrhythmias like ventricular fibrillation are fatal and also can cause death of patient. The classification of arrhythmias is very important as some arrhythmias are severely fatal while others are not. For classification, various methods have been used. The detection of arrhythmia is an important task in clinical reasons which can initiate life saving operations [1].

ECG SIGNAL CHARACTERISTICS

ECG is a nearly periodic signal that reflects the activity of the heart. A lot of information on the normal and pathological physiology of heart can be obtained from ECG. The ECG signal is represented as PQRST waveform as seen in Fig.1. The first phase of cardiac muscle activation is the stimulation of the right and left atria by an electrical signal generated from SA node. The depolarization of atria appears as the P-wave on the ECG waveform. The electrical signal generated, originally generated by the SA node, then spreads through the Atrio-ventricular (AV) node, the bundle of HIS, and the Purkinje fibers to finally reach and stimulate the ventricles. The spread of electrical signal through ventricles causes ventricular contraction.

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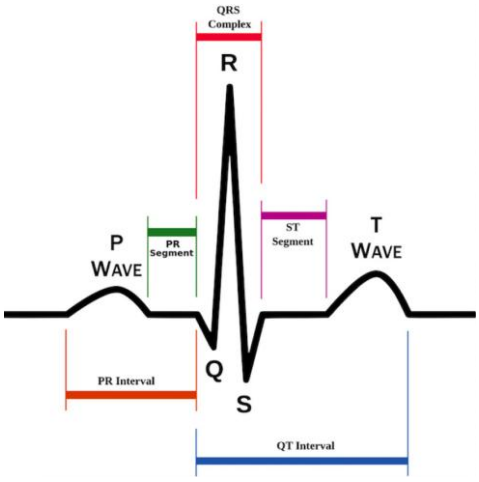

Fig.1. Normal ECG signal and various components

Each cardiac cell is surrounded by and filled with solutions of Sodium (Na+), Potassium (K+), and Calcium (Ca++). The interior of the cell membrane is considered to be negative with respect to outside during resting conditions. When an electric impulse is generated in the heart, the interior part becomes positive with respect to the exterior. This change of polarity is called depolarization. After depolarization the cell comes back to its original state. This phenomenon is called repolarization [2]. Normal ECG consists of waves, complexes and segments as shown in Table.1.

Wave/Segment	From - To	Cause	Duration (second)	Amplitude (mV)
P wave	-	Atrial depolarization	0.1	0.1 to 0.12
QRS complex	Onset of Q wave to the end of S wave	Ventricular depolarization and atrial repolarization	0.08 to 0.10	Q= 0.1 to 0.2 R=1 S=0.4
T wave	-	Ventricular repolarization	0.2	0.3
P-R interval	Onset of P wave to onset of Q wave	Atrial depolarization and conduction through AV node	0.18 (0.12 to 0.2)	-
Q-T interval	Onset of Q wave and end of T wave	Ventricular depolarization along with ventricular repolarization	0.4 to 0.42	-
S-T segment	End of S wave and onset of T wave	Isoelectric	0.08	-

Table.1. Waves of normal ECG

CARDIAC ARRHYTHMIA

Arrhythmia refers to irregular heartbeat or disturbance in the rhythm of heart. In arrhythmia, heartbeat may be fast or slow or there may be an extra beat or missed beat. When the heart beats faster than normal, it is called tachycardia. When the heart beats too slowly, it is called bradycardia. The most common type of arrhythmia is atrial fibrillation, which causes an irregular and fast heart beat.

ATRIAL FIBRILLATION

Atrial fibrillation is a rapid heart rate caused by chaotic electrical impulses in the atria. These signals result in rapid, uncoordinated, weak contractions of the atria. The chaotic electrical signals bombarded the AV node, usually resulting in irregular and rapid rhythm of the ventricles. Atrial fibrillation is associated with serious complications such as stroke. The heart rate in atrial fibrillation may range from 100 to 175 beats a minute. The normal range of a heart rate is 60 to 100 beats a minutes.

ASYSTOLE

Asystole, colloquially referred to as flat line, represents the cessation of electrical and mechanical activity of the heart. Asystole typically occurs as a deterioration of the initial non-perfusing ventricular rhythms: ventricular fibrillation (V-fib) or pulseless ventricular tachycardia (V-tach). Additionally, pulseless electrical activity (PEA) can cease and

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become asystole. Victims of sudden cardiac arrest who present with asystole as the initial rhythm have an extremely poor prognosis. Asystole typically results from de-compensation of prolonged ventricular fibrillation arrest.

II. METHODOLOGY

The following method has been adopted in this project to detect R peak to identify normal and abnormal ECG. The basic block diagram is as shown in Fig.2.,

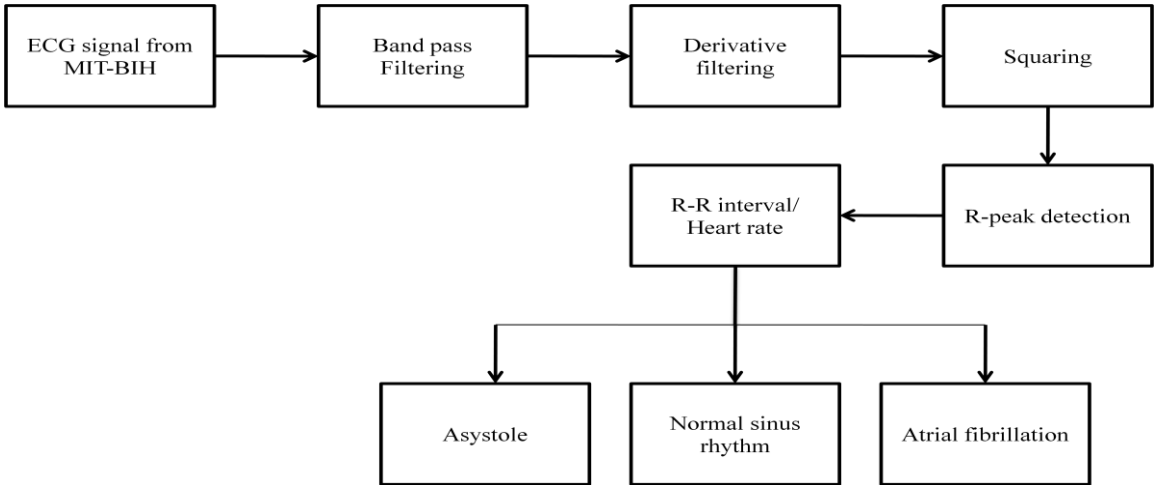

Fig.2. Proposed model

1. Data acquisition

Data acquisition is the initial process; therefore this step must be done first. Data acquisition is the process to gather many data that is used to analysis process. In this study we used MIT-BIH Atrial Fibrillation and Normal Sinus Rhythm dataset from Physionet respectively [3]. Asystole data are unavailable, as it is seen as pulse-less arrest signal. Asystole ECG signals are manually generated.

2. Filtering

The raw input ECG signal, as shown in Fig.3, is initially preprocessed using a band-pass filter to reduce the influence of different types of noises such as the baseline wander and muscle noise. In this work, low and high band-pass filters are cascaded to form a band-pass filter that can automatically remove both high and low frequency noises.

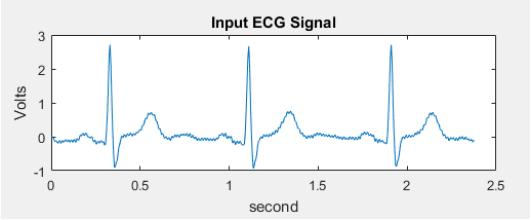

Fig.3. Raw input ECG signal

3. Derivative

To acquire the slope of the QRS complex, the noise-free signal is made to pass through differentiation, as shown in Fig.4. This mainly suppresses the low frequency components of P and T waves, and provides a large gain to high-frequency components arising from the high slopes of the QRS complex.

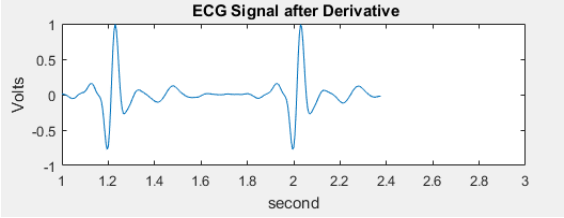

Fig.4. ECG signal after filtering and derivative

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4. Squaring

As shown in Fig.5, after derivative the output signal is squared sequentially. Consequently, all data points become positive, and the derivative output is amplified nonlinearly. This shows the higher frequencies in the signal, which are mainly due to the QRS complex.

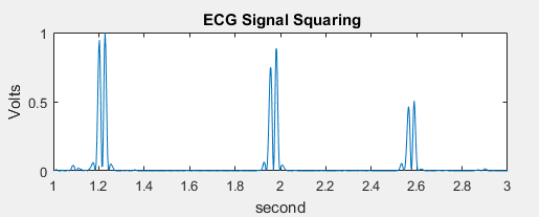

Fig.5. ECG signal after squaring

5. Peak detection

The common necessity for signal processing is to identify specific peaks in a signal and determine their characteristics. A peak is determined when a signal changes direction within a certain time interval [4] [5]. After all preprocessing steps, this algorithm can robustly detect R peaks, as shown in Fig.6.

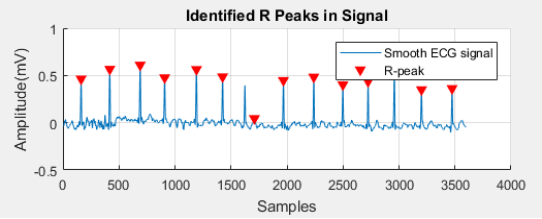

Fig.6. ECG signal after R-peak detection

6. R-R interval

The R peak is the longest peak in the ECG signal. It can be calculated by dividing the number of samples between two R peaks and sampling frequency of the signal [5]. It also plays a vital role in identifying the abnormalities of a given signal. In the of abnormal ECG signals, the R-R interval in consecutive R peaks changes significantly. The normal R-R interval time period ranges from 0.6 –1.2s. This paper describes the major role of the R-R interval in detecting diseases.

7. Heart rate

Once the R-R interval has been calculated, the heart rate is easy to calculate. The formula for calculating the heart rate is shown in equation 1.

Heart rate = 60/R-R interval in seconds------ (1)

Based on the value of the heart rate, it is possible to distinguish whether an ECG signal is normal or has some abnormalities.

III. SIMULATION RESULTS AND DISCUSSIONS

The simulations are performed both for the existing Pan–Tompkins algorithm and the proposed algorithm. The results are explored using MATLAB 2017a. The proposed algorithm, based on the Pan–Tompkins algorithm, was applied to the ECG records of the Massachusetts Institute of Technology-Beth Israel Hospital (MIT-BIH) Arrhythmia Database.

The performances of the Pan–Tompkins algorithm and the proposed algorithm for the disease detection can be analyzed using Table.2.

The detection accuracy of the proposed algorithm was as good as the Pan–Tompkins algorithm. The results of disease detection are shown in Figure 8, 9, and 10.

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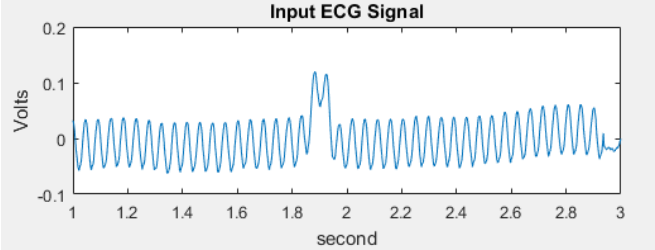

Fig.8. Asystole condition detected in test signal

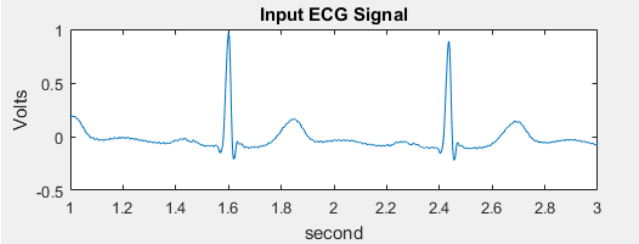

Fig.9. Normal ECG detected in test signal

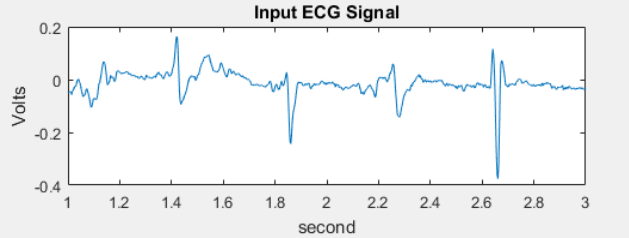

Fig.10. Atrial fibrillation detected in test signal

Heart rate comparison for MIT/BIH atrial fibrillation and normal sinus rhythm with asystole datasets.

Recorded ECG	Heart Rate	Condition
A1	135	Atrial Fibrillation
A4	123	Atrial Fibrillation
A15	128	Atrial Fibrillation
A16	148	Atrial Fibrillation
N1	78	Normal
N3	71	Normal
N6	79	Normal
N8	77	Normal
C4	0	Asystole
C6	18	Asystole
C10	0	Asystole
C13	7	Asystole

Table.2. Performance of proposed algorithm

VI. CONCLUSION

The proposed algorithm demonstrated for detection of two types of diseases among twelve ECG data samples. It successfully distinguished Asystole and Atrial fibrillation from the given records. This work was based on certain parameters such as the R-R interval and the heart rate of the ECG signal for disease detection. For future work, more parameters will be added to detect abnormal signals.

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