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ST Segment Analysis for Early Detection of Myocardial Infarction

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Abstract— Myocardial infarction is one of the most serious and prevailing heart disease faced in today's world, occurs when blood supply stops to a certain artery. Early and accurate detection of myocardial infarction reduces the mortality rate of heart attack. In this paper, we proposed an algorithm for early detection of myocardial infarction based on analysis of ST segment in electrocardiogram (ECG). This algorithm consists of following steps: loading of a database from physionet, preprocessing of a signal, detection of QRS complex, P, T wave, ST segment and other related parameters. European ST-T database was used for evaluation of an algorithm for detection of ST segment.

Keywords— Electrocardiogram (ECG), myocardial infarction (MI), ST segment, QRS complex, European ST-T database.

I. INTRODUCTION

The World Health Organization estimates that 17.7 million people die every year from cardiovascular diseases, 31% of all global deaths. Cardiovascular diseases are rising even in developing nations, which was once viewed as an issue just in the developing countries [1, 2]. An Electrocardiogram (ECG) is the graphical representation of the electrical activity of hearts from different views. Each view which is technically known as a lead is used for monitoring voltage change between the electrodes placed in the position of the body parts. There are 3 bipolar leads different namely Leads I, II, III and 9 unipolar lead namely aVR, aVL, aVF, V1 through V6. The single cycle of ECG signal is shown in Fig 1. It provides important information for heart disease diagnosis based on which clinician takes a decision [3]. Myocardial infarction is among the most serious cardiac disorder. It occurs due to occlusion of one of the coronary artery or some branches of the artery. A change in values of measured amplitudes, times and duration of the ST segment in ECG signal identifies myocardial infraction. The ST segment in ECG depicts the interval between ventricular depolarization and repolarization [4].ST segment elevation is a marker for early detection of MI.

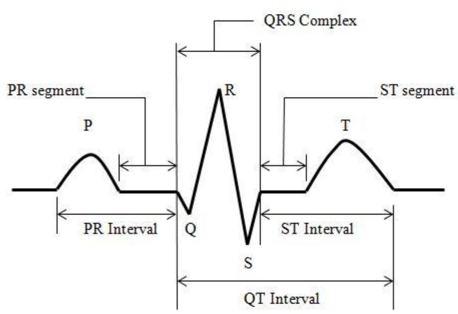

Fig1. Single-cycle ECG signal

The ST segment elevation is measured with respect to an isoelectric line which is the baseline where the amplitude is zero. Here baseline line is chosen as the flat line between P wave and Q wave. The ST segment elevation implies that the segment is above the isoelectric line. The various methods have been applied for myocardial infarction analysis and detection. This include wavelet transform based method [5-7], time domain based algorithm [7-8], neural network based method [8-11], support vector machine (SVM) [12] and many more. In this paper, we proposed an algorithm that uses elevated ST segment for identification of MI in the early state and the result is tested with respect to the European ST Database.
The paper is organized as follows: The database used in this algorithm is explained in Section II. The methodology for the proposed algorithm is in Section III. Experiments and results are explained in Section IV.

II. Material and Database

The ECG signal that is used in this paper is European ST-T Database. The database is meant to be utilized for evaluation of the algorithm for analyzing variation in ST segment and T wave. Each of the records is of two hours in duration and contains two signals where each signal is sampled at 250 samples per seconds with 12-bit resolution over a nominal 20 millivolt input range [13]. Header file consists of detail information such as patient information, type of ECG leads and number of ECG leads, patient history, clinical finding and recording equipment information. European ST-T Database is downloaded from physionet and it is converted into a readable format (.mat file). The signal is readable separately now in both the lead. Then the signal of lead V4 is used for analysis.

III. Methodology

The structure of MI detection in this work includes a series of step: ECG signal preprocessing, derivative, squaring, and detection of QRS, T and P waves, ST analysis and decision on MI. Figure 2 shows the block diagram for detection of ST segment for analysis of MI.

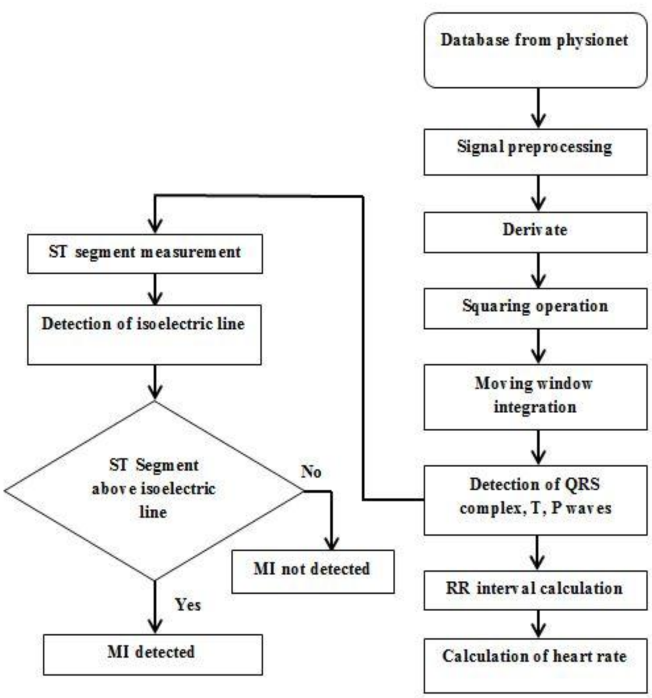

Fig.2 ST Segment detection block diagram

A. Cancellation DC drift and normalization

The DC drift cancellation operation in this algorithm reduces noise in the ECG signal obtained from physionet by matching the spectrum of the average QRS complex and further the amplitude of the signal is normalized first and then it is passed through the filter.

B. Low pass filtering

A recursive low pass filter used in this algorithm has an integer as its coefficient to reduce the execution complexity. The defined transfer function is

$$H(z) = 1/32\left[\frac{(1-z^{-6})^2}{(1-z^{-1})^2}\right]$$

Difference equation of the filter is

$$Y(n) = 2Y(n-1) - Y(n-2) + X(n) - 2X(n-6) + X(n-12)$$

The delay obtained is 6 samples produce due to filter processing [14]. Attenuation greater than 35dB at 60 Hz is provided by low pass filter to effectively suppress the power line interference noise.

C. High pass filtering

The high pass filter design is obtained on all pass filter minus a low pass filter. The transfer function of the high pass filter is

$$H(z) = (-1 + 32z^{-16} + z^{-32})/(1 + z^{-1})$$

Difference equation of the filter is

$$Y(n) = X(n-16) - 1/32[Y(n-1) + X(n) - X(n-32)]$$

The filter has 5Hz of low cut off frequency. While 32db is the gain and 16 samples is a delay.

D. Derivate operation

The derivate operation compresses low-frequency component of P and T waves and large gain is given to high- frequency component, which is generated by the high slope of ECG signal i.e. QRS complex [15]. It provides information on QRS complex slope and the transfer functions flow:

$$Y(n) = 1/8[2X(n) + X(n-1) - X(n-3) - 2X(n-4)]$$

E. Squaring operation

Squaring operation helps to make the results of ECG signal positive signify large difference results from QRS complexes. The equation of this operation is

$$Y(n) = [X(n)]^2$$

F. Moving window integration

The integration operation helps to smooth the signal to avoid merging of the QRS and T waves. Features information of waveform is mainly gained from moving window integration in addition to the slope of R wave. Then the equation is

$$Y(n) = 1\{X[n-(N-1)] + X[n-(N-2)] + \ \ldots . X(n)\}$$

Where N represents the number of samples present within the width of integration window. The width of the window must be almost same as the widest possible QRS complex.

G. Detection of QRS complex, P, T waves

In ECG signal the QRS complex represents the electrical activity of a heart during ventricular contraction. The shapes of QRS complex provide essential information regarding the heart current state. For all most, all ECG analysis algorithm QRS detection is one of the most important steps. To detect R peak we use hard thresholding method. In ECG signal the R peak which has the tallest peak is identified first in QRS complex later the lowest peak S is identified followed by Q. Other features of ECG signal like P waves location, T wave location are detected using the previously located Q, R and S waves peak.

H. ST segment Detection and Measurement

In ECG signal, the ST segment joins the end of QRS complex to the starting of T wave. It has duration of 0.08 to 0.12 sec. ST segment abnormality cause (elevation and depression) is myocardial ischemia or infarction. In this algorithm, the main focus was to extract ST segment data. The position of ST is between the end of S wave and beginning of T wave. The point where the QRS end and ST segment begin in ECG signal is known as J point. The ST segment is calculated as follows:

$ST_{\text{segment}} = \text{mean}\ (J_{point} - T_{point})$

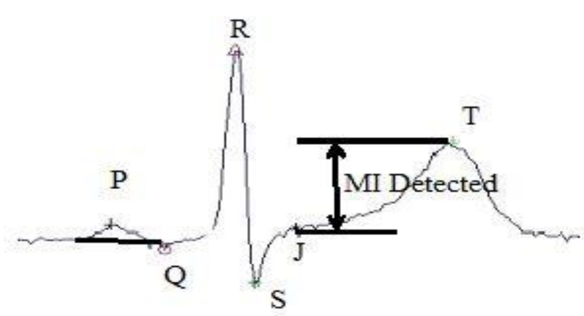

Fig.3 ST Segment and Measurement

IV. EXPERIMENTS AND RESULTS

To illustrate the performance of the algorithm, we have conducted a series of experiments on the European ST-T Database. The raw input signal used for our analysis is shown in Fig.4

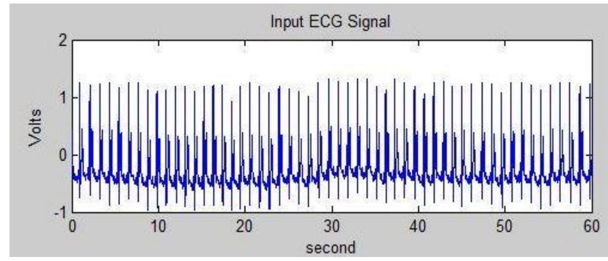

Fig.4 Raw Input ECG signal

The signal is normally contaminated with lots of noise like baseline wander, muscle artifacts, baseline drift, and power line interference which is being removed in the signal processing stage. After removal of noise from the ECG signal hard threshold is applied to detect R peaks with respect to it Q and S peak is detected. Fig.5 shows the QRS detected peaks in the signal.

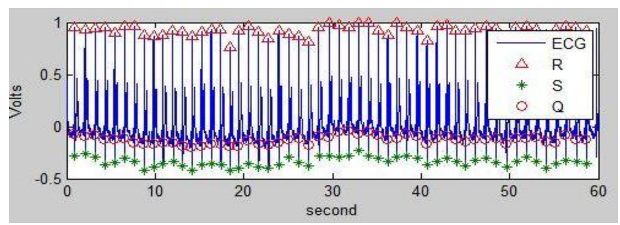

Fig.5 QRS peak detection for e0108m ECG record of EDB (1min)

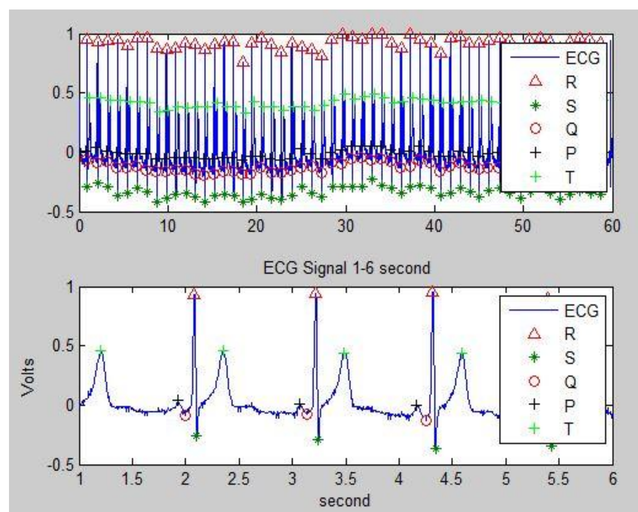

Fig5. PQRST detection for e0108m ECG record of EDB (1min and 6 sec).

After detecting P, QRS, T in ECG signal the ST segment is analyzed. The ST segment elevation which is an important parameter for early detection of MI is measured with respect to the isoelectric line (PR distance). The algorithm is checked for the record e0108m from European ST-T database (EDB).ST segment is considered as normal if the deviation lies between -0.1mV to 0.1mV

[16].If the deviation is greater than 0.1mV then the ST segment is elevated. The algorithm is checked for the record e0108m from European ST-T database (EDB).Table 1 show record for e0108m.

Table 1 The heart rate and corresponding ST segment Level of records e0108m

Beat (N)	Record e108m		
	RR interval	Heart rate	ST segment level
1	1.096	54	Elevated
2	1.084	55	Elevated
3	1.128	53	Elevated
4	1.124	53	Elevated
5	1.112	53	Elevated
6	1.052	57	Elevated
7	1.084	55	Elevated
8	1.108	54	Elevated
9	1.092	54	Elevated
10	1.060	56	Elevated
11	1.060	56	Elevated
12	1.096	54	Elevated
13	1.080	55	Elevated
14	1.032	58	Elevated
15	1.020	58	Elevated
16	1.080	55	Elevated
17	1.148	52	Elevated
18	1.108	54	Elevated
19	1.136	52	Elevated
20	1.144	52	Elevated
21	1.148	52	Elevated
22	1.116	53	Elevated
23	1.132	53	Elevated
24	1.148	52	Elevated
25	1.128	53	Elevated
26	1.080	55	Elevated
27	1.112	53	Elevated
28	1.136	52	Elevated
29	1.096	54	Elevated
30	1.064	56	Elevated

V. CONCLUSION

The algorithm is successful in detecting myocardial infarction at the early stage. The single lead signal from European ST-Database was used for this analysis. Most of the ongoing and presented work for MI detection is not much accurate. The proposed MI detection technique is able to detect more than 99% of accuracy for given database. This is automatic detection technique for MI at the early stage through ST segment analysis and does not require any prior knowledge of pathological characteristics.

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