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Analysis and Feature extraction of ECG signal for Myocardial Ischemia Detection

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***Abstract*— The recognition of the ECG waveform is very important task in the coronary intensive unit, where the classification of ECG waveforms is essential tool for the diagnosis. Analysis of the ECG signal is of great importance in the detection of cardiac anomalies. In this research paper, we represent an algorithm for automatic detection of ST segment deviation which is useful in detecting coronary heart disease (CHD) using ECG recording. Preprocessing is carried out on noisy ECG signal prior to extraction of features of ECG waveform which includes noise filtering using different techniques and then applying wavelet transform for detection of QRS complex. The proposed algorithm detects the R-peak in large number of samples and then calculates the ST segment relative level with respect to isoelectric line. The deviation in two levels is used for ischemia detection. The performance of proposed algorithm was tested on different ECG recordings from Long term ST database and the accuracy of the algorithm was found to be 98 % and hence, we conclude that the proposed algorithm may be used for practical purposes for ischemia detection.**

***Index Terms*—ECG, Ischemia, ST-segment, Isoelectric Line, Arrhythmia.**

I. Introduction

The electrocardiogram (ECG) is a diagnostic tool that records the electrical activity of the heart versus time in exquisite detail. Analyzing these details allows to detect many of the heart conditions. These conditions can vary from minor to life threatening. One cardiac cycle in ECG consists of P-QRS-T waves. The typical ECG waveform is shown in fig. (a) below. The useful features in ECG waveforms are intervals and amplitudes of these waves. The development of algorithms for accurate and quick methods for automated ECG feature extraction is of major importance for diagnosis of heart diseases.

The proposed algorithm is used to detect ST segment deviation from isoelectric line which is major cause of myocardial infarction.

Myocardial Infarction (MI) or Acute Myocardial Infarction (AMI), also known as heart attack, is the

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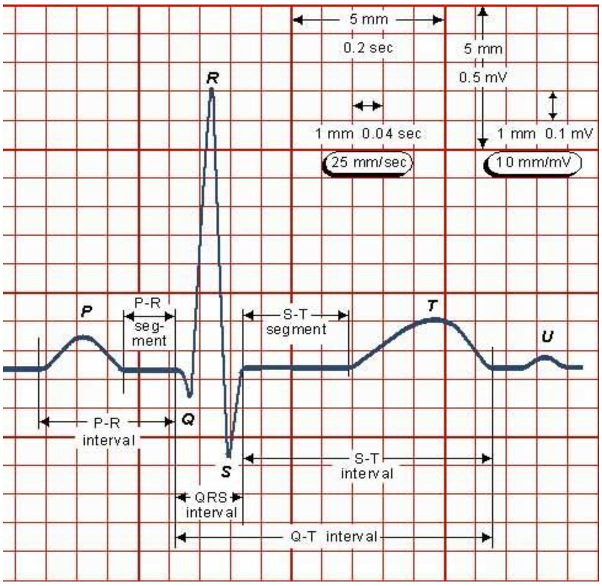

interruption of blood supply to different parts of the heart causing some heart cells to die. This occurs due to blockage of coronary artery following the rupture of a vulnerable atherosclerotic plaque which is an unstable collection of fatty acids and white blood cells in the wall of an artery. The restriction in the blood supply and oxygen shortage, if left untreated for a sufficient period of time, can even cause damage or death of a patient.

A. ***Isoelectric Line :*** Isoelectric line is flat part of ECG waveform, between T and P waves or between P waves and QRS complex. The ST segment's relative level is determined with respect to isoelectric line which can be used ro Ischemia detection. If ST segment is much below the isoelectric line, it is called ST segment depression and it is said that part of the patients heart is not getting enough oxygen (myocardial ischemia). The ST segement may also be elevated above the isoelectric line in the early stages of myocardial infarction.

B. ***ST- Segment :*** The ST segment is measured from J-Point to end of T- wave. The S point is identified as the first infletion after the R-wave. Generally S- point can be identified as a minimum point after R-Wave. The T-wave is the inflation after S-point and within 0.75 of R-R interval. The most important ECG change caused by Myocardial Ischemia is the ST elevation. The ST level is mostly used as an electrocardiographic indicator of ischemic states of the heart during physical stress. The elevation and the depression of the ST segment together with T wave changes indicate the region of ischemia near the applied lead. Therefore the ST slope is the most important feature of the ECG wave for detecting Myocardial Ischemia. The ST level may be defined as the maximum deviation from the isoelectric level.

To compare ST segment level and isoelectric line, it is required that PQ segment and ST segement to be identified more accurately which further requires identification of QRS complex. The main objective of the proposed algorithm is to correctly identify QRS complex, isoelectric line and its level and ST segment and its level.

II. PROBLEM, SOLUTION AND IMPLEMENTATION

The detection and identification of the ST segement deviation/elevation is most important task in detecting the myocardial ischemia. Several mathematical transforms and methods have been used for ECG such as discrete cosine transform, discrete fourier transform, the Karhunen-Loeve transform and wavelet transform.

Techniques such as Fuzzy Logic, Artificial Neural Networks etc also have been proposed for ST segment deviation detection. In our research work, we describe a technique for automatic detection of ST segment deviation which can be used in diagnosis of CHD using ECG recordings. The proposed algorithm used Haar wavelet coefficients for QRS detection and then determine ST segments relative level with respect to isoelectric line.

The algorithm used following steps :

- Preprocessing
- QRS Detection
- Detection of ST segment Level
- Detection of Isoelectric line level
- Comparison of ST segment level and isoelectric line.

A. ***Preprocessing*** *:* Most of the ECG waveforms are corrupted with different types of nopises such as

- Power line interference
- Muscle contraction noise
- Baseline wandering due to respiration
- Patient movement noise
- Instrumentation noise generated by electronic devices used in signal acquistion and signal processing.
- Electrosurgical noise.

I n first stage , preprocessing of ECG signal is carried out which involves removal of noise and rejection of artifacts. The standard Least-Square polynomial curve fitting technique is used in order to avoid the step line quantization error so that the reconstructed signal is acceptable for further analysis.

B. ***QRS Detection*** *:* This is another very important parameter employed for the analysis and ECG signal classification, because all other features such as P and T waves and the noset and offset of the QRS complex are defined relative to QRS complex. In abnormal cases, the QRS complex duration is 0.1 sec or more. QRS interval or duration greater than 0.12 sec.

After we filtered the signal with the seven point parabolic fileter, Haar wavelet transform is applied in order to capture small variations which are intrinsic to the signal.

The following algorithm summerizes the procedure for detecting QRS complex using Daubechie wavelet coefficients.

1. Applying Daubechie wavelets of order 1 on ECG in ‘j’ levels.
2. Finding the maximum wavelet coeffieicnts for each level [max(CDj)];
3. For each level, select the details (CDj,i) associated to QRS complex using $\beta_1 = 0.5$.

İf $|CDj,i| > \beta_1$ max(CDj), then position i $\in$ QRS Complex, else position i $\notin$ QRS Complex.

4. Identify different QRS complexes.

CDj,i and CDj, i’ are consecutive selective coefficients; β_2 = 0.1 is 0.1*(Standard QRS time duration);

$\Delta t = 1/f = 0.0005$;

İf ($t = 2^j \Delta t|i\text{-}i'| < \beta_2$, then i, i’ $\in$ same QRS Complex, else i, i’ $\notin$ same QRS Complex.

C. ***Isoelectric Level Detection*** *:* Isoelectric line is the flat parts of the ECG between the T and P waves or between P wave and the QRS complex. A band selection method is used for detection of of isoelectric line. The results obtained from QRS detection technique i.e. the magnitude of R – peak which is also known as first maxima of the ECG signal. Firstly small overlapping bands are chosesn between the maxima and minima of QRS peak. Each band is 0.05 mV wide and the two consecutive bands are differentiated by 0.1 mV.

After selecting bands, the population in each band upto 50 points to the left of maxima is calculated using MATLAB coding. The band having maximum population of points is considered as the most probable band and this is resulted as an isoelectric line.

After getting the limits of most probable band, isoelectric level is calculated by averging the points in this band and the result gives the level of isoelectric line and this level is later used for comparison with ST segment level. The average level comes out ot be -0.135 mV which is the amplitude of isoelectric line which is when subtracted from ST segment level gives the deviation of ST segement.

D. ***Detection of ST segment Level*** *:* The ST segment is the most important feature of ECG wave for identification of Myocardial Ischemia. The ST inverval is measured from the J-Point to the end of the T wave. The leevation and depression of ST segement together with T wave changes indicate the presence of Myocardial Ischemia.

In this method, the small overlapping bands are chosen between maxima and minima of QRS complex peak which is detected by QRS complex detection method. Each selected band is 0.05 mV wide and two consecutive bands are differentiated by 0.01 mV.

After selecting bands, the group of points in each selected band upto 50 points to the right of maxima is calculated by MATLAB coding. The band having maximum points is considered as most probable band and this is resulted as the ST segment. After ST segment limit is obtained, the ST segment level is calculated by averaging the points in this bands and the result gives the level of ST segment and this level can be used for ischemia detection.

E. ***Comparison of Amplitudes of Isoelectric Line and ST segment :*** This is the last step in the proposed algorithm to compare the ST segment level with isoelectric line level. If ST segment is well below the isoelectric line , it is called ST segment depression. This segment may also be elevated avove the isoelectric line in early stages of Myocardial Ischemia. When ST segment deviation is more than 0.08 mV below the isoelectric line and has an angle larger than 60 degrees measured from vertical line, it is considered as negative ST deviation or ST segment depression. The ECG wave is Myocardial Ischemic if ST deviation is more than 0.08 mV above the isoelectric line which is considered as ST elevation.

III. RESULTS & DISCUSSIONS

In most of the Myocardial ischemic cases, ST segment is either elevated or depressed. The elevation or depression of ST segment is taken as a reference with respect to isoelectric line. To establish the cases of Ischemia, it is important that we must understand the relative levels of ST segment with that of isoelectric line. As these segments are occuring immediately before and immediately after the QRS complex respectively, one of the important step in identifying the isoelectric line and ST segment is to identigy QRS complex. In this research work, we started with detected QRS complex in large number of samples.

Next step was to identify relative position of ST segment and isoelectric line. Isoelectric level was taken as most probable level for 20 samples before QRS complex at the rate of 250 samples per second. Similarly, ST segment is taken as most probable level for 20 samples after QRS complex. After finding the relative levels, we take te ST segment to be elevated or depresssed it it is 0.08 mV above or below the isoelectric line repectively.

Fig (3)-(8) shows the results of analysis of ECG signal and detection of characteristics points in ECG signal. The table 1,2 and 3 below shows the results calculated using algorithm and visual inspection.

```
-------------------------------------------------
**** DETECTION OF MYOCARDIAL INFARCTION ********
Designed By- Mr. P. R. Bokde
Buided By - Dr. N.K. Choudhari
-------------------------------------------------
RESULT  :   "MI Detected"
-------------------------------------------------------
Amplitudes of P waves
100     84      80      80      74      73      113
-------------------------------------------------------
Position of P waves
155     547     959     1348        1710        2097
-------------------------------------------------------
Amplitudes of Q waves
-25     -21     -9      -25     -21     -31     -13
-------------------------------------------------------
Position of Q waves
184     591     993     1369        1741        2131
-------------------------------------------------------
Amplitudes of R waves
1058        1073        1092        1046        1069
-------------------------------------------------------
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Fig. 2 : Part showing the values of different characteristic points of ECG signal.

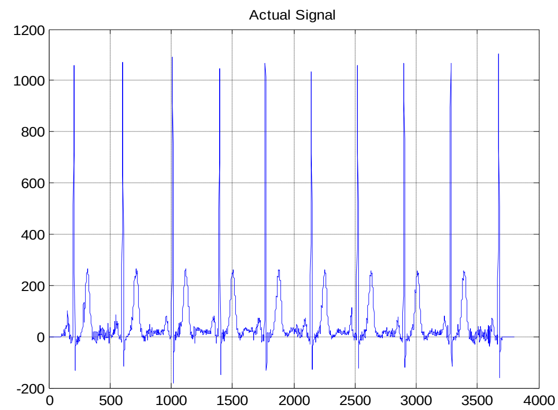

Fig. 3 : ECG Signal Sample

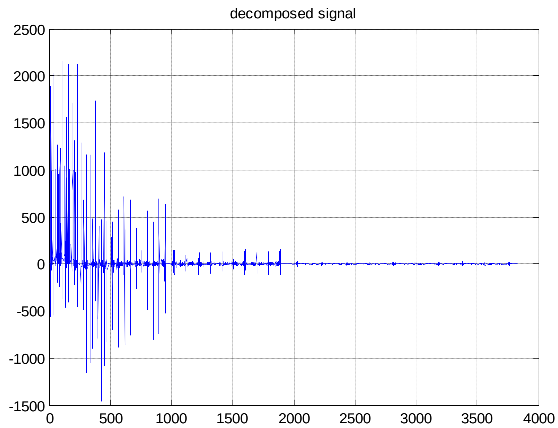

Fig. 4 : Decomposed ECG signal

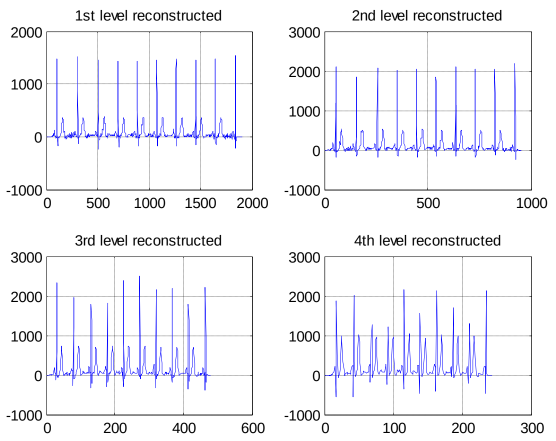

Fig. 5 : Reconstructed signal using Wavelet Transform.

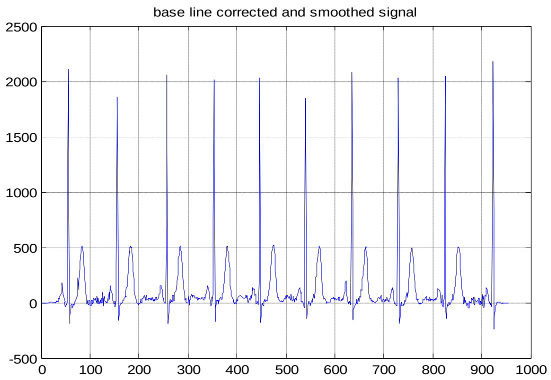

Fig : 6 : Baseline corrected and Smoothed signal after filtering.

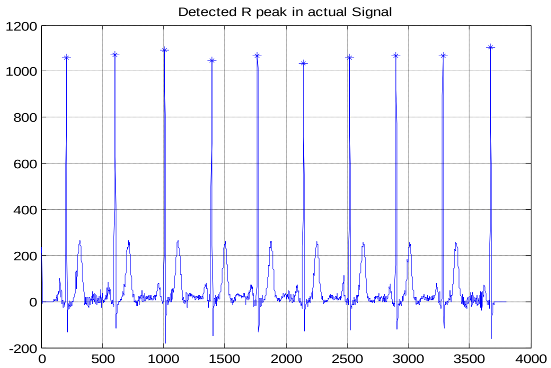

Fig. 7 : Detected R peaks in Sample ECG signal.

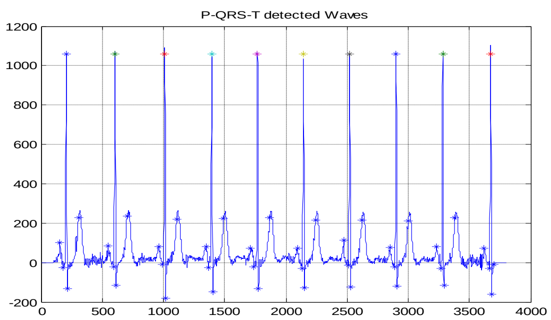

Fig. 8 : Characteristics points detected in Sample ECG signal showing ST segment Elevation.

Table 1 : ST segment detection using Visual Inspection.

Long Term ST Database No.	Peaks Detected by Visual Inspection		
	Elevated	Depressed	Normal
20131	0	36	06
20111	5	31	11
20221	0	49	01
20051	0	62	02
20031	39	0	0
20101	2	18	16

Table 2 : ST segment detection using Computer Algorithm.

Long Term ST Database No.	Peaks Detected by Computer Algorithm		
	Elevated	Depressed	Normal
20131	0	35	06
20111	5	29	13
20221	0	47	02
20051	0	61	03
20031	39	0	0
20101	2	19	15

Table 3 : Table showing Results of Myocardial Ischemia.

Long Term ST Database No.	ST Segment Elevated/Depressed	Myocardial Ischemia Detected or not?
20131	Depressed	MI Detected
20111	Depressed	MI Detected
20221	Depressed	MI Detected
20051	Depressed	MI Detected
20031	Elevated	MI Detected
20101	Depressed	MI Detected

From table, it is found that reasonable amount of accuracy is obtained by using the proposed algorithm implemented by MATLAB Software.

IV . CONCLUSION

Large Number of algorithms have been used for calculating ST segement level, but in this present work, we presented an algorithm that QRS complex on time axis. QRS complex detection is done by wavelet transform. A reasonable amount of accuracy (Approx. 98 %) is obtained using this algorithm and hence it can be therefore concluded that the proposed algorithm can be used for most of the practical purposes for detection of Myocardial Ischemia.

V. FUTURE SCOPE

In the present work, the analysis of only 6 subjects and short term recording of ECG data samples is done. The result obtained is satisfactory but the overall accuracy can be improved upto 100 % with the slight modification in the proposed algorithm. For more accurate and precise result, the work can be extended to more number of subjects and samples with different database. Presently the algorithm is tested only for database obtained from MIT-BIH database. The same algorithm can be applied to real time ECG signal obtained from patient boy and the Myocardial Ischemia can be detected in real time.

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