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QRS Detection in 12-Lead Electrocardiogram by Averaging Parametres

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Abstract— ***QRS detection in 12-Lead Electrocardiogram using 12-Lead signal averaging point by point and peak enhancement method is proposed in this paper. Initially raw data having sampling frequency (f_s) is preprocessed, using window width $f_s/2$ and f_s for two stages mean filter to remove baseline drift of raw signal. The second stage generate composite lead on the basis of averaging of all 12- Leads data point by point. The third stage enhances the peaks of composite lead by using fourth power of this signal, using mean value of this enhanced signal as threshold to determine variable window size. The next stage finds QRS high peak by taking maxima of composite lead and individual leads at variable window size. The performance of the algorithm is evaluated against CSE database the detection sensitivity (Se) 98.43% and Positive Predictivity (+P) 99.13%.***

Keywords— ***Electrocardiogram, mean filter, sampling frequency, CSE database.***

I. INTRODUCTION

The Electrocardiogram (ECG) is a basic tool for monitoring health of human being. The past few decades, increasing attention has been forced on the use of multi-lead monitoring for telemetry and ambulatory electrocardiography. There are reliable advantages of multi-lead monitoring for the detection and positioning of acute ischemia in patients with coronary artery disease. These techniques are also important for the detection and accurate diagnosis of arrhythmias, because multi-lead recordings provide important information of P wave and QRS complex morphology that cannot be determined from two or three lead recordings. The pattern of electrical propagation is not random, but spreads over the structure of the heart in a coordinated manner. This results in a measurable change in potential difference on the body surface of the subject. The ECG signals consist of P, QRS and T waves associated with each beat as shown Fig. 1.

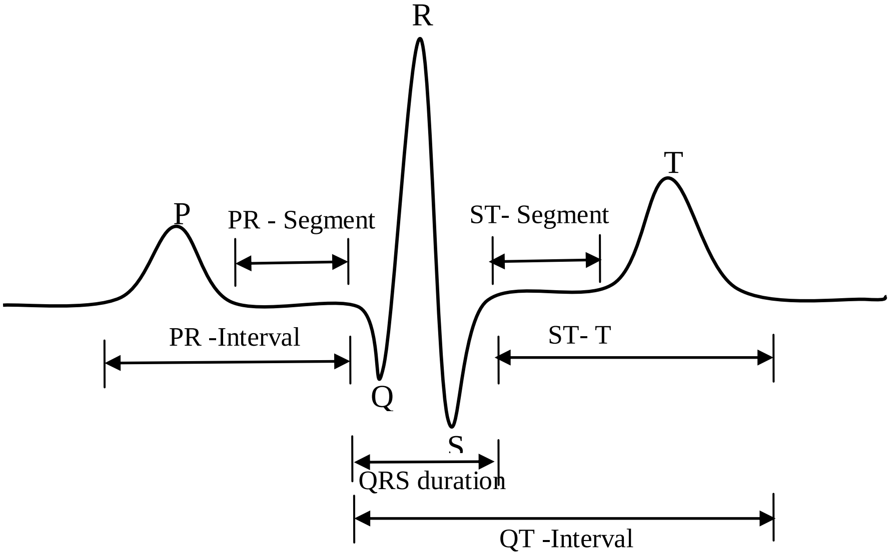

Fig.1. ECG signal

The QRS complex is the most important waveform of ECG signal, it is known as reference waveform for analysis of any heart related problems. Any cardiologist or clinician diagnoses of cardiac abnormalities by observing ECG, firstly by observing QRS complex and then other wave components. The performance of an automatic ECG analyzing system depends mostly upon the accurate and reliable detection of the QRS complex. Once the location of QRS complex is determined, then other wave components of ECG signal such as P & T waves, PQ & ST segments are determined. Therefore detection of accurate QRS complex is the most important target in automatic ECG signal analysis.

QRS detection is major problem, not only due to the morphological variation of the QRS complexes, but also occurrence of various disturbances and noise artifacts [1, 2] in the ECG signal. Within the last three decade many new approaches to the multilead QRS detection have been proposed, based on various concepts. Gritzali [3] proposed two methods for multilead QRS detection based on length transformation and energy transformation. Kyrkos et al [4] developed QRS detection for both 3-Lead and 1-Lead ECG signals using time recursive prediction techniques. Laguna et al [5] proposed multilead QRS detector on the basis of multilead QRS detection rules. Maheshwari et al [6] using spatial velocity approach, the analysis software reliably detects the QRS complexes and then other component waves in the multilead ECG. Mehta and Lingayat [7] proposed the detection of QRS complexes in 12-Lead ECG using SVM.

In this paper we propose a simple and reliable method for QRS detection in the 12-Lead simultaneous recorded ECG data. In this method raw ECG data preprocessed using two stage mean filters for removing base line drift and then averaged all 12 lead ECG data at each point which is simultaneously recorded, consist a composite signal, which is more enhanced in the QRS region and suppressed noise such as artifacts and high peak abnormality of P and T waves are smoothed. The QRS complex of composite signal again more enhanced, using fourth power of composite signal. In this method P and T waves clearly separated from QRS complexes by mean value of this enhanced data.

II. METHODOLOGY

(A) QRS detection Method

The averaging function is the frequency domain low pass characteristic. Detection criteria for complex localization are according composite lead and peak amplitudes in order to avoid false positive detection of tall P and T waves. A block diagram of the proposed method for QRS detection in 12 Lead ECG systems is shown in Fig. 2 and detail steps describe in the next section.

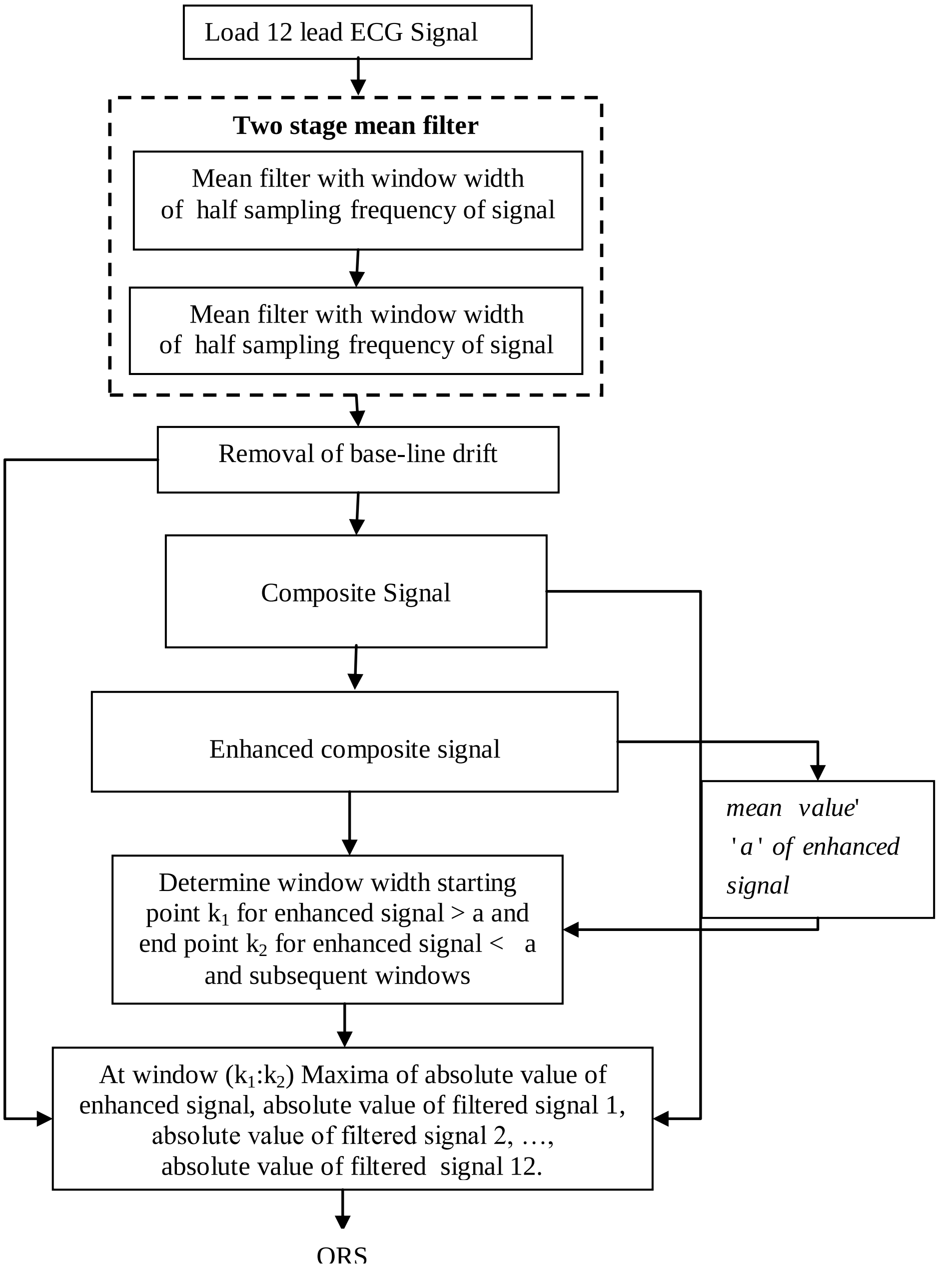

Fig.2 Block diagram for QRS detection in 12-lead ECG

(B) Method steps

1. Load 12-Lead ECG data as shown in fig. 3, having sampling frequency f_s and number of total samples N of each
2. Select a channel of ECG data.
3. Removing baseline drift, apply two stage mean filter
   (A) First stage mean filter: - using window width $f_s/2$
   (a) Input data having total samples 'N' and sampling frequency f_s
   (b) In this stage mean value of input data to be determined and stored in an array from 1 to $f_s/4$ points, using a variable window size of $f_s/4$ to $f_s/2$.
   (c) In next stage mean values of input data to be determined and stored in an array from $f_s/4+1$ to $N-f_s/4$ points, using a moving window size $f_s/2$.
   (d) In last stage mean values of input datato be determined and stored in an array from $N-f_s/4+1$ to N points, using a variable window size of $f_s/2$ to $f_s/4$.

   (B) Second stage mean filter: - using window width f_s
   (a) Take first stage data having total samples 'N'.
   (b) In this stage mean values of data to be determined and stored an array from 1 to $f_s/2$ points, using a variable window size of $f_s/2$ to f_s.
   (c) In next stage mean values of data to be determined and stored an array from $f_s/2+1$ to $N-f_s/2$ points, using a moving window size f_s.
   (d) In last stage mean values of input data to be determined and stored an array from $N-f_s/2+1$to N points, using a variable window size of f_s to $f_s/2$.
   (e) To remove baseline drift from signal, subtract second stage mean filter output from input data.

   Similarly find other remaining lead data. All 12_Lead filtered data show in fig. 4

4. Composite (Complex) Lead data developed by adding all filtered lead signal and then averaged.

In this signal QRS complex region more enhanced than P and T waves in other 12-Leads ECG system. P and T waves region also smoothed. Composite Lead wave form as shown in figure 5 (a), which morphology is approximate same as other 12_Leads.

5. Again enhancement of various peaks such as P, QRS, T waves is done by taking fourth power of composite signal as shown in fig. 5(b),
6. Mean value **'a'** of enhanced composite signal is determined.
7. Steps to determine variable window width (k_2 - k_1):
   (A) To determine starting point k_1 of first peak: compare enhanced signal to threshold value **'a'**, if it is greater than threshold value, and then mark point k_1.

   (B) To determine ending point k_2 of first peak: compare to enhanced signal from k_1 onwards to threshold value **'a'**, if this value is less, and then mark point k_2 .

8. Detection of QRS: The window ($k_1 : k_2$) when mapped in composite lead and filtered data of individual leads find maxima, high peak marked by symbol (^) as shown in fig. 5 (c) and fig. 6 respectively, which represents location of QRS of composite lead and each individual 12 leads. If detected peak is positive then it is '**R**' or otherwise **'S'** wave.
9. For next peak to last peak find starting point k_1, starting from $k_2 + refratory\ period$ as discussed in step 7 (A) and ending point k_2 as given in 7 (B). Refractory period (200 ms) [2] is used to eliminating false peak detection due to abnormal '**T**' wave.

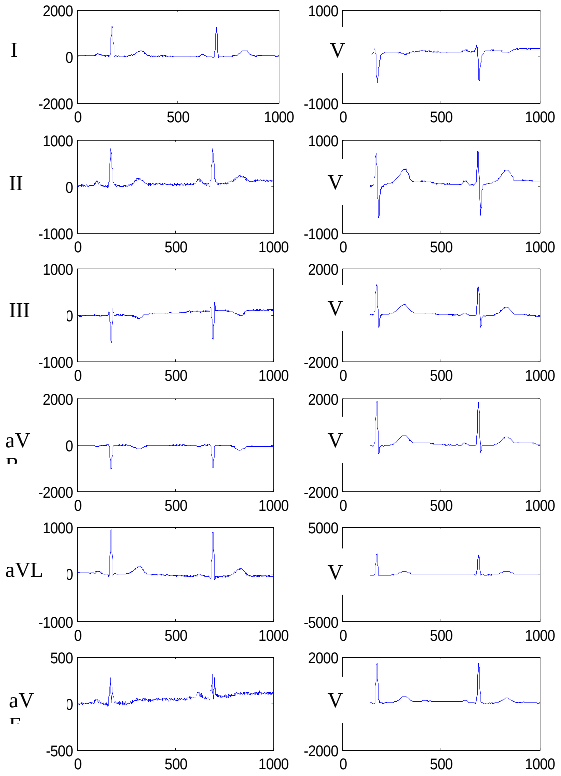

Fig.3 Original 12_Lead (MO1_008) data

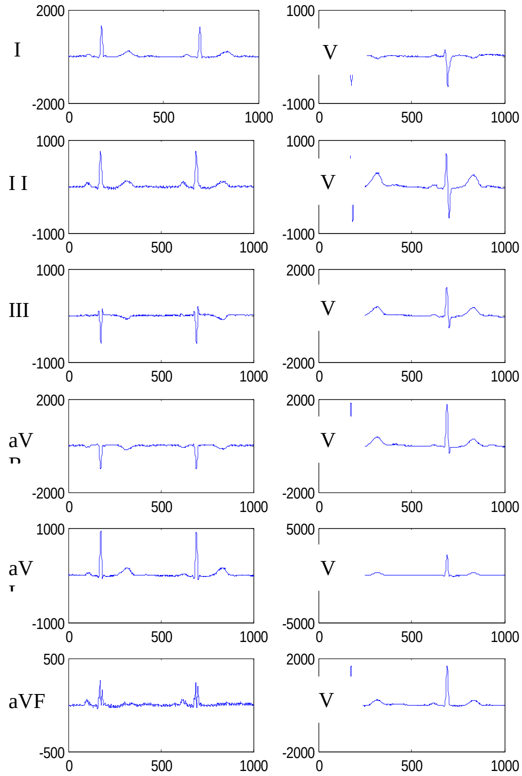

Fig.4 Filtered 12_Lead (MO1_008) data

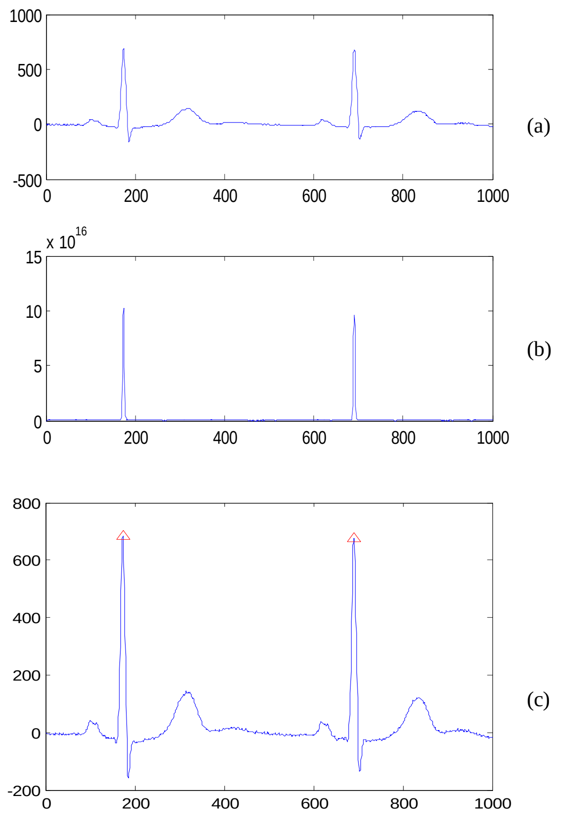

Fig. 5 (a) Composite lead, (b) Enhanced composite lead (c) QRS marking in Composite lead

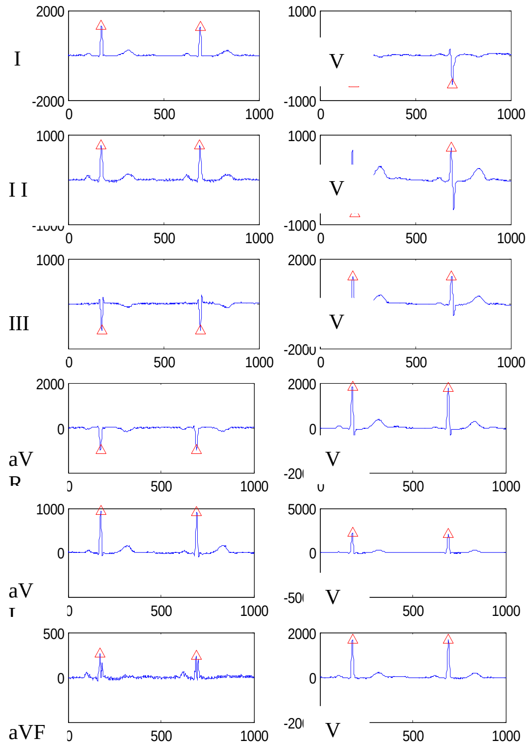

Fig. 6 QRS marking in all 12_Leads OF MO1_008 data

III. RESULTS AND DISCUSSION

The evaluation of this new proposed method was done using 125 (MO1_001 to MO1_125) cases of standard CSE multilead data set-3 [8]. The multilead CSE data set-3 contains 250 (125-125) cases and all leads of ECGs data set-3 simultaneously recorded at 500 Hz, for 8 to 10 seconds.

Fig. 7 shows QRS detection in record MO1_002 (all 12_Lead and composite lead). In this record variation in baseline drift is large and P & T waves are abnormal in different leads and the proposed method is able to correctly detect all QRS locations.

In order to evaluate the performance [9] of the proposed method, two parameters were adapted:

$$Sensitivty\ (Se) = \frac{TP}{TP + FN} \tag{1}$$

$$Positive\ Predictivity\ (+P) = \frac{TP}{TP + FN} \tag{2}$$

Where TP denotes the number of true positives, FN is the number of false negatives and FP is the number of false positives.

CSE data set-3, cases 125 (MO1_001 to MO1_125) for the QRS detection in 12_Lleads ECG system. In this data , we observe that the proposed method produced, in total 13 false positives and 24 false negatives resulting in an overall QRS detection sensitivity (Se) and positive predictivity (+P) of MO1 series are 98.43% and 99.13%, respectively. The false positive detection was eliminated due to composite lead, because composite lead averaged all normal and abnormal P and T waves.

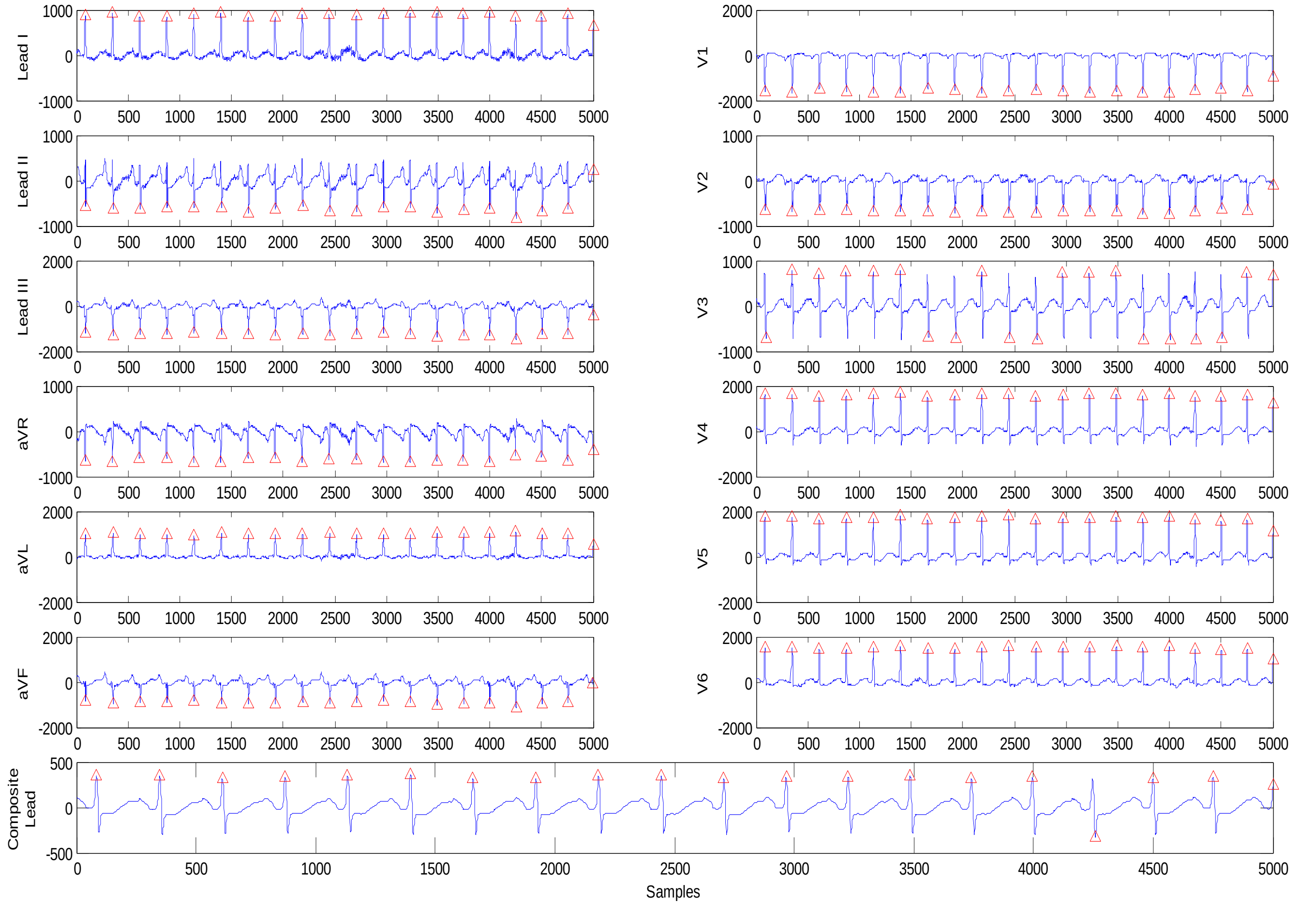

Fig. 7 QRS detection in MO1_002 CSE data

IV. CONCLUSION

An effective and reliable QRS detection method based on coherent space averaging and peak enhancements by fourth power has been presented here. This proposed new method was tested on standard CSE data set-3 and obtain good results & statistical indices are higher or comparable to those, cited in the scientific literature. The proposed method is very simple, fast and reliable to determine QRS of all 12_Leads at time. This method is easy to use in real time QRS peak detection and rhythm analysis using composite lead algorithm.

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