Wave Boundaries Detection in 12-Lead ECG Signal Using Composite Lead
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Abstract: The wave boundaries detection in 12-Lead ECG using composite lead proposed in this work. The complexes of this composite lead are more enhanced and noise free than other 12 leads. The enhance complexes of composite signal by using fourth power of this signal, using mean value of this enhanced signal as threshold to determine high peak of QRS of composite signal and individual leads at variable window size. Representative beats of composite lead signal and all 12-Leads are determined and marking boundaries of the P, QRS and T waves. The performance of the algorithm is evaluated against CSE multilead database, the main boundary marking of $P_{onset}$, $P_{offset}$, $QRS_{onset}$, $QRS_{offset}$ and $T_{end}$ estimated within limits.

Keywords: 12-Lead ECG, Composite lead signal, P-QRS-T waves, CSE multilead database

I. INTRODUCTION

Computer analysis programs are used to measure onsets and offsets of P, QRS and T waves in ECG signals based on beginning of the record or reference beat [1]. Researcher Pablo Laguna et. all used 15 leads (12 standard leads and orthogonal leads) [2] for multilead QRS detection and boundaries marking in all beats. Saxena et. all used wavelet based 12 leads separately for QRS detection and boundaries marking selected 5 beats from each lead and the find medians of 12- lead measurements [3]. Ranjan Maheshwari et. all used all leads for QRS detection and fiducial location of ECG wave components applying spatial velocity achieved 90% [4]. S. S. Mehta et. all used 12 leads electrocardiogram for the delineation of ECG wave components by using SVM and achieved onset, offset of P-wave, QRS- complex and T-wave within limit [5].

In CSE study boundary measurement of ECG signal waveform manually measured by group of referee-cardiologists. In these measurements each cardiologist marked boundaries (onset & offset of P-wave, QRS complex and end of T-wave) in selected beat provided by CSE center at home. In this method cardiologist marked boundaries by observing all in reference beat respectively ECG and VCG leads. In multilead boundaries (onset & offset of P-wave, QRS complex and end of T-wave) marking each referee requested to mark overall instead individual lead. So each referee mark boundaries earliest onset and latest offset by using translucent ruler. This visual analysis (measurements) by the referee strongly supported averaging measurements of boundaries of multilead system. So, in this procedure each referee marked boundaries based on averaging concept and thereafter taking median of these average measurements, which are the final measurements. In the CSE working party ECG analysis based on Team work, which consist of Cardiologist group, Engineering group and other group. So, cardiologist group analyses such as measurements based on visual observation (average based) give better result after review process [6-7].

In the literature, several boundary marking methods working on single or multilead system and compare with annotations marked by cardiologists. However, the marking of boundaries sometimes difficult task for expert cardiologist, in generally onset-offset for P-wave and end off the T-wave. In the proposed method we design composite signal based on averaging of 12 ECG leads signal.

II. DATABASE

The CSE multilead (15 lead) measurement database consists of two data sets i.e. data sets 3 and 4, respectively. The multilead data consist of 125 original (MOI_001 to MOI_125) and 125 artificial (MA1_001 to MA1_125) cases of standard CSE multilead data set-3 and 125 original (MO2_001 to MO2_125) and 125 artificial (MA2_001 to MA2_125) cases of standard CSE multilead data set-4. The CSE multilead database sampled at 500 Hz and length of data 8-10 seconds. The 12 SL CSE databases consist of a set of ECGs with different morphologies, normal as well as pathological. The data set 3 and 4 was analyzed by group of five expert cardiologists (referee) and eleven different 12 lead and six XYZ computer programs [6-7]. Only the wave recognition results of data set 3 have been released.

III. METHOD

The ECG analysis procedure to determine wave boundaries is divided in several steps: preprocessing, composite lead signal generation, QRS detection onset & offset marking, P and T wave detection and boundaries marking of each beat.
The recorded ECG signal has contains (a) 50 or 60Hz line interference due to power line, (b) electromyogram noise due to muscle tremor which belongs to high frequency noise, (c) wander baseline drift due to sudden patient movement or breathing and (d) motion artifact due to bad electrode. Wander baseline drift and motion artifact belong to low frequency in which the wander baseline drift frequency is lower than 1 Hz. In this proposed method for removing wander baseline drift for each ECG signal, we considered two stage median filter using window widths \( f_s/2 \) and \( f_s \), filtered. Median filter is a nonlinear filter which is simple to operate with high speed.

In this method all filtered 12 lead ECG signal add sample by sample and divided by 12 to generate composite lead signal. This generated new ECG signal reduce noise \( 2\sqrt{3} \) times and more enhanced than other 12 lead ECG signal and also contains all ECG wave component such as P- wave, QRS complex and T-wave in enhanced shape. The morphology of composite lead signal consists of all ECG complexes such as P, QRS and T wave, similar to 12-Lead ECG system. The ECG wave complexes in composite lead signal are noise free and enhanced in comparison to all 12 leads as depicted in Fig. 1.

In the present work, composite lead has been used detection of QRS complex and marking of boundaries of clinical significant ECG wave complexes using CSE dataset 3.

![Composite Lead Signal](image)

**Fig. 1:** (top) Raw 12 lead signal (middle) Filtered signal (bottom) Composite lead signal

**Detection of P-QRS-T waves locations and boundary marking**

1. Load 12-Lead ECG data, having sampling frequency \( f_s \) and number of total samples \( N \) of each data, remove baseline drift using two stage median filter having window size \( f_s/2 \) and \( f_s \), 12-Lead data set different stages.
2. Determine composite lead signal by adding all 12-Lead data point sample by sample.
3. This composite signal similar to 12-Lead ECG system and consist all complexes such as P, QRS and T waves. 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 1, which morphology is approximate same as other 12_Leads.
4. Enhancement of various peaks such as P, QRS, T waves is done by taking fourth power of composite signal. Again enhanced this composite signal.
5. Determine mean value of composite signal for detection of QRS peak.
6. Determine variable window with:
   (a) To determine starting point of first peak, compare enhanced composite signal value to threshold value, if it is greater than threshold value, and then mark start point.
   (b) To determine ending point of first peak, compare enhanced composite signal value to threshold value onwards to threshold value, if this value is less, and then mark end point.
7. Detection of QRS: The variable window, when mapped in composite lead and filtered data of individual leads find maxima, high peak (pki), which represents location of QRS of composite lead. If detected peak is positive then it is ‘R’ or otherwise ‘S’ wave.
8. Detection of QRS-onset –select a window pki -60ms or pki-80ms for R or S wave respectively and determine standard deviation using 32ms width moving window and then find minima of calculated standard deviation, represents QRS onset.
9. Similarly detection of QRS-offset –select a window pki -100ms or pki-80ms for R or S wave respectively and determine standard deviation using 32ms moving window and then find minima of calculated standard deviation, represents QRS offset.
10. Determine P-wave position by using window size QRS-onset to left 200ms and find maxima and then find its-onset and offset –select a window Ppki -120ms to Pkpi and Pkpi to Ppki-100ms and determine standard deviation using 32ms width moving window and then find minima of standard deviation.
11. Determine T-wave position by using window size QRS-offset+120ms to 240ms and find maxima and then find T-end and determine standard deviation using window width 32ms moving window and then find minima of standard deviation.
12. For next peak to last peak find all above values using step 6:11, starting from K2 + refractory period (200 ms) is used to eliminating false peak detection due to abnormal ‘T’ wave.
13. All above calculated values such as peaks and boundaries mapped on composite lead and individual leas on each beat.

IV. RESULTS AND DISCUSSIONS

This method tested on original and artificial cases of CSE data set-3. Detection and boundaries marking calculated with respect Referee measurement which is within tolerance limit depicted in Table 1. The wave boundaries marking in composite lead signal as shown in Fig 2.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Mean</th>
<th>Standard deviation (ms)</th>
<th>Limit (ms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>P_on</td>
<td>8.4</td>
<td>±12.6</td>
<td>10.2</td>
</tr>
<tr>
<td>P_off</td>
<td>5.5</td>
<td>±13.2</td>
<td>12.7</td>
</tr>
<tr>
<td>QRS_on</td>
<td>5.5</td>
<td>±5.4</td>
<td>6.5</td>
</tr>
<tr>
<td>QRS_off</td>
<td>4.8</td>
<td>±10.7</td>
<td>11.6</td>
</tr>
<tr>
<td>T_end</td>
<td>8.6</td>
<td>±19.6</td>
<td>30.6</td>
</tr>
</tbody>
</table>

Fig. 2 Wave boundaries marking in composite lead signal
V. CONCLUSION

Wave boundaries detection based on composite lead Signal has been presented here. This proposed method was tested on standard CSE data and obtain good results, this method determine all five boundaries for each beat of composite lead signal and all 12-Leads. So each beat can be analyzed using composite lead signal. This composite lead signal contains similar morphology of P-QRS-T, interval and duration are same only variation in amplitudes, it is more enhanced lead because it is a resultant of all 12 leads. This lead is suitable for all possible measurements and rhythm analysis. The ECG wave complexes in composite lead are noise free and enhanced in comparison to all 12 leads. The proposed composite lead yields detection on standard benchmark datasets which indicate its usefulness for ECG signal to mark & identify various wave components.

REFERENCES


