Author's response to reviews

Title: Characteristic Wave Detection in ECG Signal Using Morphological Transform

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Version: 4 Date: 16 August 2005

Author's response to reviews: see over
Author’s Reply to Reviewers’ Comments

We really appreciate very much reviewer’s constructive comments and valuable suggestions on the paper. Below is the reply to all the comments raised, where, the texts in blue are reviewers’ comments and the texts in black are our answers; C and A are abbreviations for Comment and Answer respectively.

Reviewer 2

Major Compulsory Revisions

There are no major compulsory revisions required by reviewer 2.

Discretionary Revisions (which the author can choose to ignore):

There are no major compulsory revisions required by reviewer 2.

Minor Essential Revisions

C1. The authors should specify in the text of the manuscript that they have used only the 1st ECG leads of the selected databases for development and testing. This information is missing in the text, although it is included in the answers to the referees’ reports.

A1: We are thankful for the reviewer’s suggestion. In the revised paper, the sentences (“The MMD detector is a single lead detection method. In this paper, we only use the ECG lead II for algorithm development and testing.”) have been added in the Section on Characteristic wave detection in ECG using the MMD detector (Page 4, 3rd paragraph). In addition,

“The proposed morphological approach for the characteristic wave detection in ECG signal was tested using the MIT-BIH arrhythmia database[21] and the QT database[22]…”

has been changed to

“The proposed morphological approach for the characteristic wave detection in ECG signal was tested using the first ECG leads from the MIT-BIH arrhythmia database[21] and the QT database[22]…” (Page 6, line 4-5)

C2. The authors should note that the claim ‘its left derivative is positive and its right derivative is negative’ is valid only for positive peak. Therefore, everywhere in the text they should specify that the discussed peak is positive (for example: page 4, 1st line from top – ‘At a peak in ECG signal, its left derivative is positive and its right derivative is negative, therefore, peaks in the ECG signal correspond to the local minima … ’ must
become ‘At a positive peak in ECG signal, its left derivative is positive and its right derivative is negative, therefore, positive peaks in the ECG signal correspond to the local minima …’

A2: We agree with the reviewer. In the revised manuscript, the peak/peaks have been changed to positive peak/peaks to avoid ambiguity.

C3. In section ‘Experimental results and discussions’ the authors declared, that they have used ‘MIT-BIH arrhythmia database’ and ‘QT database’. However, at the end of the same section they wrote: ‘Best detection performance is observed for MIT normal sinus rhythms database. The other records with poor detection performance are mostly from the European ST-T database and the Supraventricular database, in which, low signal-to-noise ratio or non-homogeneous repolarization exists.’ If they had used the European ST-T database and the MIT-BIH Supraventricular database, they must note that at the beginning of the section. Otherwise, they must correct the above listed sentence to correspond to the declared databases. Moreover, there is no ‘MIT normal sinus rhythms database’. I suppose that the authors had in mind the normal sinus rhythms from the MIT-BIH arrhythmia database, but this must be explained.

A3: In this study, we only used the MIT-BIH arrhythmia database and QT database. However, the QT database is a mixed database (reference [22]). There are 105 records in all in the QT database, in which, 15 from MIT-BIH Arrhythmia Database, 6 from MIT-BIH ST Change Database, 13 from MIT-BIH Supraventricular Arrhythmia Database, 10 from MIT-BIH Normal Sinus Rhythm Database, 33 Records from European ST-T Database, 24 records from “sudden death” patients from BIH, 4 records from MIT-BIH Long-Term ECG Database.

The sentences (“The MIT-BIH arrhythmia database contains 48 records (each 30 minutes long) with a sampling frequency of 360 Hz. The QT database is a mixed database with a sampling frequency of 250 Hz, which consists of 105 excerpts (each 15 minutes long) taken from other ECG databases, where, 15 from MIT-BIH Arrhythmia Database, 6 from the MIT-BIH ST Change Database, 13 from the MIT-BIH Supraventricular Arrhythmia Database, 10 from the MIT-BIH Normal Sinus Rhythm Database, 33 from the European ST-T Database, 24 from "sudden death" patients from BIH, and 4 records from the MIT-BIH Long-Term ECG Database.”) have been added in the 1st paragraph of the Section on Results and discussion in the revised manuscript. (Page 6).

In addition, in order to avoid confusion, the sentences

“Best detection performance is observed for MIT normal sinus rhythms database. The other records with poor detection performance are mostly from the European ST-T and the Supraventricular databases…”

have been changed to
“In the QT database, best detection performance was observed for records from the MIT normal sinus rhythms database. Records with poor detection performance were mostly from the European ST-T and the Supraventricular databases…”. (Page 8, line 9-11)

C4. Editorial corrections:

- Everywhere ‘sample frequency’ to be substituted with ‘sampling frequency’
  Corrected as suggested.

- 1st page, Abstract, Methods – ‘... where these points related to …' to become ‘... where these points are related to …'.
  Corrected as suggested.

- 2nd page, Introduction, 12 row from the top – ‘... false positive and false negatives.’ to become ‘...false positive and false negative detections.’
  Corrected as suggested.

- 3rd page, 1st row from the top – ‘different values’ to become ‘different signs’.
  Corrected as suggested.

- 4th page, 10th row from the bottom – ‘The local minima with amplitude ...’ to become ‘The local minima with absolute amplitude ...’
  Corrected as suggested.

- 4th page, 1st row from the bottom – ‘Same time interval as Q wave …’ to become ‘Same time interval as for Q wave …’
  Corrected as suggested.

- 5th page, 4th row from the top – ‘For the preprocessing in step 1, it is performed as follows:’ to become ‘The preprocessing in step 1 is performed as follows:’
  Corrected as suggested.

- 5th page, 15th row from the bottom – ‘The width of QRS generally from 0.06s to 0.12s.’ to become ‘The width of QRS is generally from 0.06s to 0.12s.’
  Corrected as suggested.

- 5th page, last paragraph – (i) ‘ThR was used for the detection of the local maxima and minima which corresponding to R peak; Thf was used for the detection of the local maxima and minima which corresponding to other characteristic waves.’ must become ‘ThR was used for the detection of the local minima, which correspond to R peaks; Thf was used for the detection of the local minima, which correspond to other characteristic waves.’
  Corrected as suggested.

- and (ii) the sentence ‘The determination of ThR and Thf assumed a tri-modal histogram from which the two valleys gave rise to the values of ThR and Thf .’ must be clarified.
  For the purpose of clarification, the paragraph has been revised to
  “For the detection of local maxima and minima, two thresholds ThR and Thf were used, which were adaptively computed from the histogram of the MMD transformed data. The
two between-peak valleys in the histogram gave rise to the values of ThR and Thf. ThR was used for the detection of the local minima, which correspond to R peaks; Thf was used for the detection of the local minima, which correspond to other characteristic waves.” (Page 5, the 2nd to last paragraph)

- 6th page, 8th row from the bottom – ‘at different scales’ should be deleted, since on page 5, the 13th row from the bottom the authors declared that ‘No calculation was performed at other scales since MMD operation does not cause drift of singular points across different scales.’
Corrected as suggested.

- 6th page, 7th row from the bottom – the “sentence” ‘Some signals.’ should be deleted; 6th row from the bottom – the comma after ‘where’ should be deleted; 5th row from the bottom – ‘ventricular contraction (PVC)’ must become ‘premature ventricular contraction (PVC)’; 4th row from the bottom – ‘beat selected from MIT-BIH’ is duplicated and this must be corrected; 3rd row from the bottom – ‘MMD transformed signal points marked’ to become ‘MMD transformed signal with marked points’
Corrected as suggested.

- 7th page, 2nd row from the top – ‘in spite’ is duplicated and this should be corrected; 3rd row from the top – ‘no preceding premature’ is also duplicated and this also should be corrected.
Corrected as suggested.

Since there are a lot of corrections in the first paragraph, I propose the whole paragraph
‘As shown in Figure 1, the characteristic waves in normal beat are observed to be well detected. For LBBB, in spite of in spite of the appearance of a sub-R peak, the boundaries of all waves are still well detected. In APC or PVC, no preceding premature P wave appears. In addition, the position of the left ‘^’ is overlapped with the ‘*’. That is, the onset of the preceding T wave is merged with the QRS complex. And, the position of the right ‘^’ is also overlapped with the ‘*’. So that the Q wave is judged to be missing. In PVC, by the MMD detector, negative peak was detected. to be inverted. Figure 2 gives more results of characteristic wave detection in ECG signal series. From the results shown in Figure 2, all three characteristic waves, the QRS complex, the P wave, the T wave, in ECG time series with normal beats, APCs, and LBBB beats, are shown to be detected reliably. Even the onsets and onsets of inverted T waves in PVCs can be detected reliably.’

to be corrected this way:

‘As shown in Figure 1, the characteristic waves in normal beat are observed to be well detected. For LBBB, in spite of the appearance of a sub-R peak, the boundaries of all waves are still well detected. In APC or PVC, no preceding premature P wave appears. In addition, the position of the left ‘^’ is overlapped with the ‘*’, because the onset of the preceding T wave is merged with the QRS complex. The position of the right ‘^’ is also overlapped with the ‘*’ and the Q wave is judged to be missing.’
Corrected as suggested.
- The sentence ‘In PVC, by the MMD detector, negative peak was detected. to be inverted.’ must be rewritten and clarified. The sentence is a typo error and it has been deleted in the revised version.

- After that the paragraph continues with: ‘Figure 2 gives more results of characteristic wave detection in ECG signal series. It is obvious that all three characteristic waves (the QRS complex, the P wave, the T wave) in ECG time series with normal beats, APCs, and LBBB beats, are detected reliably. Even the onsets and offsets of inverted T waves in PVCs can be detected reliably.’ Corrected as suggested.

- 7th page, 3rd row from the bottom – ‘in ECG analysis’ to become ‘during ECG analysis’ Corrected as suggested.

- 8th page, second paragraph ‘The statistical results of m, _, and Se, for ECG fiducial characteristic wave detection by the proposed MMD technique are obtained by the threshold-based detector (TD) in [22] and the wavelet-based detector (WD) in [23], as shown in Table 1.’ to be changed to ‘The statistical results for m, _, and Se, for ECG fiducial points and characteristic waves detection by the proposed MMD technique are compared with the threshold-based detector (TD) [22] and the wavelet-based detector (WD) [23], as shown in Table 1.’ Corrected as suggested.

- 8th page, 11th row from the bottom – ‘That is to say’ to be deleted. I recommend ‘P wave onset’ and ‘P wave offset’ to be used instead of ‘P onset’ and ‘P offset’. Corrected as suggested.

- 9th page, 2nd line from the top – ‘(from the Q wave to the offset of the T wave)’, please specify onset or offset of Q wave.
  In this study, we only detected the onsets and offsets for P wave and T wave. There was no onset and offset for Q wave to be detected.

- It is obvious that the editorial changes are too much and I am not in a position to point out all of them, so I strongly recommend the authors to look through the entire manuscript and to check for other mistakes. We are most grateful for the reviewer’s careful reviewing. We have asked two colleagues help us improving the English.