

Automatic QT Interval Measurement Using Rule-Based Gradient Method

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Abstract

In this work, we address the problem of fully automated QT-interval measurement. The method is based on detecting the Q and T points via gradient method accordingly to the beat morphology. Development and validation of the algorithm has been done using the PTB Diagnostic ECG Database prepared for Computers in Cardiology Challenge 2006.

RR analysis is used for selection of the beat on which QT interval is measured. The beginning of the Q-wave is detected on all 12-leads.

Considering T_{off} detection, morphology of repolarization phase of the beat is determined. Based on the morphology, rules are applied to particular gradients of repolarization phase to determine the T-wave end.

Additional rules were applied to omit signals with high probability of the wrong QT interval measurement.

With our method we have reached the score of 35.58ms.

1. Introduction

The QT interval is typically used to describe the cardiac repolarization period. A prolonged cardiac repolarization is one of the main predictors of fatal cardiac arrhythmias. In recent years the prolongation of the QT interval has been widely used in evaluation of drug side effects.

The only generally accepted procedure nowadays to assess the QT interval is a manual measurement that is costly and also can suffer from large inter-observer variations [6].

This year challenge [1] using the PTB database [2, 3] is dedicated to the development of automatic measurement method that could compete with the manual measurements.

2. Methods

Simple RR analysis is used for selection of the representative beat, on which QT interval is measured. The beginning of the Q-wave is detected on all 12-leads. Q-wave onset (Q_{on}) in the next period is also detected and

consequently used for isoline removal.

Considering T-wave end detection, morphology of repolarization phase of the beat is determined. Based on morphology, rules have been applied to particular gradients of repolarization phase for T-wave end determination (T_{off}).

2.1. Preprocessing

In the preprocessing phase we have used very simple power frequency filtering and we have used high pass filter with cut of frequency of 0.66Hz for clearing the worst of the baseline drift. After the filtering R-peak detection was done by Hamilton algorithm [5], modification of Pan-Tomkins [4] R-peak detection algorithm.

2.2. Beat selection

One of the crucial steps in the detection process has been the process of selection of the representative beat. In our approach the first beat, starting from the fifth beat in the signal - to avoid noisy starts of the recordings in some of the signals - has been taken if fulfilled the following conditions:

- Beat selected is at least the fifth one detected
- RR distance for the selected beat has to be in the interval of +/- 20% of the median of the RR intervals for the particular recording
- In case of alternating RR intervals the one with longer RR is selected - Figure 1 and 2

2.3. Q_{on} point detection

Our approach to the Q_{on} point selection consists of two phases - first the coarse Q_{on} point is selected. Selection is done in a window of 150 ms preceding the R-peak. The detection is done in all leads of the standard 12-lead system.

Then all the possible Q_{on} points from the 12 leads are fitted to the lead II and the first point to the R-peak fulfilling test conditions is selected as the Q_{on} point on the lead II.

As a final step in Q_{on} detection the correction is made to skip any zero-gradient part left in the signal in lead II.

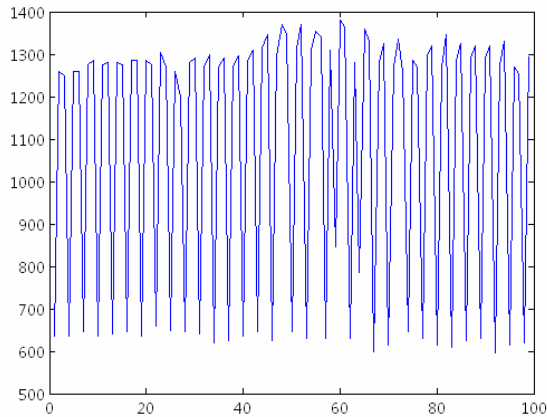


Figure 1: Example of alternating RR interval - patient023/s00851re

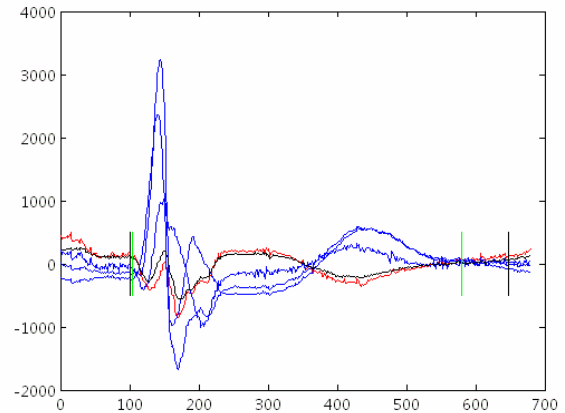


Figure 3: Example of detection of QT interval

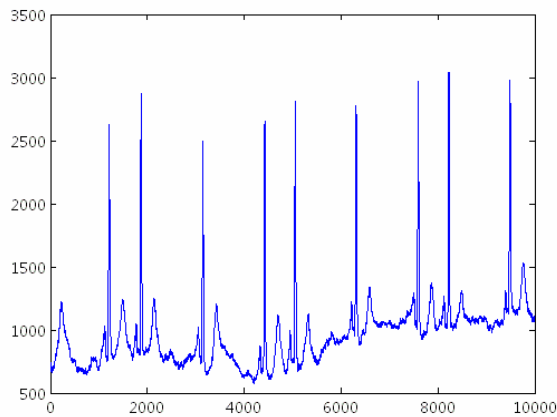


Figure 2: Example of the signal with alternating RR interval - patient023/s00851re

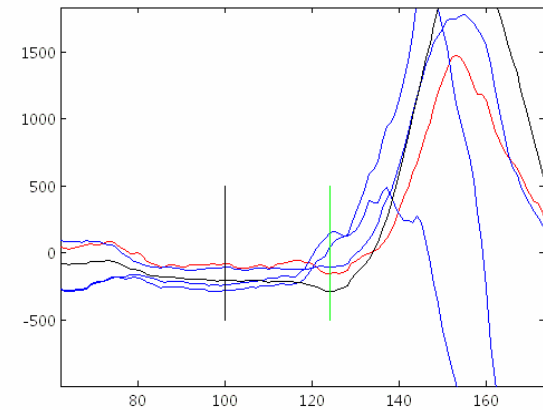


Figure 4: Detail of Q_{on} detection (first line) and corrected detection (second line)

2.4. T_{off} point detection

Two-step approach is also applied in case of the T_{off} point detection.

First we have created new lead - the summed lead. We have tested various lead combinations for summed lead creation, with combination of leads V2 and V3 among the most promising lead combinations. To our final algorithm we have found that the best results are achieved in our case using the summed lead as lead V6 summed with itself.

After the creation of the summed lead the description of the T-wave shape has been carried out. We have characterized the shape of the T-wave by its extremes the amplitude and polarity of the final extreme of the T-wave and we have used it as one of the gradient method input.

The gradient method has been given a windowed

signal starting 200 ms after R-peak of the summed signal. End of this window has been 150ms preceding the next R peak. Signal in this window has been filtered by moving average filter.

Then gradients of order 2, 4, 6, 8, 10 have been calculated using the summed channel. The first point starting from the last T-wave maxima which at least four out of the five possible gradients marked as a possible T_{off} has been selected as a coarse T_{off} point.

The second step in the T_{off} computation has been the correction phase where we have again tried to avoid part of the signal to the left of the coarse T_{off} point with zero gradients. This task has been done by finding of the part with the zero gradients in five leads (I, II, V2, V3, V4) and then computation of the median of all five suggested shifts.

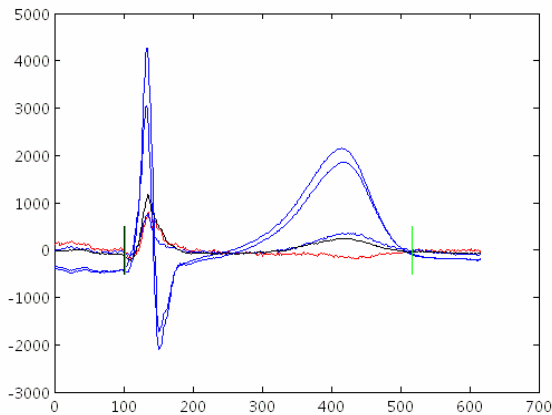


Figure 5: Example of detection of T_{off} point

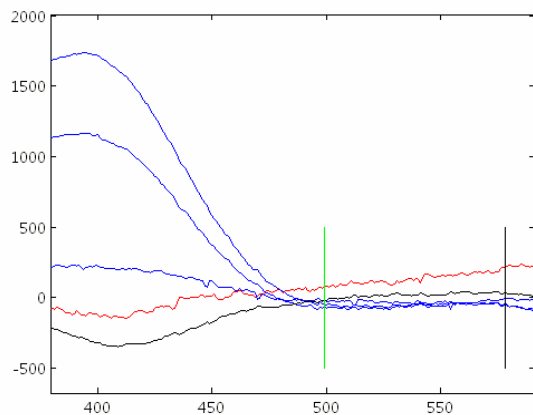


Figure 6: Detail of T_{off} point detection

3. Results

With the above stated methods we have acquired final results of 35.58 ms in division 3.

3.1. Omitted results

Important consideration regarding the challenge results has been to find criteria under which it can be said that the algorithm has not been performing well.

We have considered the following possible means of omitting the result.

- QT interval does not seem to fulfill physiological conditions
- Last T-wave maxima too small
- RR-intervals around the beat look “strange”

Finally we have used only the first criterion setting the borders as:

- QT interval length is less than 250ms

- QT interval length is more than 500ms

4. Discussion and conclusions

Our approach to solve the task of the QT automatic measurement has been based upon gradient method that has been restrained by rules describing the T-wave morphology.

We have tried to adapt gradients according to the amplitude of the last extreme of the T-wave. And although we have tried to compute results on gradients of different orders our algorithm suffers from the gradient method common drawback – sensitivity to noise.

The largest errors of our algorithm have occurred when small T-waves has been present or the signal was very noisy.

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