A Premature Ventricular Contraction detection method for Cardiac MR Acquisitions using morphology feature

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Introduction

Premature Ventricular Contractions (PVCs) are ectopic heart beats with ventricular origin. The presence of PVCs degrades image quality, if the gated scans do not differentiate them from normal beats. Accurate detection of PVC not only improves image, but also provides auxiliary information to facilitate diagnosis of ventricular arrhythmias. Many PVC detection algorithms have been proposed [1,2], few consider the noise in MR environment, including distortion due to magnetohydrodynamic effect, gradient noise, and radio-frequency interference. This work proposed a method to detect R-wave and PVC, using combined feature of noise resistant 2D VCG morphological distance, the R-peak duration and RR interval.

Methods

The proposed algorithm consists of four processing stages.

1. Pre-processor

The combination of a high pass filter and a low pass filter is used to achieve a 1-35 Hz passband for pre-processing.

2. Self-training

The joint *a priori* probability distribution of the R-R interval, the VCG amplitude and the VCG duration of the R-peak is used to identify the reference from initial 10 seconds of the VCG. The VCG amplitude is the amplitude of the 2D local maximum spatial vector in the R-wave [3]. The VCG duration is the number of sample spatial vectors in the R-wave, whose distance to the local maximum spatial vector is less than 0.3 mv [4]. A single reference represents features extracted from one normal QRS wave. The feature set consists of truncated QRS segments from both ECG traces, represented by a 2xN spatial-time structure, the VCG duration, and the RR interval to the previous consecutive normal beat. Total of M (M>1) references are extracted.

3. Feature measurement

Two morphological distance operators are used to measure the shape and amplitude similarities between the VCG in a moving window and the references[4], given by

$$Dshape = \min_i \sqrt{\left\|XR_i - X - a_i\right\|^2 + \left\|YR_i - Y - b_i\right\|^2},\quad a_i = \sum_{i=1}^{M}(XR_i - X)/N,\quad b_i = \sum_{i=1}^{M}(YR_i - Y)/N,\quad Damp = \min_i \sqrt{(u_i - u)^2 + (v_i - v)^2},\quad i \in [1, M],$$

where (XRi,YRi) is the ith reference, (X, Y) is the VCG segment in the current moving window. (ui,vi) is the reference peaks, (u,v) is the local maximum.

An RR interval difference operator is used to test the early appearance of the beat, which is a sign for premature contraction.

$DRR = \min_i (RR - RR_i) / \overline{RR_{i\in[1,M]}}$, where the denominator represents the mean of the reference RR intervals.

VCG duration as defined in stage 1 is the forth operator for differentiating normal beat, PVC, and noise. Figure 1 illustrates the reference and the extracted features.

4. Detection

Local maximum peaks within the a priori VCG duration range are detected as candidates for further measurements. The measurements from the two morphological distance operators compare with the thresholds calculated from the reference QRS segments to detect the normal beats. Only both measurements less than the thresholds result in the trigger for normal beats. The measurements from the shape distance operator, the RR interval operator and the duration compare with the thresholds to detect the PVCs. Two of the measurements within the range of the PVC thresholds generate the trigger for PVC.

Results

This method was tested using two-channel ECG data, including 10 PVC patient files from MIT_BIH arrhythmia Database, total of 300 minutes recording, 18494 normal beats and 2410 PVC cases. Figure 2 (a)-(d) showed the histograms of the measurements from four feature operator for normal beats and PVCs obtained from one patient, which illustrates good separation ability of the operators. The performance criterion includes sensitivity, specificity and the time delay between the onset of the R peak and the detection of the beats. The sensitivity calculated using the number of correctly detected PVC beats over total number of PVC beats. The specificity calculated by the number of correctly detected normal beats over total number of normal beats. The overall sensitivity and specificity are 97% and 96%, with 31 ms mean time delay.

References

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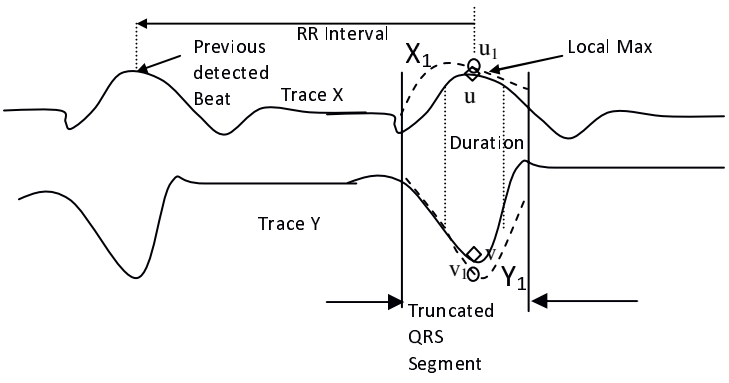

Figure 1. The feature extractions, including the duration at 0.3Mv level, RR interval, and truncated QRS segment.

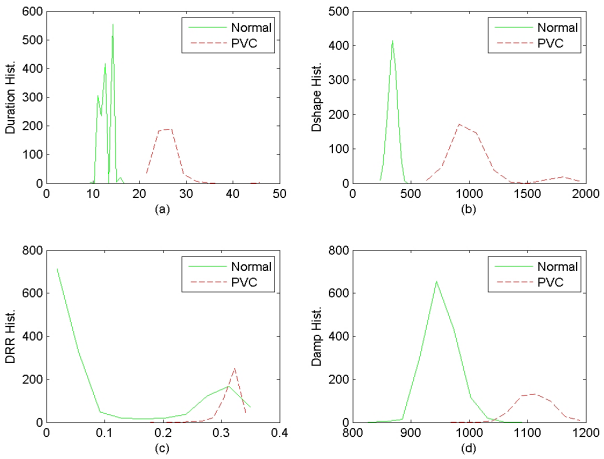

Figure 2. The histogram of the feature measurements from one patient.