A REAL-TIME QRS DETECTION AND DELINEATION ALGORITHM BASED ON THE INFLECTION ANGLE OF THE ECG WAVEFORM

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ABSTRACT

A fast and accurate algorithm is developed for the detection and delineation of QRS complexes. This algorithm uses an efficient data compression scheme to reduce the size of the whole processing points. According to the principle of human visual cognition of ECG waveform, an inflection angle (IA) between 180° and -180° is defined to detect and delineate the QRS complexes. Easy implementation, accurate delineation, fast execution speed, baseline ignored, and no adaptive threshold values are the advantage of using inflection angle. The average time to detect and delineate one QRS complex is 0.25 second on PC/AT. Results of successful application of this algorithm to 5 typical arrhythmia cases in the presence of noise, muscle arteface, baseline drift and morphology changes are presented.

INTRODUCTION

The first task of any set of ECG analysis algorithms either in time domain or in frequency domain is to detect and delineate the QRS complexes. The accuracy of such algorithms will ultimately determine the reliability and versatility of the subsequent analysis approach.

Some QRS detectors have incorporated automatic gain control feedback loops which change threshold values by the slopes of the QRS complexes already detected in order to increase the immunity of muscle noise. Unfortunately, it exists some sudden changes in the QRS morphology when arrhythmias occurs and the threshold values can't be adjusted so fast as to achieve the detection task. Besides, the baseline drift and large P and T waves may present significant false triggering problems to QRS detector. The algorithm proposed in this paper not only can overcome the previous problems but also provides a fast and precise QRS delineator.

The basic idea of our approach comes from the principle of human visual cognition of ECG waveform. After surveyed many ECG morphology in the literature and the clinical trials, we draw three conclusions to recognize the QRS complex as follows :

1. The absolute value of the IA in R point is greater than 115° (Fig.1).
2. The absolute value of the IA in Q and S points are greater than 23° and less than the absolute value of IA in R point.
3. The amplitude difference between Q and R and between R and S exceed the average amplitude variation.

METHOD DESCRIPTION

The new QRS detection and delineation algorithm comprises six steps :

1. A Preprocessing is used to reduce the noise and muscle artefact.
2. A new data compression scheme [1] makes use of a differential filter and piecewise linear approximation to extract the inflection points (IP) which can be brought into use for identifing significant features such as P, Q, R, S and T points. After data compression, approximately 1/10 of total original sampling points is reserved for further processing.
3. The average amplitude variation now can be obtained from the following formula:

   $$AAV = 1/n * \sum_{i=1}^{n} Da(IP_i, IP_{i-1})$$

   where IP_i is ith inflection point and $Da(IP_i, IP_{i-1})$ is the amplitude difference between IP_i and IP_{i-1}.
4. The IA in each IP is calculated by three nearby IP, IP_{i-1}, IP_i and IP_{i+1}, as follows:

   $$IA_i = Tan^{-1}(Da(IP_i, IP_{i-1})/Dt(IP_i, IP_{i-1})) - Tan^{-1}(Da(IP_{i+1}, IP_i)/Dt(IP_{i+1}, IP_i))$$

   where IA_i is the IA in IP_i and $Dt(IP_i, IP_{i-1})$ is the number of sampling points between IP_i and IP_{i-1}.
5. If the absolute value of IA_j is greater than 1.57 (60°), then searching backward and forward to find 2 inflection points, IP_i and IP_k. The absolute values of IA_i and IA_k need to be both greater than 0.4 (23°). Also, the sign of IA_i and IA_k need to be oppsite to the IA_j.
6. The IA in IP_j is then recalculated by IP_i, IP_j and IP_k. If the new absolute value of IA_j is greater than 2.0 (115°) and the absolute value of amplitude

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difference between IP_i and IP_j and between IP_j and IP_k are both greater than 1.5*AAV, then we treat IP_i, IP_j and IP_k as Q, R and S points, respectively.

RESULTS

We slsect some special ECG data from the monitoring system of National Taiwan University Hospital, MIT-BIH data base and KONTRON MEDICAL 994 arrhythmia simulator to validate the performance of our algorithm. The program is implemented on the PC/AT. The sampling rate is 250 samples/sec. The average speed is 0.25 second for one QRS detection and delineation.Fig.2 illustrates 5 typical arrhythmia cases of ECG and its results.

CONCLUSION

Due to the efficient data compression and succinct detection and delineation definition, our novel algorithm can be easily implemented and fast executed. According to the nature of inflection angle, the baseline wander can be ignored and no threshold values need to be adjusted during processing. So, the detection and delineation results are really precise and match the outcomes of human recognition. However, different sampling rate will affect the detection accuracy. The sampling frequency between 200 Hz and 500 Hz is therefore strongly suggested. One more important property of our research is this algorithm can be extended to detect multiphasic QRS complexes. In summary, the whole process is defined very clearly and is suitable for use in a real-time ECG monitoring or diagnosis system.

REFERENCES

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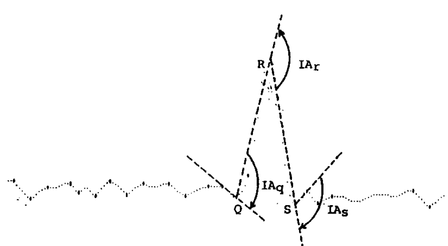

Fig.1 IAq is the inflection angle in Q, IAr is the inflection angle in R, and IAs is the inflection angle in S. Inflection points (IP) are marked with '+'.

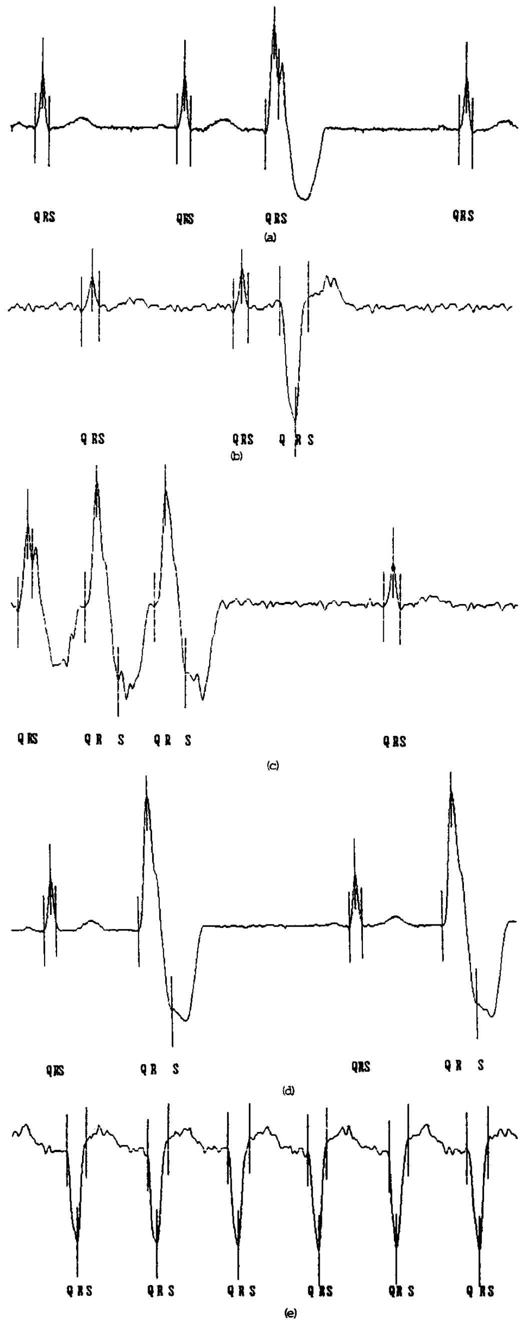

Fig.2 (a) Premature ventricular contraction case
(b) R on T case
(c) VES run case
(d) Bigeminy case
(e) Ventricular tachycardia case

The QRS complexes detection and delineation results of 5 typical arrhythmia cases are shown above (a) to (e).