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PREMATURE VENTRICULAR CONTRACTION BEAT DETECTION BASED ON SYMBOLIC DYNAMICS ANALYSIS

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ABSTRACT

Premature Ventricular Contraction (PVC) beats are of great importantance in evaluating and predicting life-threatening ventricular arrhythmias. In this paper, an algorithm is proposed for the identificaton of PVC beats. ECG signal is first conveted into a symbolic string sequence of '0's and '1's using a thresholding algorithm; Secondly, the length of all substrings composed only with the symbol '1' is estimated; thirdly, the lengths of these substrings are theresholded to detect the PVC beats. Compared to other PVC beat detectors, the proposed algorithm decreases the computational burden, and furthermore, doesn't require for QRS complex detection or calculation of morphological features of the ECG signal. The proposed algorithm has a gross sensitivity of 98.8% for ten patients from the MIT Arrhythmia Database.

KEYWORDS:

ECG Premature Ventricular Contracton
Symbolic Dynamics

1 INTRODUCTION

An electrocardiogram is a graphical record of the electrical activity of the heart. A normal ECG, in most cases, rules out the presence of cardiac diseases. An abnormal ECG may indicate the presence of a cardiac disease and further investigations are performed. An ECG can be beneficial in detecting the disease and sometimes even its extent.

PVCs have clinical importance since they exhibit symptoms or they may signal an increased risk of sudden cardiac death. The presence of PVCs has also been shown to be associated with an increased total mortality in some patient subgroups, suggesting that PVCs are a marker of a more severe disease process rather than the provocateur of a terminal electrical event. Therefore, accurate detection of PVC beats is of great significance for stratifying patients at high risk and predicting life-threatening ventricular arrhythmias. Also automatic classification of heart beats is very important for automated arrhythmia monitoring devices.

Numerous methods for beat classification have been proposed, such as the linear prediction method proposed by K.P. Lin, Hilbert transform analysis, classification of heart beats based on Neural Network, and Hidden Markov Model analysis(e.g., [1], [2], [3]). Since surface ECG singals are usually blurred by DC drift, powerline noise, electromagnetic noise and motion artifacts, automatic PVC detection is a very difficult task in surface ECG anlysis.

Cardiac rhythms are generated by dynamic systems that manifest nonlinear properties. As an effective analytic tool for non-linearity analysis, symbolic dynamics has been applied to cardiology recently, especially in HRV analysis (e.g.,[4]). X.Zhang, *et al*. proposed a VT/VF detection algorithm using complexity measure based on symbolic dynamics, where they transformed the ECG signal into a 2-symbol string sequence and computed the complexity measure of the string sequence (e.g.,[5]).

In this paper, symbolic dynamics analysis is applied to the detection of PVC beats. A symbolic string sequence is generated by automatically setting the thresholds. On the basis that QRS duration of PVC beats are much wider than normal beats, the PVC detection is fulfilled by thresholding the length of the substring consisting of only the symbol '1 ' corresponding to the QRS duration. The threshold is determined by nearest neighbour cluster techniques. Ten patients from the MIT-BIH Arrhythmia Database are selected to verify the algorithm. The gross specificity of the proposed detection result is 98.8%. This algorithm needs not QRS complex detection and is very simple in implementation and computation.

2 COMPUTATIONAL SCHEME

Fig. 1 shows the typical PVC and normal beats on the surface ECG signal. In the next subsections, the overall computational methodology will be given in more details.

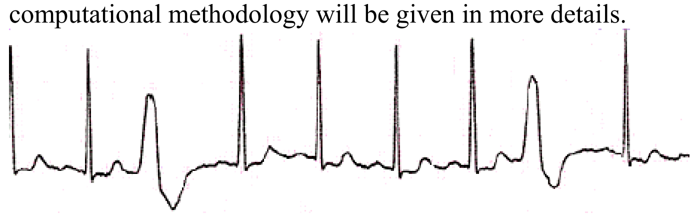
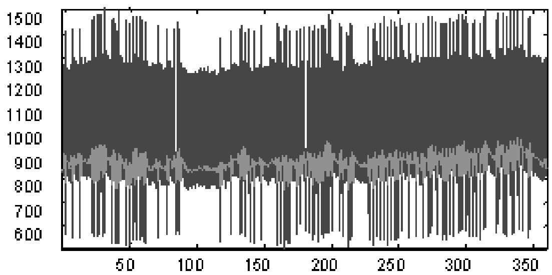


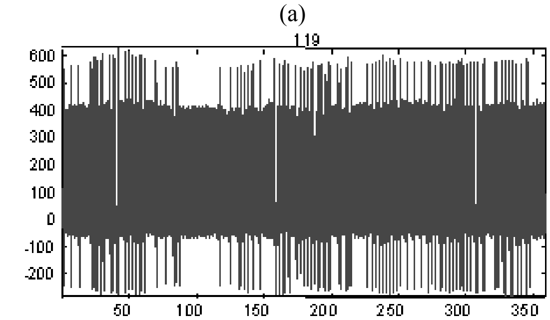
Fig. 1 Typical PVC Beat and Normal Beat in Surface ECG Signal

2.1 PRE-PROCESSING

For recorded ECG signals, there exist four kinds of noise: baseline drift, 60 Hz power-line, electromagnetic, and motion artifacts. High pass filtering is used to remove baseline drift and a 60 Hz notch filter to remove power-line noise.



(a)



(b)

Fig. 2 Pre-processing result. (a) Grey Line Represents The Baseline Drift; (B) Pre-Processed Result

2.2 SYMBOL SEQUENCE GENERATION

Converting the ECG signal into the symbolic sequence is the key step in symbolic analysis of the ECG signal. Here, a thresholding method is used to converting ECG into the symbol sequence. The proper thresholds are those that could separate different episodes. In our application, the thresholds are set statistically.

Suppose a time windowed ECG signal $\{x_i\}\ i = 1,2,\cdots,N$, where N is the number of samples within each window and f_s is the sampling frequency. The threshold is set by the following equation:

$$\begin{aligned}&\text{if } (N_c + P_c) > \alpha 1 \times N \\ &\quad Thresh = \alpha 2 * PositiveMax \\ &\text{else} \\ &\quad Thresh = \alpha 3 * PositiveMax\end{aligned}$$

Where

N_c: Number of points falling into the band $[\beta \times NegativeMin, 0]$

P_c: Number of points falling into the band $[0, \beta \times PositiveMax]$

β: Adaptive parameter, $\beta = 0.1$ in this application

$\alpha 1, \alpha 2, \alpha 3$: Parameters for setting the threshold.

Threshold the ECG signal $\{x_i\}$ and convert it into the string sequence $\{s_i\}$, where:

$$s_i = \begin{cases} 1 & x_i > thresh \\ 0 & Otherwise \end{cases}$$

2.3 SUBSTRING EXTRACTION

In our application, we hypothesize that the R wave is positive for all surface ECG signals used. So, the length $\{l_j\}\ j = 1,2,\cdots,M$ of the extracted substrings with consecutive symbol '1' could be used to indicate the width of the corresponding beats.

2.4 PVC BEAT DETECTOR

The PVC detection is implemented by thresholding the length of the substring consisting of only the '1' symbol. First, calculate the length histogram of the stratified substrings, and then use a nearest neighbour clustering method (corresponding to non-PVC class and PVC class) to set the threshold. PVC detection is acomplished by the following thresholding:

$$PVC_i = \begin{cases} 1 & l_i > thresh \\ 0 & Otherwise \end{cases}$$

Where:

1 indicates the beat type is PVC

0 indicates the beat type other than PVC beat

3 EXPERIMENTAL RESULTS

Ten patients were selected from the MIT/BIH Arrhythmia Database with the sample frequency being 360Hz, and only one channel used for PVC beat detection analysis. Fig. 3 shows the length of the substrings with consecutive symbol '1'. Fig.4. shows the length histogram of the extracted substrings. From Fig. 3, there are obviously two clusters corresponding to non-PVC class and PVC class. The PVC detection results for the MIT Arrhythmia Database are shown in Table 1.

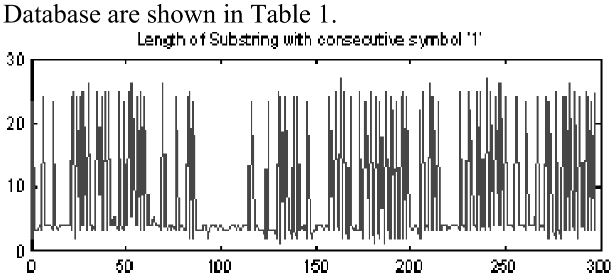


Fig 3. Length of Substrings with Consecutive '1' Symbols

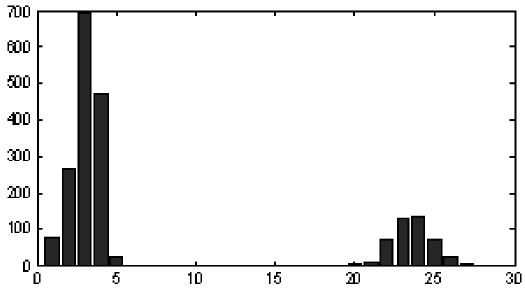


Fig. 4. Length Histogram of Substrings with Consecutive ' Symbol 1's

Table 1 Detection Results for MIT Arrhythmia Database

	PVC Total	PVC_TP	PVC_FN	PVC_FP
Mit100	1	1	0	0
Mit105	31	31	1	0
Mit106	52	52	0	7
Mit119	444	444	0	0
Mit200	826	794	32	0
Mit201	198	198	0	12
Mit202	19	22	0	3
Mit208	992	992	0	157
Mit209	1	0	1	2
Mit210	194	190	4	0
Total	2758	2724	38	181
		0.987672		

4 CONCLUSION

Simple PVC beat detection algorithm is proposed based on symbolic analysis of the ECG signal. A symbolic string sequence is generated by automatically setting thresholds. On the basis that QRS duration of PVC beats are much wider than normal beats, the PVC detection is fulfilled by thresholding the length of the substring consisting of only the '1' symbol corresponding to QRS duration. The threshold is determined by nearest neighbour cluster techniques. Ten patients from MIT Arrhythmia Database are selected to verify the algorithm. The gross specificity of the proposed detection result is 98.8%. This algorithm has no need for QRS complex detection and is very simple in implementation and computation.

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