QRS AND ECTOPIC BEAT DETECTION IN CORRUPTED BY MOVEMENTS ELECTROCARDIOGRAM

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Summary: *Two algorithms for ventricular beat detection were improved and combined in one procedure. Scanned electrocardiographic recordings taken from the AHA database were superimposed with disturbances caused by involuntary patient movement or provoked by the life-saving people for example during defibrillation. The accuracy of the procedure was assessed.*

Introduction

Each automated analysis of electrocardiographic signals (ECG) begins with detection of the QRS complex – the most prominent wave in the RR interval. Many hard and software algorithms have been proposed (THAKOR and WEBSTER, 1982; PAHLM and SÖRNMO, 1984, FRIESEN *et al.*, 1990; SUPPAPPOLA and SUN, 1995). KADAMBE elaborated an approach based on wavelet transform (1999). A new mathematical way was reported by TRAHANIAS (1993) which apply morphological operations for assessment of the signal shape. A presence of ectopic beats complicates the identification but the most important problem is how to reject the high T waves. Good results are obtained with a ventricular beat classifier based on fractal number clustering (BAKARDJIAN, 1992). Real or quasi-real time detection is done almost always by hardware solutions. However, DOTSINSKY (1991) reported a simple real time algorithm. The QRS complex is selected from among other candidates by means of the following parameters: i) high amplitude, ii) steep leading and/or trailing slopes and iii) sharp peaks. Two differences between the current sample $\mathbf{S_i}$ and the samples $\mathbf{S_{i-n}}$ and $\mathbf{S_{i+n}}$ are calculated where **n** is usually the sample number in 20 ms. If both differences are of the same sign, its unsigned sum $\mathbf{U_i}$ represents a detected peak. This value is compared with an adaptive threshold **M** and the current sample is considered to be a QRS complex if $\mathbf{U_i > M}$. The law of the threshold decreasing consists of two parts of different slopes. Recently, an algorithm for boundary delineation of ventricular ectopic beat was proposed (DOTSINSKY and CHRISTOV, 1997). It looks for appearance of two consecutive wave components with large amplitude and opposite sign, thus making an attempt to cover a large part of the bizarre ectopic shapes.

Involuntary patient movements often accompany the ECG acquisition. Disturbances may be provoked also in emergency cases by the life-saving people for example during defibrillation.

We modified some parameters of the software real time algorithms for QRS and ectopic ventricular beat detection organizing them in a common procedure that copes to some extent with disturbing movements.

Materials and Algorithm

Amplifier connected to a front-end PC board for analogue-to-digital conversion collected different type of disturbances obtained by voluntary provoked muscle contractions and movements. Some recordings from the AHA database were scanned. They were selected among the most complicated rhythm abnormalities with difficult for detection waveforms. The signals are arbitrarily superimposed by the disturbances multiplied by a coefficient ≥ 1.

The improvements in the algorithm for QRS detection are as follows:

- Comb filters with first zeros in 50, 41.6(6) and 31.25 Hz are applied consecutively. The non-multiple values are due to the 250 Hz sampling rate of the AHA recordings. Low-frequency cut-off of 1 Hz is accomplished by a bilinear transform. The set of these filters has the advantage to introduce a fast going optimal pass-band procedure that enhance the spectrum QRS components.
- Each QRS candidate is deleted if its distance to the previously detected complex is lower than 200 ms.
- The initial value of the adaptive threshold $\mathbf{M}_i$ equals 0.7 of the calculated U_i corresponding to detected and confirmed QRS complex.
- The adaptive threshold decreasing starts 200ms after the current QRS detection.

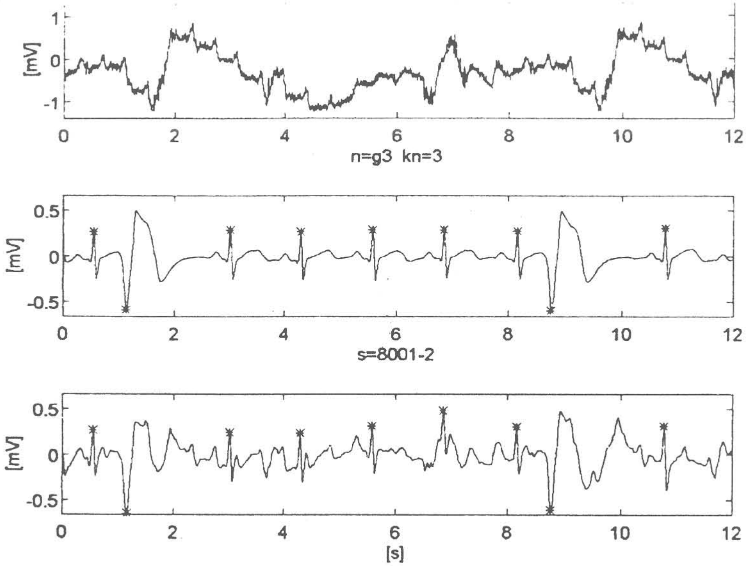
The following improvements in the algorithm for ectopic beat delineation are introduced:

- The duration of ectopic beat candidates is limited to 250 ms.
- Since regular QRS complexes may be recognized also, each ectopic beat located nearer than 200 ms to another regular or ectopic ventricular beat is deleted.

The accuracy of the procedure is assessed by means of program written for the software package MATLAB.

Results

Six Figures are presented. The upper traces show the disturbance, the middle – the ‘pure’ ECG signal and the lower – the mixed signal. Asterisks mark the detected QRS complexes. Note that each ordinate of the diagrams is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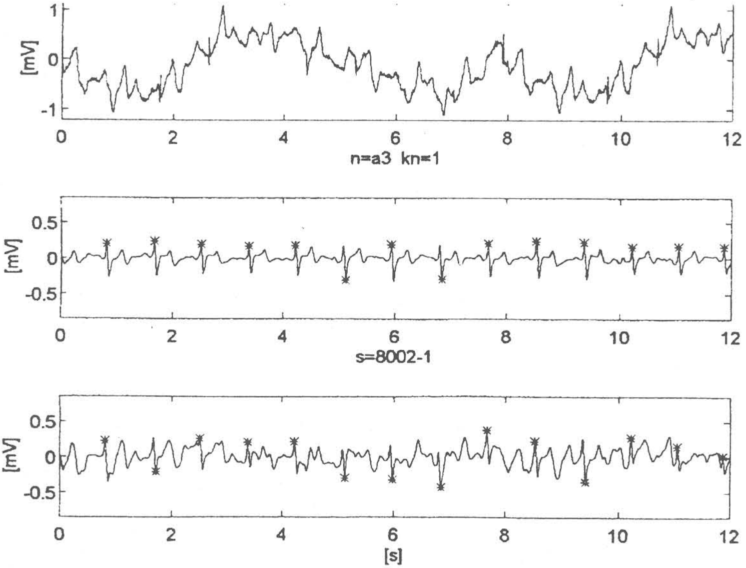
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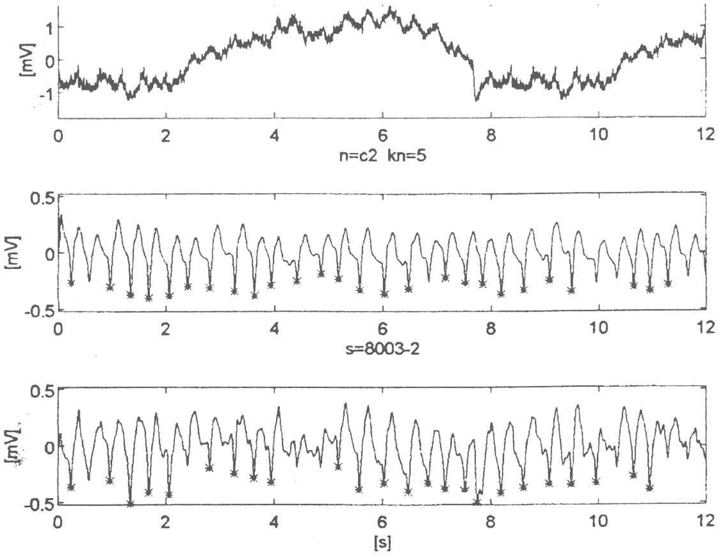
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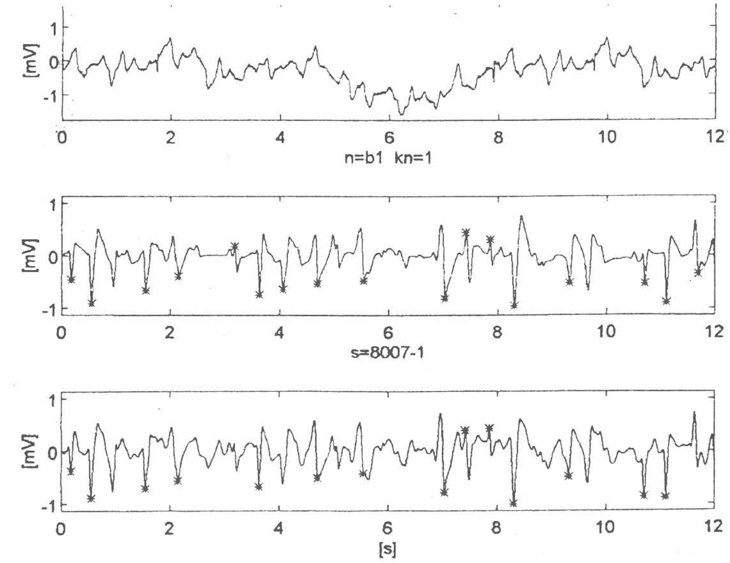
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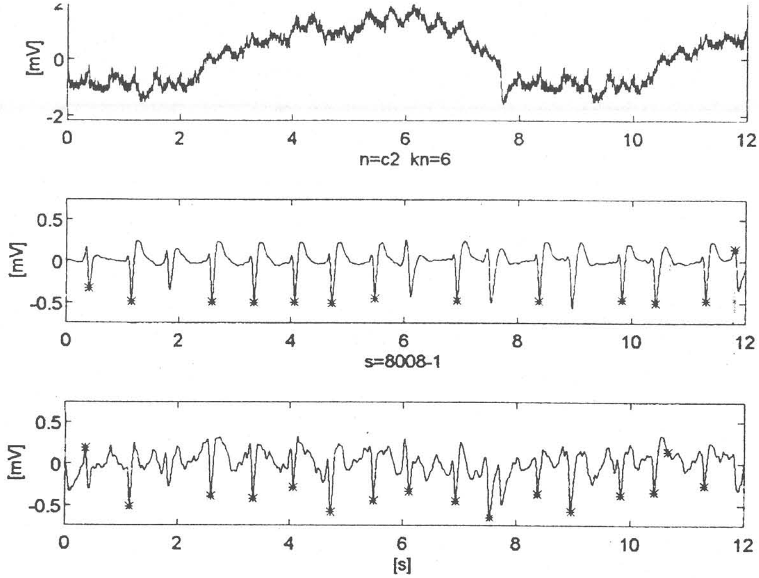
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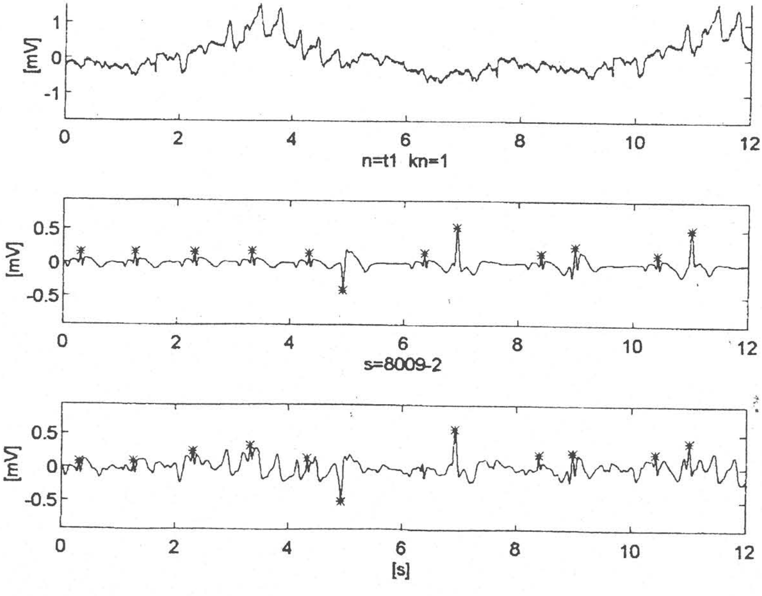
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scaled optimally in [mV] by MATLAB depending on its amplitude. The letter **n** denotes the type of the disturbance. The symbols **a**, **b**, **c**, **g**, **r** and **t** are instead: patient arms moving, movement of the patient cable, continuously body tremor accompanying by convulsive movements, frequent and profound respiration (gasp), quasi-rhythmic movements like disturbances provoked by car moving on an evil way, and simulation of cardiopulmonary resuscitation (CPR) obtained by depressing rhythmically the chest, respectively. $\mathbf{k_n}$ is the coefficient of multiplication of the disturbance. The AHA signals s are specified by their original number.

Discussion

The neighborly diagram presentation of detected QRS complexes in 'pure' and mixed signals help the assessment of the procedure efficiency in presence of disturbances and may depict the amplitude limit to which it is realistically to rely on satisfactory detection accuracy. As can be seen, the noises $\mathbf{3*g_3}$ and $\mathbf{1*a_3}$ added to the signals 8001-2 and 8002-1 neither shift the detected locations nor neglect (introduce) QRS complexes. The other disturbances provoke a very limited number of differences that makes the procedure suitable for automatic ECG analysis before decision making for defibrillation shock.

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