DISCRIMINATION BETWEEN NORMAL AND ECTOPIC BEATS

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This work is an extension of already published algorithm for ventricular beat detection in single channel electrocardiograms [1]. The obtained specificity and sensitivity are good, which was the aim of the paper, but the discrimination between normal and ectopic beats is somewhere erroneous. The improved beats discrimination includes: i) assigning as template the last but one beat with minimum area during the first 32 ventricular beats; ii) introducing most sophisticated criteria for divergence, like complex changes in peak-to-peak, positive and negative amplitudes; multistage assessment of the deviation in widths measured at determined positive and negative levels around the baseline; ratios between second order differences; number of baseline crossing, etc. iii) ongoing update of the template parameters; iv) refusal of discrimination when some criteria have been not met.

Keywords: ventricular beats, normal beats, ectopic beats, discrimination

1. INTRODUCTION

The ventricular beat (VB) detection is the first step in both morphological and rhythm analysis. It is followed by discrimination between normal (NB) and ectopic beats (EB). The parameters of the former ones are measured and used for association of the electrocardiogram with normal or several abnormal classes (morphological analysis). The EB are divided in different types according to their shape and/or time of occurrence correlated to the neighboring beats appearance that is used further for rhythm disorders discovery.

This work is an extension of already published algorithm for ventricular beat detection in single channel electrocardiograms [1]. The obtained specificity and sensitivity are good, which was the aim of the paper, but the discrimination between NB and EB is somewhere erroneous. This is due mainly to the fast but unreliable rule for chosen a beat with polarity equal to that of the prevalent number within an initial sequence as template, which is used then for subsequent discrimination based on polarity change as well as some deviations in widths and amplitudes. Here an improved algorithm version is proposed giving more accurate classification of NB and EB.

2. MATERIALS

ECG recordings were taken from AHA database (except for section 8xxx containing fibrillation signals) and MIT-BIH Arrhythmia database. Their total duration is 42480 s. The signals were used in MALLAB environment for developing of algorithm branches concerning mainly the VB discrimination. Still, an overall test of the VB detection was carried out too.

3. METHOD AND ALGORITHM

Preprocessing

The already published algorithm [1] applied high-pass filtering with 1 Hz cut-off and comb filter with first zero in 50 or 60 Hz depending on the database used. In this study the cut-off is increased up to 2 Hz to better eliminate the influence of baseline drift as well as noisy small undulations resembling parts of EB. Additional comb filter with first zero in about 40 Hz is introduced to suppress high signal components that may impede the accurate VB detection too.

Template investigation

NB template is searching among the first 32 VB but not longer than 30 s, during which at least 16 VB have to be detected. The summary area S_{pn} of unsigned positive S_p and negative S_n parts of the complexes that are located outside the ±400 μV baseline margin is calculated over a period of ±80 ms around the detected VB peak. The template is associated with the beat of last but one minimum area. However, some additional restrictions to the candidates are introduced. The numbers (samples) of the summarized positive w_p and negative w_n amplitudes must: i) belong together to the interval $6 \leq w_p + w_n < 16$ and ii) result in $S_{pn} \geq 16$ mV.ms, which is calculated taking in consideration the value of the intersample interval T (4 ms for SR=250 Hz and 2.77 ms for SR=360 Hz). The number of baseline crossings within ±140 ms around the VB peak has no exceeds 3. Thus, some narrow EB and/or artifacts are removed from the template investigation. Besides, shorter than 10 ms wave shape over 3.5 mV, which may be found in the unfiltered signal 20 ms before the VB peak, inhibits the investigation since such artifact may create false template in the analyzed filtered signal.

A rescue template is designated in parallel. It is used when the above described approach fails. This happens with low amplitude and relatively narrow VB. Here the alternative criteria for w_p, w_n and S_{pn} are: $w_p + w_n \leq 16$; $w_p < 20$; $w_n < 20$; $S_{pn} \geq 8$ mV.ms.

When neither basic nor rescue template is found, a branch of the algorithm outputs refusal of discrimination.

Discrimination rule

In presence of template, a sophisticated multicomponent rule for VB discrimination is activated. It includes complex changes in S_{pn}; peak-to-peak A_{pp}, positive A_p and negative A_n amplitudes; multistage assessment of the deviation in widths w_p and w_n measured at the determined positive and negative levels around the baseline; ratios between second order differences like ΔS_p-ΔS_n; number of zero line crossings, beats sign etc. The rule components, which compare parameters between the template (marked by $_t$ in subscript) and ongoing VB, give points for the threshold score as shown in the Appendix

Template updating

Ongoing update of the template parameters is provided for, whenever a NB is acknowledged. Its parameters values lead up to 0.5% variations of the discrimination rule values. This small contribution is found to correspond adequately to the slow changes in the shape of the ongoing NB with the time.

4. Results and Discussion

Selected epochs of some representative recordings are shown in Fig. 1-6. The lower traces are processed signals where symbols for NB (*) and EB (°) are set. The same signals before filtering can be observed in the middle of the Figures. The upper traces show the complementary channels (d1 or d2), which offers an auxiliary point of view in case of uncertainty when assessing the accuracy of the VB classification.

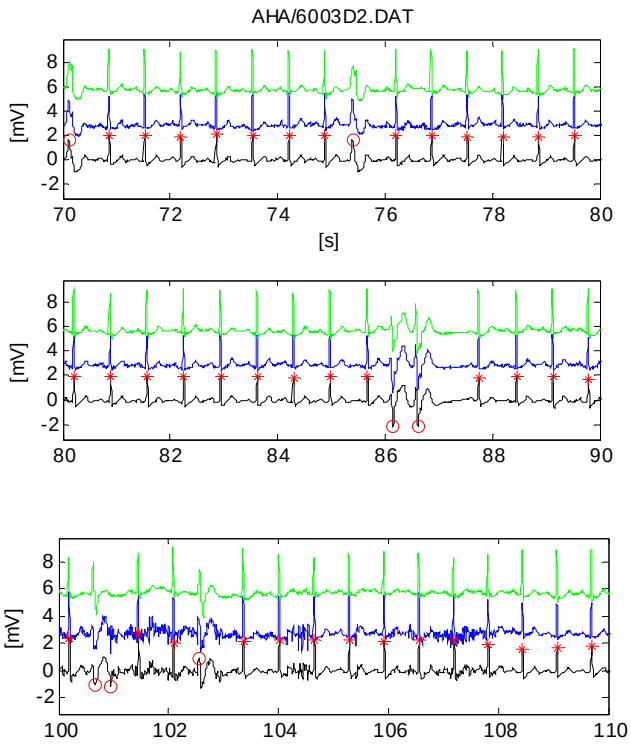

Fig. 1

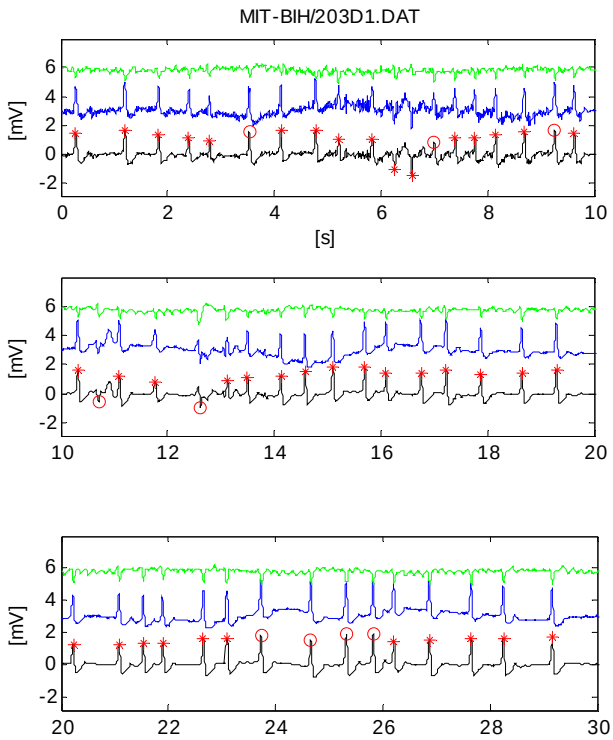

Fig. 2

The results obtained are generally better compared to these published in [1]. Different types of correctly classified EB can be seen in Fig. 1 (AHA 6003 d2 recording) and Fig. 2 (MIT-BIH 203 d1 recording). Nevertheless, some signals with very difficult for recognition wave shape provoke single erroneous classifications. Evidently, the false second EB between 100th and 102nd s in Fig. 1 is due to noise in the processed channel. Two complicated EB from 10th through 14th s in Fig. 2 are exactly detected. The artifact like large P-wave after the first one is successfully rejected. Some marked EB in the third graphic of Fig. 2 resemble the NB but the auxiliary lead of this recording doesn't contribute to a decisive evaluation.

The first graphic of Fig. 3 shows a perfect discrimination of epoch with bigeminy taken from the MIT-BIH 208 d2 recording. Farther, one false NB is set immediately after the EB between 52nd and 54th s.

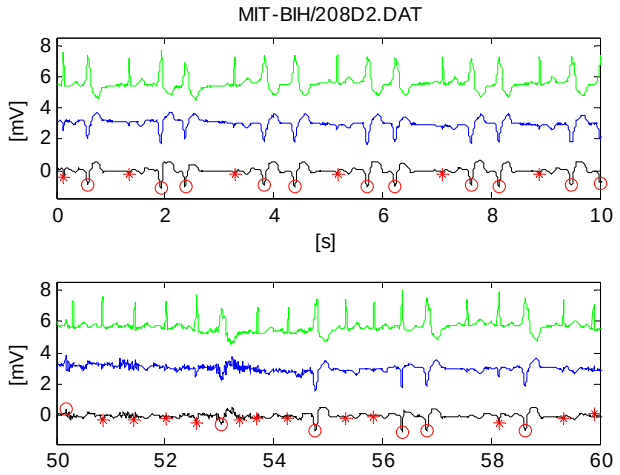

Fig. 3

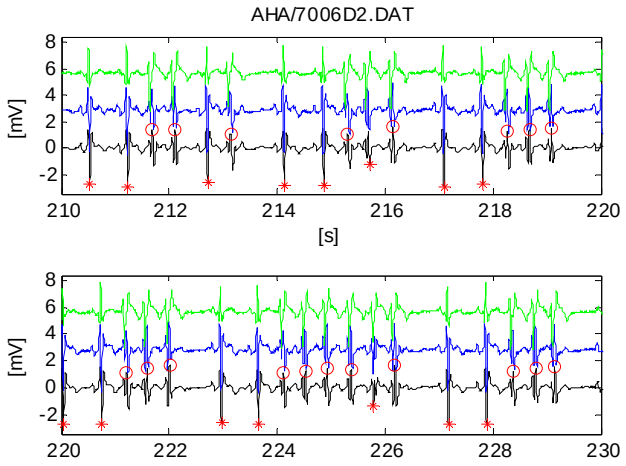

Fig. 4

The classification of the presented in Fig. 4 epochs of the AHA 7006 d1 recording is correct except for the two erroneously marked NB just before the 216th and 226th s. High estimation merit the VB discrimination in the last two signals despite the three false EB from 10th through 14th s due to insufficiently suppressed muscle noise.

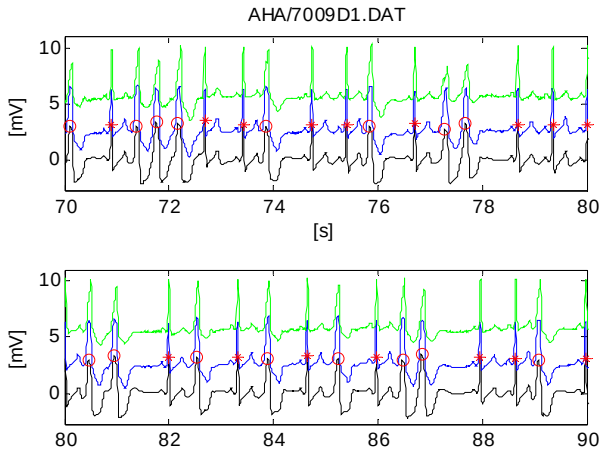

Fig. 5

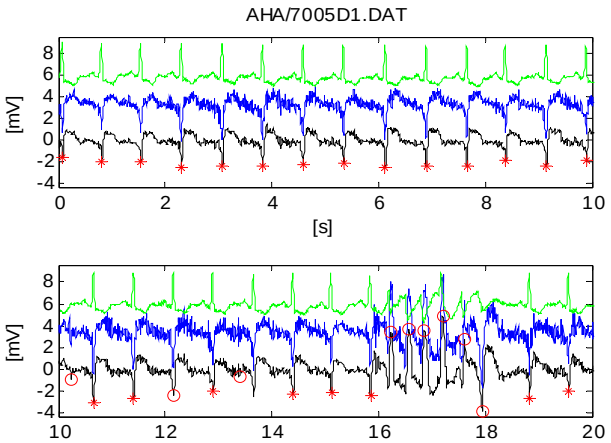

Fig. 6

5. Conclusions

I our opinion, a totally perfect VB discrimination hardly may be obtained even with neural networks. Besides, such approach can not be implemented in quasi-real time working ECG instrument.

The proposed approach improves the discrimination between NB and VB. The results are generally good. Nevertheless, the method may be improved and directed further to additional EB categorization in sub-classes.

The template determination is a key-problem of each beat classification.

The one-channel detection has the disadvantages to operate very often on low amplitude noisy ECG signals with considerable normal variations in shape. From the other hand, many real cases use imperatively one-channel signal only.

6. ACKNOWLEDGEMENTS

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7. REFERENCES:

[1] DOTSINSKY I. and STOYANOV T. (2004): 'Ventricular beat detection in single channel electrocardiograms', *BioMedical Engineering OnLine*, 3/1/3, http://www.biomedical-engineering-online.com/content/3/1/3.

Appendix

ΔS_{pn}=abs(S_{pn}- S_{pnt}); ΔS_p=abs(S_p- S_{pt}); ΔS_n=abs(S_n- S_{nt});
ΔA_{pp}=abs(A_{pp}- A_{ppt}); Δw_p=abs(w_p- w_{pt}); Δw_n=abs(w_n- w_{nt});

• if $\Delta S_{pn}>0.7\ S_{pnt}$	1 point
• if $A_{ppt}<3$ & $S_{pnt}>20$ &abs(ΔS_p-ΔS_n)>0.35(ΔS_p+ΔS_n)	2 points
• if $A_{pp}>0.2\ A_{ppt}$ & $S_{pnt}\leq 20$ &abs(ΔS_p-ΔS_n)>0.2(ΔS_p+ΔS_n)	1.5 points
• if $w_pT>32$ ms	2 points
• if $w_pT>24$ ms	1 point
• if $w_pT>16$ ms	0.5 point
• if $w_nT>32$ ms	2 points
• if $w_nT>24$ ms	1 point
• if $w_nT>16$ ms	0.5 point
• if abs(Δw_p-Δw_n)>0.2(Δw_p+Δw_n)	1.5 points
• if $\Delta A_{pp}>0.4\ A_{ppt}$	0.5 point
• if $\Delta A_{pp}>0.2\ A_{ppt}$ &$\Delta A_p>0.4\ A_{pt}$ &$sign_{VB}\neq sign_t$	1 point
• if $\Delta A_{pp}>0.2\ A_{ppt}$ &$\Delta A_n>0.4\ A_{nt}$ &$sign_{VB}\neq sign_t$	1 point
• if $\Delta A_{pp}>0.2\ A_{ppt}$ &$\Delta S_p>0.7\ S_{pt}$ &crossings≥4	1 point
• if $\Delta A_{pp}>0.2\ A_{ppt}$ &$\Delta S_n>0.7\ S_{nt}$ &crossings≥4	1 point
• if $\Delta A_{pp}>0.2\ A_{ppt}$ & abs(ΔA_p-ΔA_n)>0.2(ΔA_p+ΔA_n)	1 point
Threshold score:	4 points