DETECTION OF VENTRICULAR FIBRILLATION

Ivan Dotsinsky#, Irena Jekova#, *Maria Botsivaly, *Konstantinos Koutsourakis
#Centre of Biomedical Engineering - Bulgarian Academy of Sciences
and Technical University of Sofia
*Technological Educational Institution of Athens
E-mail for correspondence: iadoc@argo.bas.bg

Summary: *The detection of ventricular fibrillation is one of the most complicated and responsible for decision making cases. We tried to solve the problem in a sense just opposite to the traditional approaches. We improved an algorithm for QRS and ectopic beat identification adding two complementary branches. The first deletes all suspiciously detected ventricular beats. The criterion takes in consideration relatively equal widths and inter-beat distances in the range of 320 ms classifying them as ventricular fibrillation. The second branch looks all over the signal for amplitudes exceeding the limit of ± 150 μV and the algorithm marks them also as fibrillation waves if no QRS detected complexes are located nearer than 320 ms.*

Introduction

Ventricular fibrillation (VF) is dangerous cardiac disturbance leading to inevitable fatal exit if no defibrillation shock is applied on the subject before a few of crucial minutes have been elapsed. Very often such accidents are coming suddenly on the street or anywhere else in absence of qualified person around. Therefore, an automatic fibrillation detection that may be incorporated in defibrillation devices has to be very high appreciated.

Many software methods for fibrillation detection have been developed.

In the time-domain threshold crossing intervals (TCI) and auto-correlation function (ACF) are usually applied (CLATON *et al.*, 1993). The signal is processed by a third-order high-pass Butterworth filter with a 0.7 Hz cut-off frequency (THAKOR *et al.*, 1990). The power-line interference is additionally suppressed. Epochs of 4s are divided in 1s segments where thresholds at 20% of the maximum values in the corresponding segment are set. The intervals between two consecutive crossings of the threshold are measured. Then the mean TCI is calculated. If its value exceeds 400ms, the segment is classified as non-VF. Otherwise a complicated testing process is introduced. CHEN *et al.* (1987) proposed a short-term ACF contributing to VF separating from normal heart activity by aperiodicity assessment.

In the frequency-domain a spectral analysis is normally used (CLATON *et al.*, 1993). The inconvenience is in the generally off-line implementation of the method.

The normal cardiac rhythm is monitored by some of the abundant techniques for QRS detection. A real-time working algorithm (DOTSINSKY, 1991) pays attention to waves with high amplitudes, steep leading and/or trailing slopes and sharp peaks. A presence of ectopic beats usually embarrasses the ventricular beat identification. It may be improved by a real-time algorithm searching for two consecutive large amplitude opposite-signed wave parts (DOTSINSKY and CHRISTOV, 1997).

Method and algorithm

We borrowed recordings from the AHA database and processed them by means of the software package MATLAB.

We elaborated a non-trivial method for VF recognition starting with QRS complex detection. Then waves with amplitude beyond a relatively low threshold are located. They are classified as VF if they are far enough from the already detected surrounding QRS complexes.

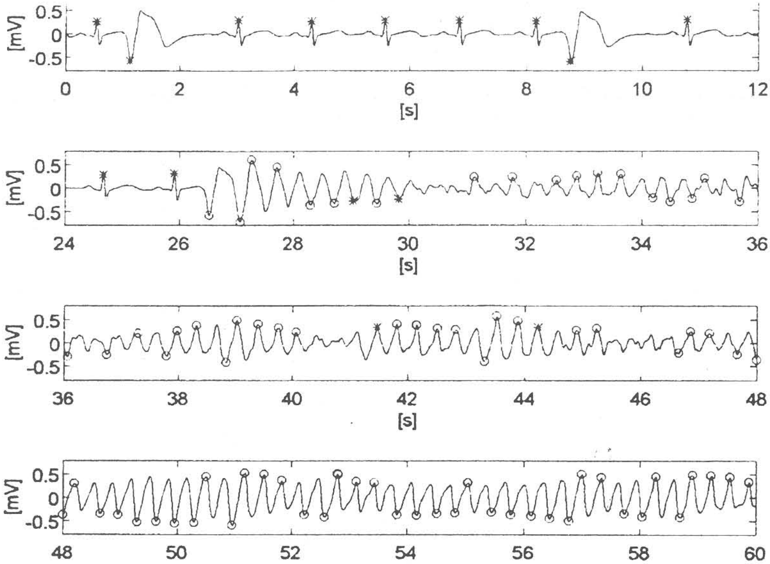
We used the above mentioned real-time algorithms (DOTSINSKY, 1991; DOTSINSKY and CHRISTOV, 1997). As there is no absolutely perfect algorithm for ventricular beat detection we apply a second pass to compensate the false classification of relatively steep and sharp fibrillation waves as normal QRS complexes. The left and right neighborhoods of each of them are investigated until sequences of two opposite extremums are found in both directions. Then the four time-intervals are averaged. A mean value of the extremum amplitude differences (MEAD) is computed too. An already detected QRS complex is discarded and marked as VF if the following 3 criteria are met:

- the average time-interval (ATI) is lower than 320ms;
- each time-interval is in the range of (1 ± 0.7)ATI;
- each amplitude difference is in the range of (1 ± 0.7)MEAD.

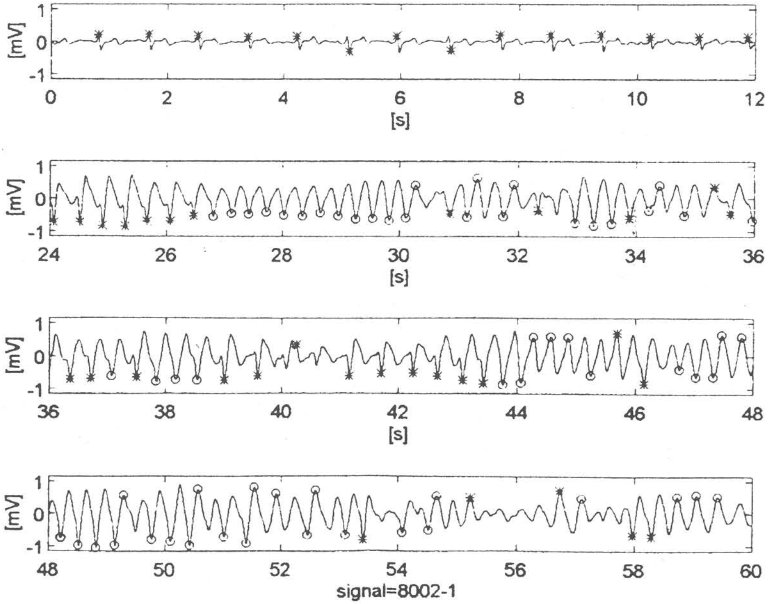
A third pass extracts any wave with amplitude exceeding $\pm150\mu V$. They are classified also as VF if their distances to the nearest left and right QRS complexes are higher than 320ms.

Results and discussion

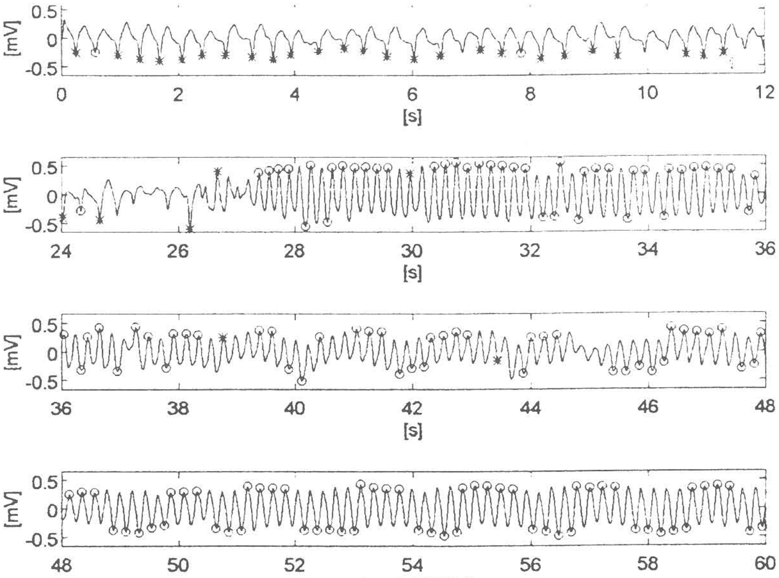
Seven Figures show parts of AHA recordings taken before and during VF. As it can be seen, the algorithm copes successfully with different shapes of regular QRS complexes and ectopic beats (signals 8001-2, 8007-1) marked by asterisks and VF waves noted by circle. Even very low-amplitude QRS complexes (signals 8002-1, 8009-2) are almost entirely detected except for the first 5 seconds of the 8006-2 recording. The beats belonging to the transitions from normal heart activity to VF are very difficult to be differentiated. Even the AHA annotations done by very experienced cardiologists allow ambiguity in the interpretation (signals 8001-2, 8002-1, 8008-1, 8009-2). Two intervals of VF in the signal 8006-2 may be confounded with assystoly if they are separately analyzed.



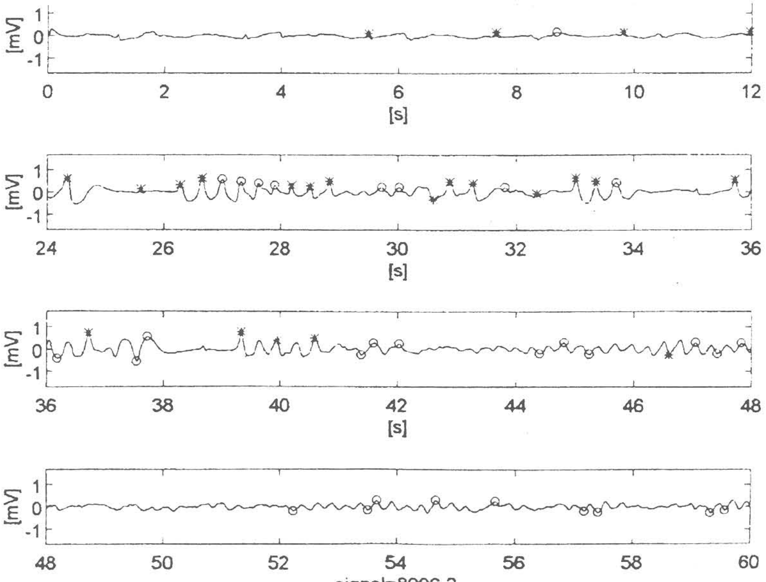
signal=8001-2



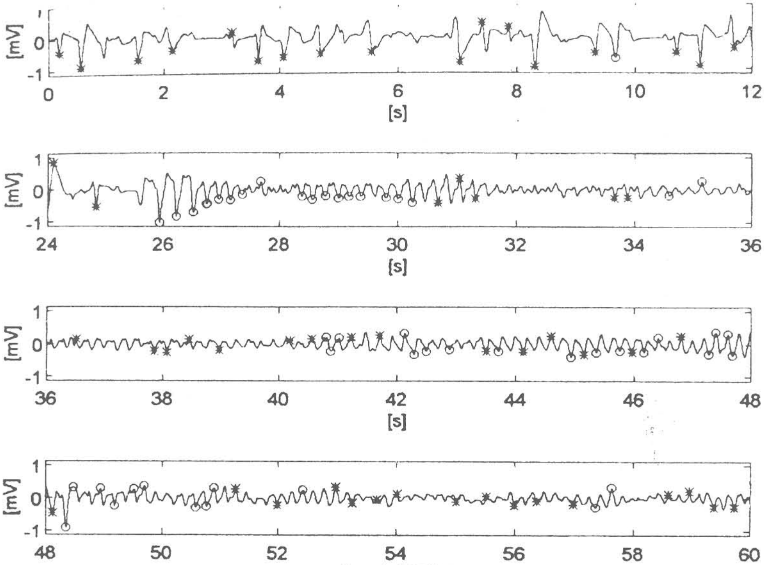
signal=8002-1



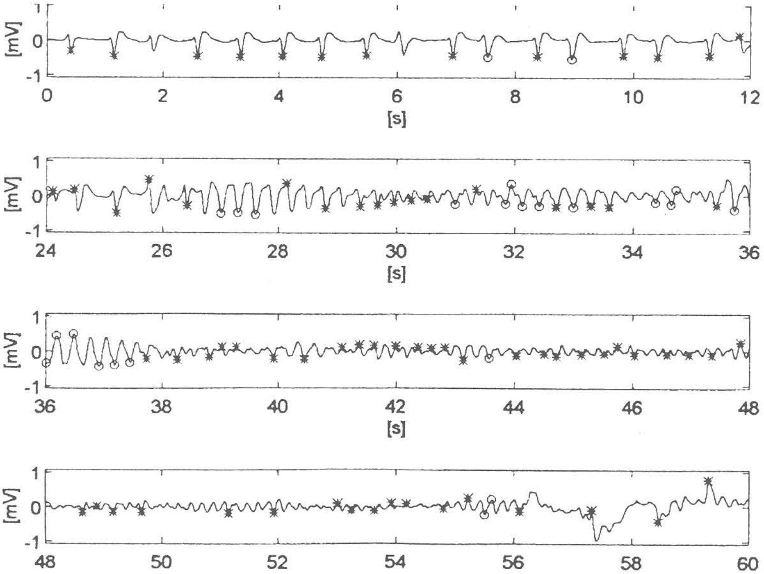
signal=8003-2



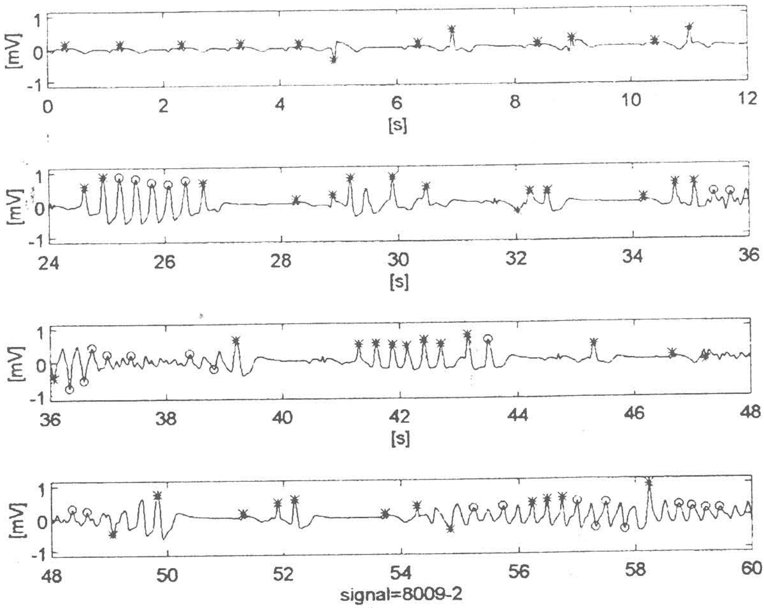
signal=8006-2



signal=8007-1



signal=8008-1



Conclusion

Despite some lacks, long enough intervals of detected VF may be observed everywhere in the Figures. Therefore, we hope we found a competitive algorithm for automatic defibrillation detection.

References

1. CHEN S., THAKOR N.V. and MOWER M.M. (1987): 'Ventricular fibrillation detection by a regression test on the autocorrelation function', *Med. Biol. Eng. Comput.*, **25**, 241-249.
2. CLATON R.H., MURRAY A. and CAMPBELL R.W.F. (1993): 'Comparison of four techniques for recognition of ventricular fibrillation from the surface ECG', *Med. Biol. Eng. Comput.*, **31**, 111-117.
3. DOTSINSKY I. (1991): 'Software real time QRS detection', *Med. Biol. Eng. Comput.* **29**, Supplement, 337.
4. DOTSINSKY I. and CHRISTOV I., (1997): 'Detection of QRS complexes and ventricular ectopic beats in the electrocardiogram', *International Scientific Colloquium*, Ilmenau, Band 2, 99-103.
5. THAKOR N.V., YI-SHENG Z. and KONG-YAN P. (1990): 'Ventricular tachicardia and fibrillation detection by a sequential hypothesis testing algorithm', *IEEE Trans. BME*, **37**, 837-843.