Algorithm of automatic fibrillation detection

N.A. Bazaev, A.N. Gusev, A.V. Mikitas*

Moscow Institute of Electronic Technology (Technical University), e-mail: simple210@yandex.ru
**Zelenogradskii Innovative Technological Centre*

Every year more than 300 thousand people die from sudden heart arrest in Russia. One can restore the proper work of heart via injection of adrenaline, heart massage or via transmitting a short electrical impulse of current of high power through heart (procedure of defibrillation). The efficiency of such procedure rapidly falls with time and the faster defibrillation is accomplished the more chances the patient has to survive. In case of providing the procedure of defibrillation in time, many people who became victim of sudden heart arrest, could be saved. That is why development of devices for automatic analyzing of ECG and making decision of necessity of shock therapy is a very actual task.

The algorithm that had been used in the first domestic defibrillator possesses high characteristics of sensitivity and specificity (99 % and 100 % corresponsive), however its actuation time is relatively high - till 15 seconds. Later a solution for decreasing of the action time was found: the intra threshold time-frequency algorithm was developed which auction time equaled to 4.1 seconds. However, its sensitivity and specificity turned out to be not so good (71.0 % and 93.3 % corresponsive). The aim of this work was to increase parameters of the intra threshold time-frequency algorithm.

The chances of developing an algorithm based on one critical parameter that possess high sensitivity and specificity are not high. That is why the result algorithm should be a combination of several critical parameters. During the work some known critical parameters were analyzed and also some new were suggested. Only four of them were used in the final algorithm.

1. Relative number of samples that are outside the informative interval.

This critical parameter was used in the method of Intra Threshold Time-Frequency Analyze. The informative interval is (-0.2·MaxAmplitude; 0.2·MaxAmplitude). In this method the number of samples that are outside the informative interval is counted and this number is divided to the number of all samples in the analyzed window. In this way we get the relative frequency. That method gave possibility to define different type of signals.

It's linear and that means it is easy programmable and works fast. It's very important to define no shock rhythms as fast as possible because these are most of situations.

$$Wd = \frac{N_1}{N_1 + N_2},$$

where N_1 is the number of samples that are outside the informative interval and N_2 is the number of samples that are inside it. It was decided that in case *Wd* is less than 0.47 the episode is classified as no shock rhythm. Otherwise fibrillation is detected. It was found out that the best window length is 4 seconds. Selectivity and specificity of this critical parameter are 79.9 % and 83.9 % corresponsive.

2. VF-Filtering method

It is said that in case of fibrillation the spectral power is mostly between 1 and 9 Hz. And otherwise the spectral power is distributed between 1 and 30 Hz. That is why one can filter the initial signal, in other words to cut 0-9 constituents from it and compare the power of initial ECG-signal with the power of filtered ECG-signal. The critical parameter is counted due to the following equation:

$$Pw = 255 \cdot \frac{\sum_i FilteredECG_i}{\sum_i InitialECG_i}.$$

If Pw is less than 75 then the episode is decided to be no shock. If Pw is larger than 110 then the episode is decided to be shock. Otherwise we need an additional parameter to make a decision.

3. Method of subtracting a combined signal.

The idea of this method is to get the residual of the absolute initial signal and the combined signal that is unique for every window. At first, one need to find picks that cross the threshold of 0.9·MaxAmplitude. Then the combined signal is formed. The combined signal is equal to the initial signal from the beginning of the window and to the first pick and from the last pick to the end of the window. Between two picks that go one after another the combined signal is counted due to formula:

$$R = \frac{1}{2} \cdot MaxVal \cdot \left(\sin\left(\frac{\pi}{2} + \frac{2 \cdot \pi \cdot t}{T} \right) + 1 \right),$$

where *T* is the time interval between two picks, *MaxVal* is the maximum value in the taken window. The critical parameter is calculated in the following way:

$$S = \left\| \left| \sum_i ECG(i) \right| - \left| \sum_i R(i) \right| \right\|.$$

If *S* is lower then 600 the rhythm is considered to be shock. It is very critical to use prefiltration before using this parameter, because signals may contain drift of isoline. The necessary correction can be made with help of Kaiser Filter. The window length is taken 4 seconds and is considered to be optimal. The selectivity and specificity of this critical parameter are 77.0 % and 93.1 % corresponsive.

4. Number of picks that cross threshold of 0.3·*MaxVal*

As it was found out, there is correlation between the number of picks that cross the mentioned threshold and fibrillation. In case of fibrillation the number of picks was more then 25. The length of the window was also taken equal to 4 seconds because it was supposed to be used in combination with the previous critical parameter. It was analyzed how the threshold influence the quality of separating fibrillation from other rhythms. It was found out that one can chose any threshold from the interval: (0.2-0.5)·*MaxVal*. Separation of fibrillation from other rhythms will be of the same quality. But one has to take into consideration that the critical number of picks should be recalculated for a certain threshold. Selectivity and specificity of the critical parameter are 78.7 % and 95.1 % corresponsive.

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As the first link it is suggested to use the relative number of samples outside the informative interval because it is the fastest algorithm and it can detect sinus rhythms very well. It’s specificity on signals that contain sinus rhythms is more than 99 %. In order to raise the quality of detection ranges of values of three critical parameters were divided into 3 areas: one responsible for no shock rhythms, one responsible for shock rhythms and one responsible for undefined rhythm. And the range of values of one critical parameter (number of picks that cross the threshold) is divided into 2 areas that are responsible for shock and no shock rhythms. This critical parameter is used as the last (the third one) link of the algorithm in order to make final decision. The second link is used to separate shock and no shock rhythm using two other critical parameters. The block-scheme of the algorithm is given in the figure 1.

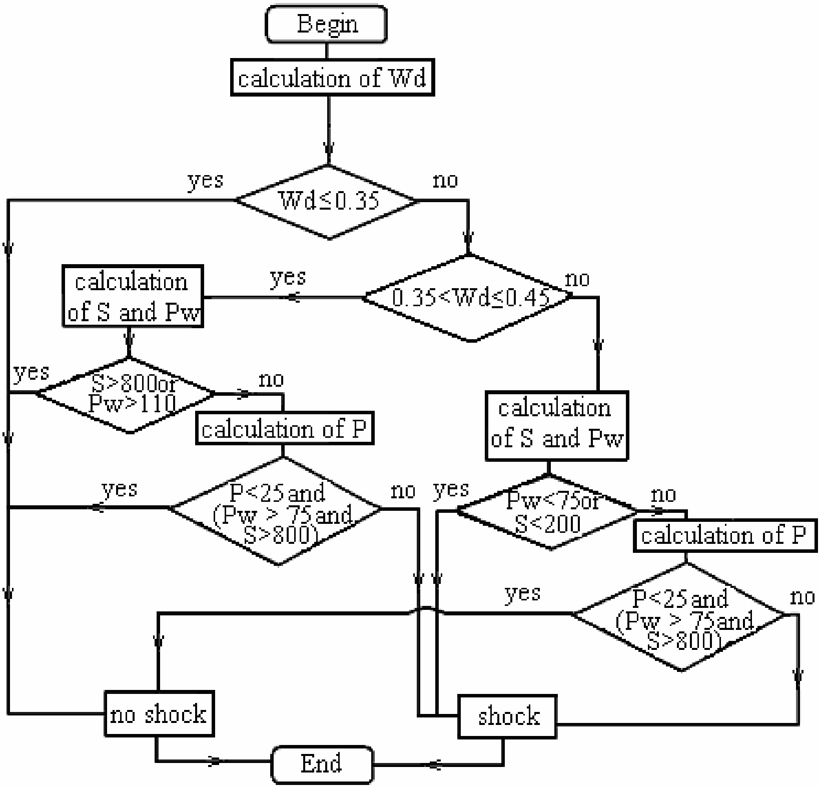

Figure 1. Block-scheme of the algorithm.

Sensitivity and specificity of the algorithm are 94.3 % and 98.4 % corresponsive. The prefiltration included the use of Butterwort filters and Kaiser Filter. The mentioned results were received with the order of filters 4 and 16 corresponsive. As a result we have the algorithm which action time is 4.1 seconds, but with sensitivity of only 94.3 %. That is not enough, so the future work will be devoted to how to raise it. And of course of it will be possible to raise specificity to at lest 99 %.

The given work is executed at partial financial support of the Russian Fund of Basic Researches, project N 05-08-50300.