

Detection R wave in ECG for realization cardioversion procedure

Introduction

There are spent the cardioversion procedures in clinics, in order to delete vitally dangerous heart arrhythmias. Cardioversion is electrical pulse of defibrillator, which synchronizes with R wave of ECG signal. Risk of ventricular fibrillation approach grows with asynchronous pulse of defibrillator; therefore the basic parameter of any QRS detection algorithm is specificity, which characterizes amount of incorrectly registered R waves.

Method

The given paper is devoted to algorithm of definition R wave in ECG, using threshold meanings of signal amplitude and time intervals between R waves. The process of detecting R waves assumes some stages. Initially signal is passed through 2 filters. The first filter is high-pass filter with a passband equal to 8 Hz, second filter is low-pass filter with a passband equal to 24 Hz. The given way of a filtration is chosen for reduction of noise influence on initial ECG, and also for reduction of influence P and T waves on acceptance of the decision by algorithm, because their spectrum is in the field of frequencies from 0.5 up to 10 Hz. In figure 1 is submitted ECG on the left, and spectrum, appropriate to him, on the right. The top figure – ECG before filtration with expressed P and T waves, and spectrum, appropriate to him, bottom figure a signal after filtration, with the appreciably reduced amplitude P and T waves, and the spectrum, appropriate to him. Further is calculated speed of signal increase in each point under the formula:

$$y_n = |x_n - x_{n-2}|,$$

where x_n – n meaning of the filtered signal. Next stage – choice a time interval, in which will be investigated the amplitude and increased speed of forward front of a signal. In the given paper was chosen 2 seconds time interval, in which determined the following parameters:

$$\max X > |\min X| \begin{cases} \text{yes, } x_n = x_n, T = \max X, \\ \text{no, } x_n = -x_n, T = |\min X|, \end{cases}$$

where X – array of ECG signal meanings on the time interval (x_{n-2C}, x_n) , C – frequency of discretization.

Further we determine the maximal meaning y_n on the interval (y_{n-2C}, y_n) :

$$B = \max(y_{n-2C}, y_n).$$

R wave should satisfy to the following conditions:

$$\begin{aligned} x_n &< x_{n-1}, \\ x_{n-1} &> x_{n-3}, \\ x_{n-2} &\leq x_{n-1}, \\ x_{n-3} &\leq x_{n-2}, \\ \max(y_{n-15}, y_n) &> 0,25 * B. \end{aligned}$$

If all above described conditions are true, first seven R waves are detected according to the criterion:

$$x_{n-1} > 0,75 * T,$$

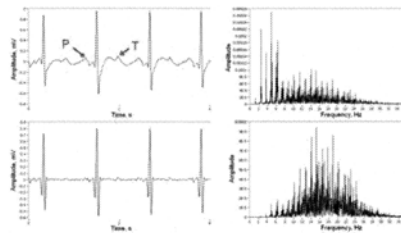


Figure 1: ECG and its spectrum

Further, this expression is replaced as follows:

$$x_{n-1} > 0,65 * P,$$

where P – arithmetical mean of amplitude last seven detected R waves, calculated under the formula:

$$P = \frac{P_1 + P_2 + \dots + P_7}{7}.$$

At each new definition of R wave: P_1 deleted, array of amplitude is displacement on one meaning to the left; P_7 is equated to the new meaning of R wave P_{NEW} (fig. 2). P_{NEW} is determined as follows:

$$P_{NEW} > 1,5P \begin{cases} \text{yes, } P_{NEW} = 1,2P, \\ \text{no, } P_{NEW} = P_{NEW}. \end{cases}$$

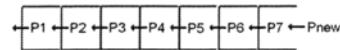


Figure 2: Array of amplitudes displacement

Thus, it was received parameter P , which defines changing amplitudes of R waves. After detection R wave, the following peak can be detecting only after 200 ms. Further instant meaning of pulse is calculated under the formula:

$$Pl = \frac{C * 60}{l},$$

where l – amount of signal points between two next R waves.

First five meanings exceeding 45 bit per minute (bpm), write in array and their arithmetical mean is calculated:

$$PL = \frac{Pl_1 + Pl_2 + Pl_3 + Pl_4 + Pl_5}{5}.$$

The instant meaning of pulse is calculated for each following R waves. If this meaning:

- in 2 times more than PL , given R wave is not detected;
- less than 45 bpm, R wave is detected;
- in other cases R wave is detected, and the new meaning of array is replaced meaning Pl_5 , array is displaced, by analogy to the array P .

The given algorithm was analyzed by MIT-BIH Arrhythmia database, which contains 48 records by duration 30 minutes everyone. Parameters of sensitivity and specificity of the developed algorithm have made: 95.3% and 99.6%.

Sensitivity calculated under the formula:

$$Se = \frac{TP}{TP + FN},$$

where TP – amount of the correctly registered reductions, FN – amount of the incorrectly missed reductions.

Specificity calculated under the formula:

$$Sp = \frac{TP}{TP + FP},$$

where FP - amount of the incorrectly registered reductions.

Conclusion

The submitted algorithm of definition R waves can be used in real time systems, because does not require difficult mathematical calculations and works with the current reports of ECG. The high parameters of algorithm specificity is shown, that the probability of detecting wrong R wave makes less than 1 %, that allows to use the given algorithm for cardioversion.

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