Methods of processing, analysis and definition of QRS in ECG

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Cardiovascular diseases have the first place in the world by death-rate. Electrocardiogram is a most widespread method which diagnose of heart patient. The basic component of ECG signal is the QRS which is responsible for ventricular depolarization. The doctor diagnoses the patient using features of the given component. The important factor is the measurement of intervals time between R-peaks (variability of an intimate rhythm) QRS of ECG signal. All above described factors can be measured using an automatic mode that will allows to simplify doctor's job or it will allows to diagnose when the doctor is absent.

The important factor that influence on ECG detection are noises.

The noises, presented in ECG, we can divide into two basic categories:

- noises caused by external physical factors;
- tool noises caused by the ECG device.

The external factors are caused by physiological features of a person, and tool factors are caused by features of measuring engineering, used for registration of a signal.

The most important noises caused by external physical factors are:

- noises of power electrical lines;
- noises of contacting electrodes;
- electrical activity of muscles;
- jumps or displacement of isoline;
- drift isoline owing to respiratory activity;
- noise of the peripheral equipment.

It is possible to allocate some strips in a spectrum ECS, in which the major capacity of noise is usually concentrated, while the capacity of a useful signal in the data is minimal.

Such strips are:

- frequency less than 0.5 Hz – the basic capacity of drift isoline noise;
- 50/60 Hz - noises of electrical power lines;
- 35-40 Hz - noises of muscles electrical activity;
- more than 100 Hz- high-frequency noises of a different nature.

The basic capacity of QRS is concentrated in the field of frequencies 2-20 Hz with presence of a maximum on frequency about 15 Hz.

These above parameters should be used for ECG processing.

In a course of standard ECS representation is possible to determine, that the greatest amplitude meaning has R wave, of a QRS. Tracing intervals between waves R is possible to check meaning of the pulse in a real time, and trace that's changing. Threshold meaning, which can carry adaptive character or have the certain meanings, can be used for these purposes.

The detecting QRS by threshold meaning assumes for the following operations:

- choose the threshold meanings of a researched signal, supposed, that all R wave should be stacked in the given interval (for example, the interval from 0,75 mV up to 5 mV), and it is possible to use adaptive threshold meaning;
- makes the binary signal, all the meanings of the voltage which have got inside researched interval are equated to 1, all meanings outside researched interval are equated to 0.

First R wave settles down in the middle of the threshold and is calculated under the formula:

$$T_R = \frac{t_2 - t_1}{2}, \tag{1}$$

where t_1 - transition from 0 in 1, t_2 - transition from 1 in 0

The next method QRS detection is based on the assumption, that speed of QRS increasing is the greatest in comparison with other components.

The signal ECG is represented as array: $x(1), x(2), x(3),..., x(k)$, where k - amount of elements in array. The comparison of three following one after another report of a signal ECG is made:

$$x(n) - x(n-1) > 0{,}125\ mV$$

and

$$x(n+1) - x(n) > 0{,}125\ mV, \tag{2}$$

if the condition (2) is implement, the meaning of array is equated to 1, if no, to 0.

Two above described methods have formed the basis for development of QRS detecting algorithm in ECG.

The algorithm works with adaptive threshold meanings, amplitude of the filtered signal and first derivative. It combines an opportunity to investigate a signal on the maximal meaning both on increasing and decreasing speed of a signal front. The threshold meanings get out according to duration of a researched interval.

Initially signal is passed through 2 FIR Kaiser filters. The first filter is high-pass filter 26-th order with a passband equal to 8 Hz, second filter is low-pass filter 8 order with a passband equal to 24 Hz.

The detecting process assumes the following operations:

- filtered signal is represented as array $X(n)$, and first derivative is searched under the formula:

$$Y(n) = \left| X(n+1) - X(n-1) \right|; \tag{3}$$

- time interval choice, in which will be investigated arrays $X(n)$ and $Y(n)$, and allocation subarrays $x(n)$ and $y(n)$ on a researched interval;

- searching maximal meaning of array $x(n)$ and maximal meaning of array $y(n)$, and the threshold meanings are allocated according to the formula:

$$A = 0{,}6 \max[x(n)],$$
$$B = 0{,}6 \max[y(n)]; \tag{4}$$

- allocating the meanings appropriate from array $x(n)$ according to the following criterion:

$$0{,}3\, mV < \max[x(n)] < 5\, mV,$$

and

$$x(i) > A \text{ или } x(i) > 0{,}3\, mV, \text{ where } i = 0, 1, 2, \ldots, n-1; \tag{5}$$

- allocating the meanings appropriate from array $y(n)$ according to the following criterion:

$$\max[x(y)] < 2\ mV\ ,$$

and

$$y(i) > B,\ \text{where}\ i = 0, 1, 2, ..., n-1\ ; \tag{6}$$

- then these conditions are combined, and the new array consisting from zero and one is formed. As far as one of the above described conditions is done, enters one in array, otherwise zero. There is one more condition: as soon as first one is found out following one can be found out only through 150 ms. Thus, in a new array the ones will correspond to QRS detection of an initial ECG.

The given algorithm was analyzed by a MIT-BIH Arrhythmia database, which contains 48 records by duration 30 minutes everyone. Below in a table, are given data for algorithm working for time intervals: 1 s, 2 s, 4 s.

Table

Results data of detecting

Length of window (s)	Sensitivity (%) Se	Specificity (%) Sp
1	99,96	96,62
2	99,77	98,95
4	99,67	99,28

Parameters of sensitivity and specificity of the developed algorithm, using a window in 4 s, have made: 99,67% and 99,29%

These data are comparable with results of QRS detecting of the best algorithms.

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