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Processing the Cardio Signals of Wavelet Function

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***Abstract:** A method for processing and analyzing ECG signals based on wavelet transform in an electrocardiography system is proposed. The ECG spectrum is arranged in a series of Gaussian delta functions. A method of vector representation of data in binary codes is proposed. This method allows you to detect minor changes in subsequent studies.*

***Keywords:** ECG signal, wavelet transform, delta function, series expansion..*

I. INTRODUCTION

Wavelet analysis has already found its application in many branches of science, especially for processing temporary signals [1]. There are many works where the question was raised of improving the algorithm for constructing the correlation function using wavelet functions [2]. The medical sector is not averse to this. An electrocardiogram (ECG) is a record of electrical potentials of heart activity, taken from one or more leads, and consists of a periodic sequence of cardio cycles. Currently, wavelet analysis is promising for the analysis of an ECG signal. Wavelets are a generic name for families of mathematical functions of a certain form that are local in time and frequency, and in which all functions are obtained from one basic (generating) function by its shifts and stretches along the time axis. Compared with the decomposition of signals, Fourier orders, wavelets are able to represent local features of signals with much higher accuracy, up to breaks of the first kind [3].

The aim of this work is to improve the methods of analysis of electrocardiographic signals. In this paper, we propose the method and the ways for further processing of cardiac signals using discrete wavelets. In the research of cardiosignols, a cardiogram is used in the equipment where the periodic sinusoidal solid curve is depicted. From a medical point of view, the valuable information is considered the graphical behavior of certain intervals in each period. The first and most important part of ECG signal analysis is the correct detection of QRS complexes.

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The QRS complex is the easiest way of waveform detection, but the highest possible detection accuracy is needed. Once QRS complexes position detection, detection of T-waves and P-waves can follow [4-8]. When the cardiogram changes, the diagnosis of the functioning of the patient's heart is determined. Receiving signals is carried out using a device that records the magnitude of the potential of electric current over time. This suggests that the information is obtained in a discrete form and only then by connecting these points do they get a solid curve (cardiogram). When determining signals by measuring potential over time, the potential value is determined at time point t0. If we imagine that the signal at a specific point t0 is determined by the presence of several small signals in its vicinity, then the resulting cardiac signal can be represented as sums of wavelet functions or Delta functions.

In the research [9–11], the authors proposed processing continuous spectra of physical processes in the behavior of discrete perturbations using decomposition, representing it as the sum of finite delta-functions. Correct and accurate determination of the ECG is very important for the diagnosis of heart disease. In this article, we present an improved version of the ECG differentiation approach.

The presented approach to ECG differentiation is based on the continuous form of wavelet transform (CWT). Wavelet transform at different scales describes the temporal response of a signal in different frequency bands. While binary wavelet transform (DWT) is limited to scales that are powers of two, CWT can be estimated at any real positive scale. Using CWT instead of DWT gives us more options. By choosing the optimal scale, we can minimize the effects of noise, artifacts, and baseline drift. The CWT of the time-continuous signal x (t) is determined by the integral [1-3].

$$X(t) = \frac{1}{a}\int_{-\infty}^{\infty} x(t)\,\psi\left(\frac{t-t_0}{a}\right)dt \qquad (1)$$

where ψ (t) - wavelet function, a - scale parameter, and t0 -translation parameter.

For the case of discretization

$$X(t) = \sum_{i=1}^{\infty} x(n_i)\,\frac{1}{a}\,\psi\left(\frac{t-t_{0i}}{a}\right) \qquad (2)$$

The calculation of a continuous signal in time is performed according to the following formula:

$$X(T) = \sum_{K=1}^{\infty}\sum_{I=1}^{\infty} X(N_I)\,\frac{1}{A}\,\Psi\left(\frac{T_K-T_{0I}}{A}\right) \qquad (3)$$

II. DELTA FUNCTION SELECTION

We tested several wavelet prototypes to find the best wavelet to distinguish between ECGs. In [9,10], an asymmetric function of the following form was used as a delta function:

$$\psi(t, t_0, \omega) = \frac{1}{\omega}\exp\left(\frac{(t-t_0)}{\omega} - -\exp\left(\frac{t-t_0}{\omega}\right)\right) \quad (4)$$

If the exponential function in the exponent is approximated to 2 orders of magnitude.

$$\psi(t, t_0, \omega) = \frac{1}{\omega}\exp\left(\frac{(t-t_0)}{\omega} - \left(1 + \frac{(t-t_0)}{\omega} + \frac{(t-t_0)^2}{2\omega^2}\right)\right)$$

Simplifying the expression, and after rationing, we obtain a Gaussian distribution:

$$\psi(t, t_0, \omega) = \frac{1}{\sqrt{2\pi\omega}}\exp\left(-\frac{(t-t_0)^2}{2\omega^2}\right) \quad (5)$$

Fig. 1 shows graphs according to formula (5) for various ω.

Then the calculation of the continuous signal in time is performed according to the following formula:

$$X(t) = \sum_{k=1}^{M}\sum_{i=1}^{N} x(n_i)\frac{1}{\sqrt{2\pi}\omega}\exp\left(-\frac{(t_k - t_{0i})^2}{2\omega^2}\right) \quad (6)$$

The value of M is selected based on the case i.e. based on the values of the studied time range. The value of N is determined so that with increasing $(t_k - t_{0i})^2$ it becomes not significant. It can be considered as a finite number.

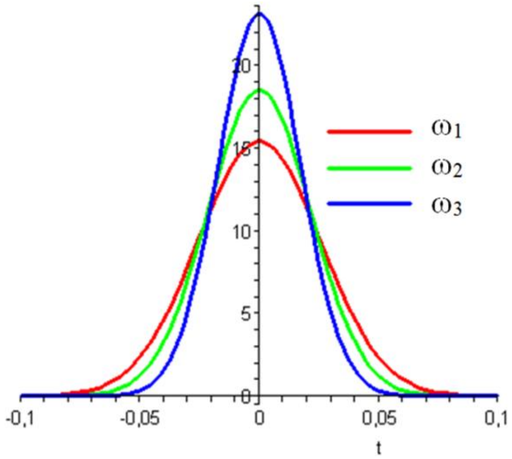

Fig. 1. Graphs according to formula (5) for various ω

This reasoning of the works [3,4,9,10] allows us to use formula (5) in the future. Moreover, we are faced with the task of determining the coefficients $x(n_i)$. It should be noted that now we will search for the coefficients in the form of 0 and 1 in the time range of one cycle period of the ongoing process.

The algorithm for determining the coefficients

We will determine the coefficients in the form of 0 and 1. We will achieve such an arrangement of the coefficients of 0 and 1 that, by changing the time parameter, function (6) describes the behavior of the received cardiogram signal. To do this, we previously determined the division of the time range into small sections. In this case, 1 second of the time range per 100 equal parts. We will determine the presence of a "wave" (5) at each 100 time points. Coefficient 1 means the presence of and 0 means that a shallow wave at this point trails. For complete agreement between the signal graphs and (6), we first need to calibrate function (5) with respect to the parameter ω. After choosing ω, the effective delta gap for the wavelet will be refined (5). When determining the coefficients, the presence of a wave at a given point ti depends on how much function (6) is in the attractive neighborhood ti-n<ti<ti+n and the resulting cardiogram is consistent. If the set of waves in the form of (6) has reached the signal one and does not signal it, then the coefficient at ti will need to take the value 1. And if it has exceeded, then the coefficient at ti will take the value 0. It is worth noting that we will set the threshold superiority by ε. Thus, to determine the coefficients $x(n_i)$ according to the presented algorithm, the parameter ti will run over the time interval τ (in this case, 1 second) calculates and compares the values of X (t) with the signal values at the significant surroundings ti-n<ti<ti+n.

After N iterations (in this case, N = 100), we obtain N coefficients consisting of 0 or 1 and obtain a curve determined by formula (6) which, in accordance with the signal plot (Fig. 2a), with an accuracy of ε, which was set initially.

III. VECTOR DATA REPRESENTATIONS

After the calculations, we got a curve describing the signal ECG. This was accomplished by selecting the coefficients $x(n_i)$ in the amount of N, which are an N-dimensional binary vector, i.e. the coordinate vector whose digits are 0 and 1. These coefficients are the main indicators that can store valuable information for processing data. Each presence of a small wave at a time point ti, which is determined by the presence of a coefficient corresponding to a unit in ti. This case allows us to represent the resulting binary vector in the form of barcodes, where the presence of a dash line on the time scale means 1 and emptiness means the presence of 0 (Fig. 2b). When diagnosing, it will be sufficient to determine the presence and absence of dash lines in the time interval. Obtaining a binary vector depends on the choice of a wavelet or delta function, in this case the formula (6) is a Gaussian function, and of course it depends on the determination algorithm.

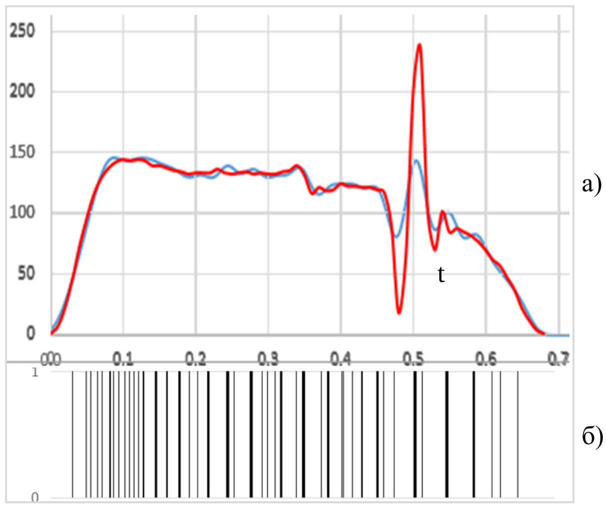

Fig. 2. a) the signal ECG is red [12] and the curve obtained by the formula (6) is blue. b) ECG presented in the form of bar codes.

When processing with the same algorithm, we get a specific graph, a specific binary vector and a specificencoding stroke for a unique ECG.

IV. RESULT AND DISCUSSION

The applicability of wavelet decomposition to describe ECG signals was shown in [1,3]. Wavelet decomposition allows us to consider the signals as a continuous function, depending on time. [3,4,5] an algorithm for determining the coefficients of the wavelet decomposition is proposed, and these coefficients are different. We proposed an algorithm for reducing the coefficients of the wavelet decomposition, where the coefficients consist of 0 and 1. Using these coefficients leads to differences in the coefficients of the differences in the density of the wavelets. Therefore, the applicability of this method can be determined by the following relation:

$$\left| k\frac{1}{a}\psi\left(\frac{t-t_{0n}}{a}\right) - \sum_{i=n-k/2}^{n+k/2} x(n_i)\frac{1}{a}\psi\left(\frac{t-t_{0i}}{a}\right) \right| < \varepsilon$$

where, k, the coefficient corresponding to the Wavelet n, x(ni) is 0 or 1, ε-determines by how much the Wavelet decomposition coincides with the obtained delta decomposition. Thus, according to the proposed algorithm, we obtain a vector representation of the ECG signals of the place of the wavelet decomposition with accuracy ε.

V. CONCLUSION

Choosing a delta function, constructing an algorithm for determining the coefficients, we obtain a unique vector representation of the ECG signals. From the resulting vector we can build an ECG in the form of barcodes. This can simplify the task of storing data and transmitting ECG signal information. Vector representation of ECG signals can make a significant contribution to the observation of changes in consequences. By finding the difference of the two binary vectors of the subsequent ECG, it will be possible to detect minor changes in the form of a binary vector where, the number of units has decreased, maybe where -1 has appeared that carries valuable information about changes in the patient's state.

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