APPLICATION OF WAVELET-TECHNOLOGIES IN PROCESSING OF ELECTROCARDIOGRAMS

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ABSTRACT

In the given work it is offered to use wavelet-technologies for primary processing an electrocardiosignal. Wavelet-functions which used in a cardiology are held. Wavelet-spectrograms for an electrocardiogram and RR-intervalogram have been constructed. Results of wavelet-transformations can be used in cardiodiagnostics, in particular for researches of thin structure of an electrocardiogram

I. INTRODUCTION

In an electrocardiology for detection, extraction and the analysis various components of electrocardiogram are applied various methods of processing of digital signals. Under time and amplitude characteristics of peaks and intervals of electrocardiograms (ECG) the doctor-cardiologist can determine presence of those or other diseases at the researched patient.

The classical approach in electrocardiology – is use techniques of the analysis of time domain of a signal which have various applications (standard ECG-measurement, measurement of frequency of cardiac reductions, etc.) [1]. However measurements of amplitude and duration of ECG-component by means of methods of the analysis of time domain are not always sufficient for the description of all features of an electrocardiogram-signal. For example, definition of the late potential located in QRS-complex, cannot be executed with use of these methods. At the same time the analysis of time domain of frequency of cardiac reductions gives the full information on behavior of RR-intervals and parasympathetic influence. But sympathetic ordering cannot be estimated on the basis of measurements of frequency of cardiac reductions in time domain [2]. Successes of an ECG-diagnostics in much are bound to use of the mathematical apparatus of representation of signals in the form of series Fourier. However last years it became obvious, that it appears ineffective at the description of local features of functions (peaks, sharp differences).

Digitized electrocardiogram-signal is final, therefore it has sharp borders. It leads to fuzzying of all certain frequencies. To avoid that, at calculation fast Fourier transform is applied to an electrocardiogram so-called "window" Fourier transform to smooth decrease of boundary of an ECG-signal up to zero with deleting its intermittence. Limitation of this approach that there is a decrease of the permission on frequency, that is decreases quality of definition of frequencies in an electrocardiogram-signal. Other inevitable limitation of Fourier transform consists that it does not allow determining exact position frequent component in a signal. These components vary in time. The QRS-complex is a high-frequency component whereas T peak contains low-frequency components. Therefore exact definition of frequencies of an electrocardiogram-signal in time, that is, usage of wavelet-transformation is necessary. Wavelet-transformation differs from Fourier transform by that operation of multiplying on "window" contains in the most basic function, thus to occur adapting of "window" to a signal at a rescaling.

II. WAVELET-ANALYSIS

New perspective method in digital processing of the signals, allowing receiving dependence of amplitude on frequency and time is wavelet-transformation. Every wavelet has certain duration, position in time and frequency band. It is known, that from methods of the wavelet-analysis in cardiology use Morlet, Daubechies, Mexican hat (figure 1) and discrete harmonic wavelet-transformations more often [3].

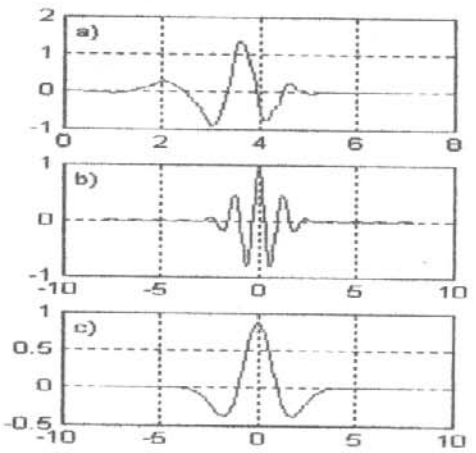

Figure 1. Wavelet examples: a) Daubechies, b) Morlet, c) Mexican hat

As advantage of application of a method consider its higher noise stability that allows to give less attention to procedures of preliminary filtration, interpolation of data, effectively to work in conditions of greater interferences. There are two types of wavelet: continuous and is discrete-orthogonal transforms.

Advantage of wavelet-transformation consists in ability to allocate a detail of an electrocardiogram with the best local permission on frequency at research of variability of cardiac rhythm, an electrocardiogram of a high-resolution, selection QRS-complex. The continuous method allows revealing in the frequency domain abnormal potentials inside QRS-complex, extended QT segment, to research P and T waves, and also QT and ST segments. Orthogonal wavelet-transformation effectively compresses an electrocardiogram (for example, in 6 times at an error of 2%) [4]. At continuous conversion wavelet-coefficients of a signal s, corresponding scale coefficient a and to position b, are defined by the formula:

$$C_{a,b} = W[f](a,b) = \frac{1}{\sqrt{a}} \int_{-\infty}^{\infty} s(t)\overline{\psi\left(\frac{t-b}{a}\right)}\,dt,$$

where t – time axis, ψ(x) – wavelet-function.

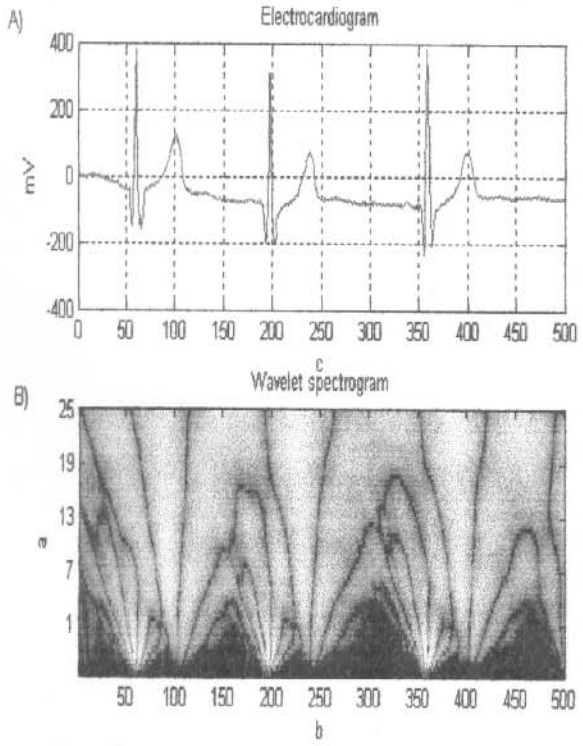

Figure 2. Electrocardiogram (A) and its wavelet-spectrogram (B)

The result of wavelet-transformation is a matrix containing wavelet- coefficients. It is represented on a phase plane in the form of cells of identical square, but the different form. It allows to localize well low-frequency details of a signal in the frequency domain (prevailing harmonics), and high-frequency – in time domain (sharp jumps, peaks, etc.). Each cell contains an element of the coefficients matrix and colored in correspondence with value of the coefficient. The received graphics image is called as the wavelet-spectrogram (figure 2) [5].

III. RESULTS AND DISCUSSION

On the wavelet-spectrogram QRS-complex well appears on high frequencies (at small values of coefficients a), P and T waves also are well visible on small frequencies (at great values of coefficients a).

On figure 3 results of application of wavelet-transformation for research of change of spectral components of a rhythm in time are presented.

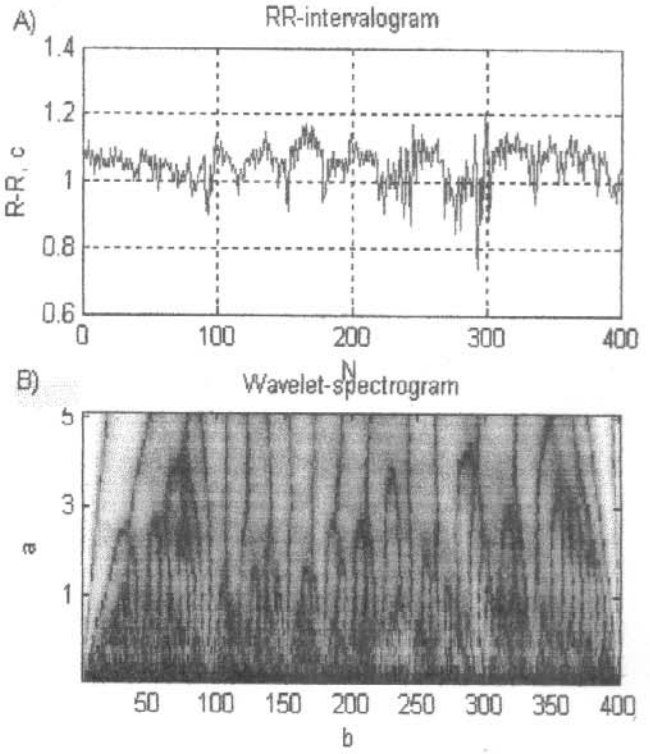

Figure 3. Fragment of RR-intervalogram (A) and its wavelet-spectrogram (B)

The review of publications on wavelet application of conversion to the analysis of cardiographic-signals has shown that the method of the wavelet-analysis has the best diagnostic possibilities and prognostic potentialities in critical conditions on comparison with a Fourier

(harmonious) analysis. Use of wavelet-transformation is represented to the most perspective at the analysis of critical conditions when search of criteria of transition periods – the sharp modify structures of cardiac rhythm previous development terminal arrhythmias with the subsequent cardiac standstill. Thus, the wavelet-analysis not only increases efficiency of estimations of variability of cardiac rhythm, but also is an effective method for research of late potentials and polarization in QRS-complex. Now this method only starts to take root and its research for wide clinical application is required.

IV. CONCLUSION

The wavelet transformation is a new promising technique in non-invasive electrocardiology providing improved methods for late-potential detection, heart rate variability analysis and evaluation of the repolarization segment abnormalities. The benefit of the wavelet transformation lies in its capacity to highlight details of the ECG signal with optimal time-frequency resolution. Since the application of wavelet transformation in electrocardiology is a relatively new field of research, many methodological aspects (choice of the mother wavelet, values of the scale parameters) of the wavelet technique will require further investigations in order to improve the clinical usefulness of this novel signal processing technique. Simultaneously diagnostic and prognostic significance of wavelet techniques in various fields of electrocardiology needs to be established in clinical studies.

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