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ALGORITHMICAL AND SOFTWARE PROCESSING OF PCG-SIGNALS FOR DIAGNOSING STENOSIS OF THE AORTIC VALVE OF THE HEART

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In the field of medical cardiodiagnostics, non-invasive medico-biological methods are widely used to diagnose aortic valve stenosis, in particular auscultation [1,2], electrocardiography [3,4], echocardiography [5,6,9,11] and phonocardiography [1,7,10,13,14]. Phonocardiography provides a study of the acoustic phenomenon (determining the degree of attenuation and presence of heart tones, the level of intensity, duration and shape of the systolic noise), which is related to the functioning of the aortic valve of the heart. This is achieved by analyzing the registered PCG-signals (Fig. 1-2) in order to determine the parameters of the sound phenomena that are formed during the operation of the heart valves.

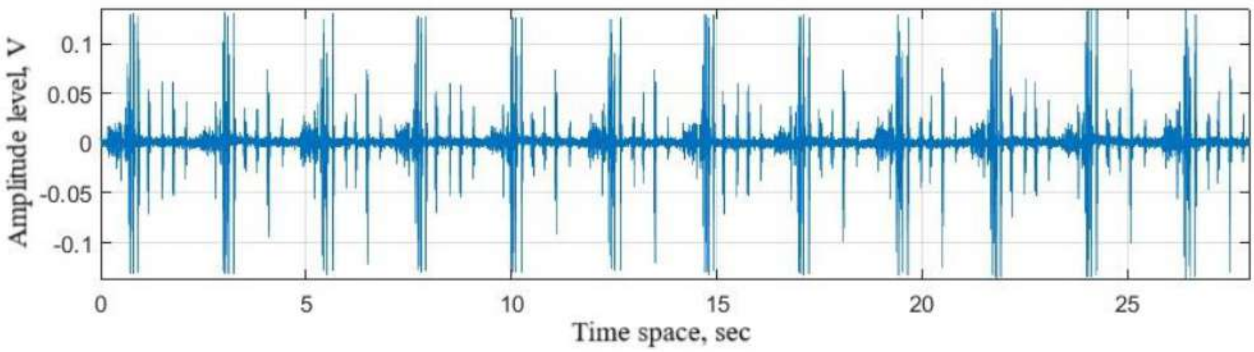

Figure 1. PCG-signals (normal)

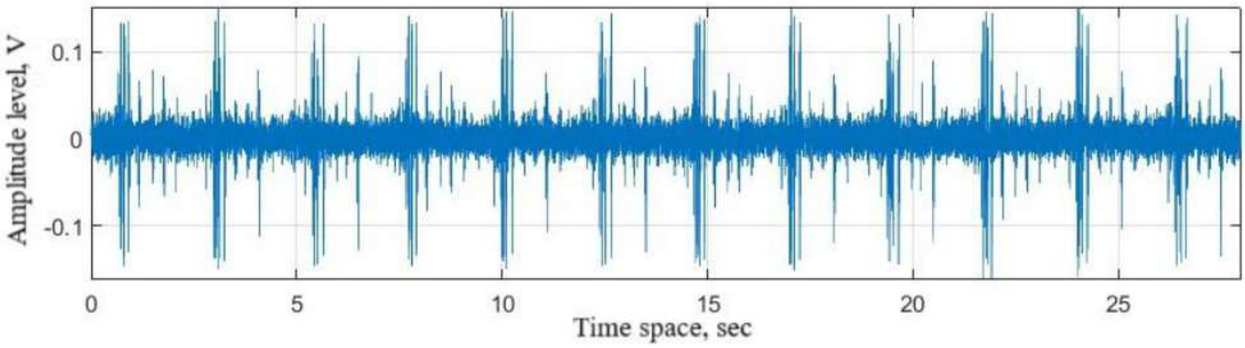

Figure 2. PCG-signals (aortic stenosis)

Empirical PCG-signals, when considered as non-stationary, contain short-term high- and low-frequency components in their structure. Thus, for their processing it would be useful to use a transformation that would provide different windows for different frequencies (narrow for high frequencies and wide for low frequencies). The wavelet transformation meets these conditions and is the basis of the method of processing PCG-signals using wavelets.

In the core of the wavelet processing of the PCG-signal there is an expression [8]:

$$C(a,b)=\frac{1}{\sqrt{a}}\sum_{t=0}^{t\max} x(t)\psi(t,a,b), \tag{1}$$

where $\psi(t,a,b)$ - a basis (function) that ensures the determination of the effectiveness of the study of fluctuating processes (time variability) of the PCG-signal in relation to time, which is extremely relevant for detecting the moment of time when there is a variation in the functioning of the heart valves.

The process of selecting the basis of wavelets $\psi(t,a,b)$ is determined by the similarity of the shape of the PCG-signal function to the wavelet of the mother function.

The most similar basis to the structure of the PCG-signal from the sign of aortic stenosis is the Gaussian basis. This basis is the simplest and is described by the expression:

$$\psi(t)=(-1)^n \frac{d^n}{dt^n} e^{-\frac{t^2}{2}}, \tag{2}$$

where n – the order of the Gaussian basis.

On the basis of the wavelet processing of the PCG-signal with the Gaussian basis, the algorithm shown in Fig. 3 is implemented.

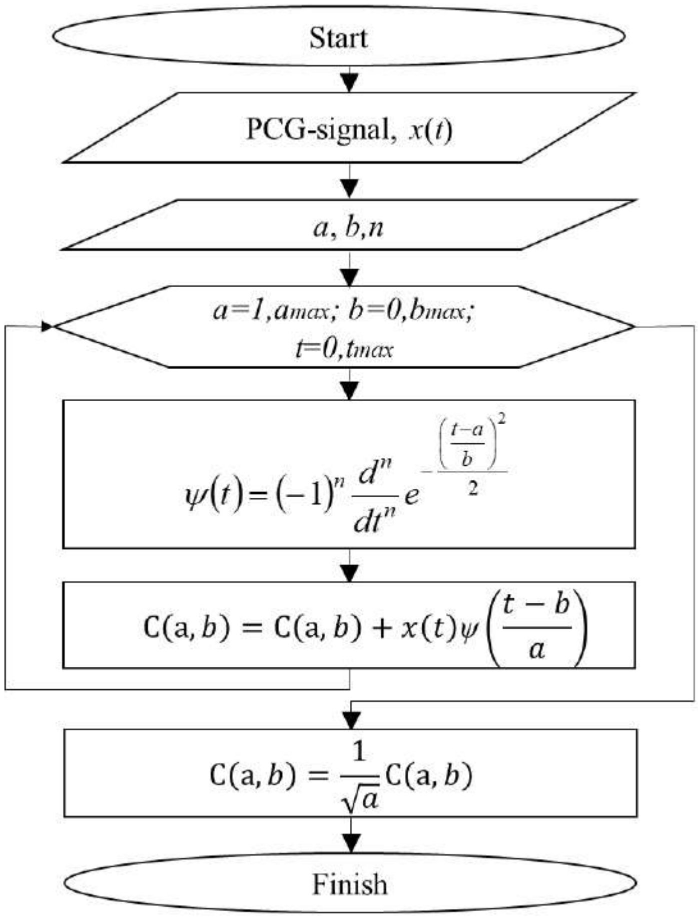

Figure 3. Wavelet algorithm for PCG-signal processing with a Gaussian basis

In Fig. 4 shows graphical images of realizations of the amplitude wavelet spectra of the PCG-signal depending on the frequency and scale in conditions of medical norm and aortic stenosis. This approach provides a detailed study of fluctuations in both frequency and time dimensions, taking into account the different scales, which provides a procedure for a full-fledged analysis of the PCG-signal in all spaces at the same time.

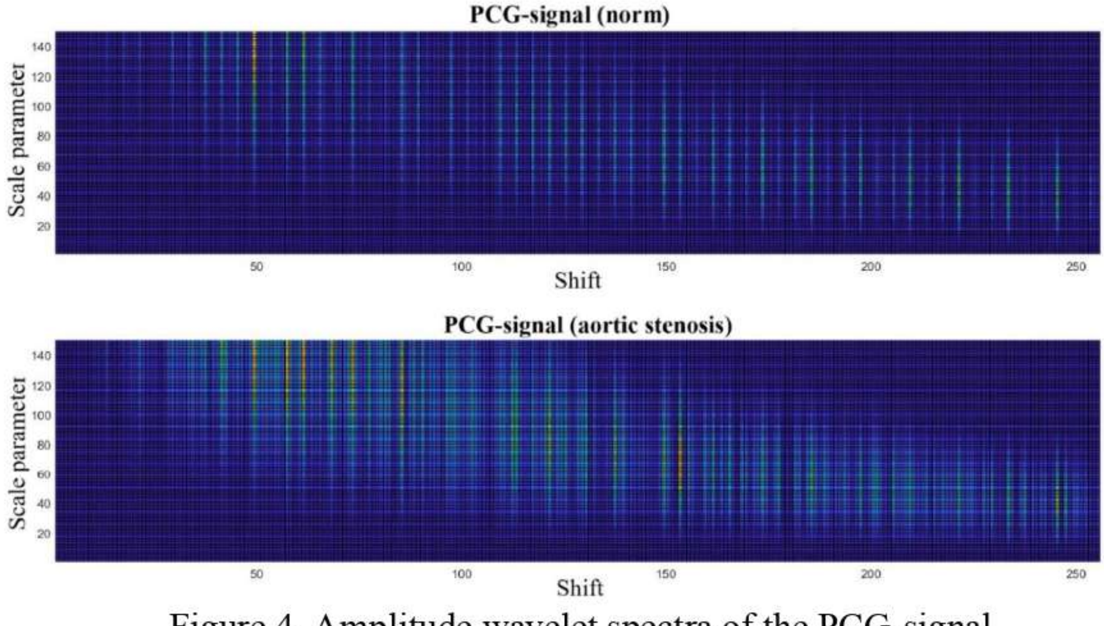

Figure 4. Amplitude wavelet spectra of the PCG-signal

Amplitude wavelet spectra (Fig. 4) in their dependence on the scale parameter and shift quantitatively reflect the localization processes in the structure of the PCG-signal and its temporal variability. Fig. 4 shows that the structural homogeneity of the wavelet spectra in the Gaussian basis is noted for the states of normality and aortic stenosis, but there is a change in the amplitude values, which indicates variability in the functioning of the heart valves. Aortic stenosis is characterized by an increase in the intensity of spectra and an increase in their density, in contrast to the normal state.

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