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APPLICATION OF THE DOBESHI WAVELET METHOD IN DIGITAL PROCESSING OF SIGNALS

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Abstract: This article is devoted to the construction of Weivlet models, which are considered important in digital processing of Biomedicine signals. These models were built using Dobeshi veyvlets. Dobeshi Weyvlet models have high accuracy in digital performance of Biomedicine signals, this makes a significant contribution to the patient's disease response to provide useful information on how physicians make decisions. As an example, the initial experimental data of its signal from human body sensors were obtained, and on the basis of these data, Dobeshi Weyvlet models were built and their errors were assessed. It is known that Dobeshi wavelets were used in order to reduce signals error, and as a result, error reduction was achieved.

Keywords: Dobeshi veyvlet, Veyvlet modification, digital performance error, scaling and Veyvlet function.

Introduction. Scientific advancement globally, especially in the field of medicine, is currently relying on modern diagnostic methods based on information technologies. Developing computer technologies is one of the fundamental issues in contemporary healthcare, where numerical processing methods for biosignals extracted from the human body play a crucial role. Therefore, the development and utilization of computer technologies in creating numerical processing methods for biosignals are of great importance in modern medicine.

As a result, the non-invasive recording of temperature from various points on the human body and numerical processing of signals using wavelet methods have gained significant importance in the current era. Digital processing of signals aims to extend, store, and extract valuable information through various modifications. Wavelets are generalized mathematical functions for specific types of signal processing, localized in both time and frequency. They capture all functions in a single basis, and their extraction and representation in time and frequency domains are obtained through changes introduced in the wavelet transform.

Therefore, the use of wavelet methods in the development of numerical processing techniques for biosignals holds substantial importance in contemporary medicine. This involves analyzing and localizing time functions in terms of time and frequency, contributing to the efficient management of specific medical devices, the study of various biological signal types, and the proper handling of surgical procedures. As a result, the integration of wavelet methods is crucial for the advancement of current medical practices and the robustness of ethical, rare, and technological progress.

It is known that many signals are composed of harmonics (sinusoids) at different frequencies. However, sinusoidal components are infinite, and in these functions, changes in the signal over time are not captured. To preserve changes, instead of infinite waves, short waves are used, which accept exactly the same values during their time interval for storage.

A wavelet consists of functions with a compact appearance, and it is used not only for periodic functions, but also for non-periodic functions.

In the engineering challenges of applying the theory of digital signal processing, wavelets are utilized in solving problems related to numerical solutions of differential equations, the theory of approximation, and some theoretical issues in the theory of functions.

Preliminary Information

The following is a description of the Discrete Wavelet Transform method, particularly focusing on the analysis of the Daubechies wavelet, which is commonly used in providing numerical processing for signals in our article. In addition, the possibility of developing a fast wavelet transform algorithm for discrete signals has emerged. One of the advantages of this algorithm is that it requires c·N operations for signal transformation and reconstruction. Here, c- is the number of coefficients, and N- is the number of discrete values of the signal.

It should be emphasized that the construction of Daubechies wavelets is based on the scaling function, and therefore, it involves coefficients at specific levels. This particular characteristic led us to choose Daubechies wavelets for the purpose of signal transformation in biomedical signal processing, as discussed in this article.

The scaling function and the wavelet equation have been formulated for constructing the Daubechies wavelet:

$$\begin{aligned} \varphi(t) &= \sqrt{2}\sum_k h_k \varphi(2t-k) \\ \psi(t) &= \sqrt{2}\sum_k g_k \varphi(2t-k) \end{aligned} \tag{1}$$

The wavelet function $\psi(t)$ of the Daubechies wavelet is typically denoted by the letter D, and it is characterized by appending a number that corresponds to the suitable scale for the Daubechies wavelet, such as D2, D4, D6, indicating the added numbers for the appropriate scale.

The conditions of orthogonality and compact support for wavelet transformation are stated as follows:

$$|m_0(\omega)|^2 + |m_0(\omega+\pi)|^2 = 1 \tag{2}$$

here,

$$|m_0(\omega)| = \sum_n \frac{h_n e^{-in\omega}}{\sqrt{2}}$$

$$\frac{d^l \psi\omega}{d\omega}\Big|_{\omega=0} = 0, \qquad l = 0,1,\ldots,N-1$$

$$m_0(\omega) \infty \left(\frac{1+e^{i\omega}}{2}\right)^N$$

$$M_0(\omega) = \cos^{2N}\frac{\omega}{2} \cdot L(\omega)$$

here,

$$L(\omega) = P\sin^2\frac{\omega}{2}$$

$m_0(\omega)$ is used to find the h_n coefficients, in this case, the form of the polynomial P is as follows:

$$P(y) = (1-y)^{-N}(1-y^N P(1-y))$$

The coefficients of scaling and wavelet functions in formula (1), represented by h_k and g_k, are in a corresponding relationship, forming the scaling and wavelet transform coefficients, for them, according to formula (2), the following equality holds:

$$\begin{cases} h_0^2 + h_1^2 + h_2^2 + h_3^2 = 1 \\ h_2 h_0 + h_3 h_1 = 0 \\ h_3 - h_2 + h_1 - h_0 = 0 \\ 0h_3 - 1h_2 + 2h_1 - 3h_0 = 0 \end{cases}$$

by solving this equation,

$$h_0 = \frac{1+\sqrt{3}}{4\sqrt{2}}, \; h_1 = \frac{3+\sqrt{3}}{4\sqrt{2}}$$

$$h_2 = \frac{3-\sqrt{3}}{4\sqrt{2}}, \; h_3 = \frac{1-\sqrt{3}}{4\sqrt{2}}$$

After determining the h_k coefficients, g_k coefficients are determined through the following relationship using the h_k coefficients:

$$g_k = (-1)^k h_{2M-k-1}$$

$$g_0 = h_3, \; g_1 = -h_2, \; g_2 = h_1, \; g_3 = -h_0$$

The calculation of the coefficients $\{a_i, \; d_i\}$ is required $\varphi(t)$ for the wavelet transform. These coefficients are determined through the following integral·

$$a_k = (f, \varphi_k) = \int_R f(x)\overline{\varphi_k(x)}dx \qquad (3)$$

$$d_k = (f, \psi_k) = \int_R f(x)\overline{\psi_k(x)}dx \qquad (4)$$

It is necessary to emphasize that the problem of finding coefficients $\{a_i, d_i\}$ in (3) and (4) involves the computation of multiple integrals. To solve this problem, Mall's recommended method utilizes a fast wavelet transform approach. The Mall algorithm provides the capability to compute wavelet modification coefficients using algebraic operations.

$$a_i = h_0 f_{2i} + h_1 f_{2i+1} + h_2 f_{2i+2} + h_3 f_{2i+3}$$
$$d_i = g_0 f_{2i} + g_1 f_{2i+1} + g_2 f_{2i+2} + g_3 f_{2i+3} \quad (5)$$

a_i scaling coefficients of Daubechies, d_i wavelet coefficients of Daubechies.

This equation (5) provides fast algorithms for computing wavelet coefficients. According to the formula (5), the wavelet modification based on Daubechies wavelet is expressed as follows:

$$D(a,b) = \sum_i a_i + \sum_i d_i \quad (6)$$

When the fourth-order wavelet modification of Daubechies is applied, two coefficients for the scaling function $\varphi(t)$ are set to zero.

3. Analysis of Digital Processing of Signals Obtained from Temperature Sensors of the Human Body.

Based on the introduced model, preliminary data obtained from human body sensors were digitally processed using Daubechies wavelet method.

Errors arising from the interpolation of signals obtained from human body sensors using Daubechies wavelet method were evaluated according to formula (6). The absolute and relative errors of digital processing of signals using Daubechies wavelet method are evaluated as follows.

$$\Delta = \max_{a \le x \le b} |f(x_i) - db_i| \quad (7)$$

$$\delta = \frac{|f(x_i) - db_i|}{f(x_i)} \cdot 100\% \quad (8)$$

In this context, Δ - denotes the absolute error in Daubechies wavelets, and δ - represents the relative error of Daubechies wavelet. Using formulas (7) and (8), let's present the evaluation of errors in the form of a table.

Table 1

x(i)	Human body temperature	Db2	f-db2	error
0	30,8	30,75	0,05	
0,1	30,6	30,02	0,58	
0,2	30	29,73	0,27	
0,3	29,8	29,71	0,09	
0,4	29,3	29,23	0,07	0,008
0,5	29,5	29,41	0,09	
0,6	29,7	29,62	0,08	
0,7	30	29,93	0,07	
0,8	30,2	30,14	0,06	
0,9	30,5	30,01	0,49	
1	30,3	30,22	0,08	

In the table, recent body temperatures are presented, including:

- The interpolation result in the second scaling of the Daubechies wavelet for Db2 dataset.

- The difference (discrepancy) between the recent data and the interpolation results for the f-db2 dataset.

The graph in Figure 1 depicts the results of digital processing of body temperature data using the Daubechies (db2) wavelet method.

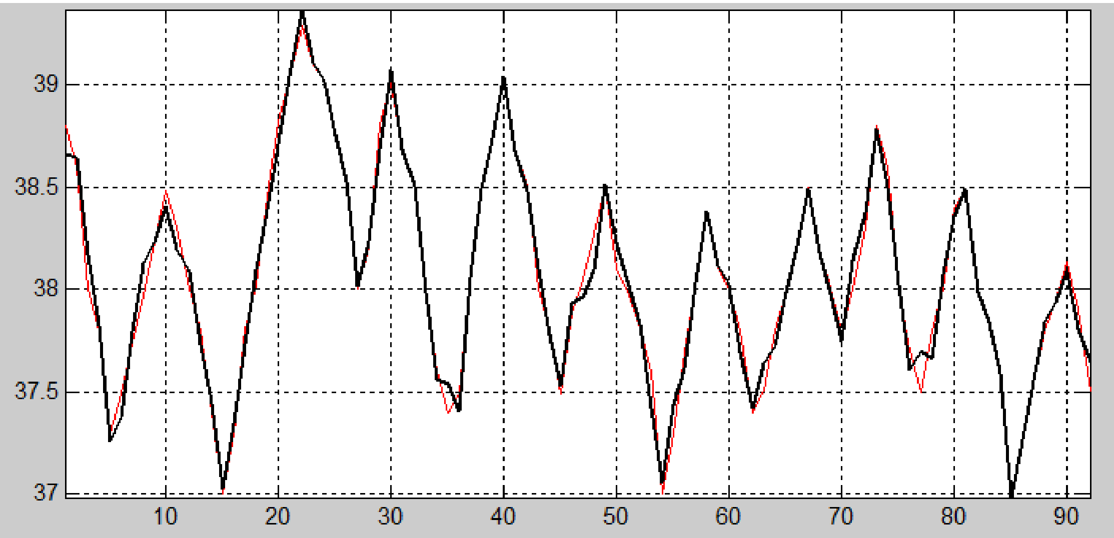

Figure 1. Graph of the results of digital processing of body temperature data using the Daubechies (db2) wavelet method.

The red lines in the 1- figure represent the signal obtained from the human body temperature sensor, while the black lines depict the interpolation result using Daubechies (db2) wavelet.

Conclusion. A numerical processing model for the signal obtained from human body temperature sensors using Daubechies wavelets was developed, and its errors were evaluated. The obtained results indicate that in the evaluation process, the numerical processing error of Daubechies wavelets in interpolating the signal from human body temperature sensors was equal to 0.008%.

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