How to Cite:
Urakov Sh, U., Juraev, J. U., Kholmurodova, D. K., Raxmanova, F. E., & Tohirova, F. O. (2022). Using biomedical signals with the help of fragmentary-wavelets on digital processing. *International Journal of Health Sciences*, *6*(S8), 950–959. https://doi.org/10.53730/ijhs.v6nS8.9962

Using biomedical signals with the help of fragmentary-wavelets on digital processing

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***Abstract*---**This article is devoted to rebuilt for an important fragmentary of wavelet models of Biomedical Signal Processing. These models were built using Haar's fragmentary-unchanged wavelets as well as Doubechi wavelets. The Haar's fragmentary-unchanged wavelets models has a high accuracy for Biomedical signals on digital work, and this provides doctors for making any useful decisions about the patients diseases. For example, the first signal of Gastroenterology experimental information was took, and there were built on the basis of this information the of fragmentary-unchanged and Doubechi wavelet models and evaluated their errors. It is known that modification of signals using fragmentary wavelets results in formation of orthonormal wavelets, due to there will be sharp increase in errors along the signal graph, thus in order to reduce errors Doubechi wavelets were used and achieved the goal.

***Keywords*---**Doubechi wavelets, conversion wavelets, digital processing error, relative error, orthonormal wavelets.

Manuscript submitted: 27 March 2022, Manuscript revised: 9 May 2022, Accepted for publication: 18 June 2022

Introduction

There are many types of wavelets available today. The most common is the Haar's wavelets. The Haar's wavelets is expressed in an iterative form. The main disadvantage of the Haar's wavelets is, it has lack of analytical views of function and also increase errors in the restoration of compression coefficients. It should be noted that any type of wavelet advantage of the signal depends on analysis[2], because scaling functions of wavelets apparently interpreted to the different types analyses.

In matters of image recognition from wavelets, during the processing and synthesis of various signals, such as speech, in the analysis of various images in nature (color of the retina, radiography of the kidney, studying the surface properties of crystals and nanoobjects, satellite images of clouds or planetary surfaces, etc. can be used in the study of the properties of vortex fields and in other cases [14].

The wave lines of extend along the signal graph with the time of axis. In most cases, the Haar's-wavelets graph closer along the form of a one-way wave lines signal, which some signals compress a handful of good results. Its mathematical interpretation allows the analysis of wave states at different frequencies. The amplitude of the graph of the Haar's-wavelet function decreases to zero and produces vibration waves[1].

The Main Part

Construction of the Haar's-Wavelet

The Haar's wavelet has fast-conversion algorithms, and its orthogonal wavelest is widely used in solving practical problems. In the Haar's bases [2] it is considered as a wavelet. The Haar's wavelets attract the attention of experts for two reasons:

1. To reduce the number of coefficient relative to the total number of binary segments (giving for accuracy approach).
2. Absence of "long" operations in the calculation of coefficients. It only uses adding,scaling and conversion operations.

Deficiency of the Haar's fragmentary-unchanged wavelets is increasing errors while approaching to signal, that exceed 0.1% of the signal to ensure the accuracy of coefficients that it will be required to memorize[4].

The process of signaling the wavelets are based on the use of two types of functions[3]: the wavelet function and the scaling function, they are built by a single mother wavelet $\psi(t)$, moving along the signal in time *b* and conversion the time scale *a*:

$$\psi_{ab}(t) = \frac{1}{\sqrt{|a|}}\psi\left(\frac{t-b}{a}\right), \quad (a,b) \in R, \; \psi(t) \in L^2(R)$$

In the digital signal processing, wavelet[12] functions are used to separate the details and local properties of signals, and a scaling function is used to approximate signals. In the selection of wavelet functions, special attention was paid to their characteristics such as smoothness, carrier size, and the number of zero-value cases[6].

We define V^0 a set of invariant functions in all $[0,1]$ intervals, that is, a set of linear vectors. In this case, the following scaling function belongs to the set-V^0:

$$\phi(t) = \phi_{0,0}(t) = \begin{cases} 1, & 0 \le t < 1 \\ 0, & \text{otherwise} \end{cases} \qquad (1)$$

when scaling function is $i = 0$.

V^1-set $\left[0, \frac{1}{2}\right]$ and $\left[\frac{1}{2}, 1\right]$ are the set of functions that do not change in the interval, it forms linear vectors. The scaling function belongs to the V^1-set and is considered as its wavelet functions[5]:

$$\phi_{1,0}(t) = \phi(2t) = \begin{cases} 1, & 0 \le t < \frac{1}{2} \\ 0, & \text{otherwise} \end{cases}$$

and

$$\phi_{1,1}(t) = \phi(2t-1) = \begin{cases} 1, & \frac{1}{2} \le t < 1 \\ 0, & \text{otherwise} \end{cases} \qquad (2)$$

when scaling function is $i = 1$.

This function is constant in the $[0,1]$ interval, $\left[0, \frac{1}{2}\right]$ and in the $\left[\frac{1}{2}, 1\right]$ intervals as well. Therefore, each element of the V^0 set is also an element of the set V^1, i.e. the relationship is appropriate. We define collection in a similar way of the set, V^2- $\left[0, \frac{1}{4}\right]$, $\left[\frac{1}{4}, \frac{1}{2}\right]$, $\left[\frac{1}{2}, \frac{3}{4}\right]$, $\left[\frac{3}{4}, 1\right]$ Collections of functions relative to interval. A V^n set of similar scaling functions, i.e.

$$\phi_{n,j}(t) = \phi(2^n t - j), \; j = 0,1,\ldots,2^n - 1$$

$$0 \le 2^n t - j < 1, \; \frac{j}{2^n} \le t < \frac{j+1}{2^n}$$

$$\phi_{n,j}(t)=\begin{cases}1, & \frac{j}{2^n}\le t<\frac{j+1}{2^n}\\ 0, & \text{акс холда}\end{cases},\quad j=0,1,\ldots,2^n-1 \quad (3)$$

$$V^0\subset V^1\subset\ldots\subset V^n\subset\ldots$$

Here, $i=n$ of scaling function is $0\le 2^n t-j<1,\ \frac{j}{2^n}\le t<\frac{j+1}{2^n}$

the scaling function of conversion interval, relating the $\phi_{n,j}(t)$ - to V^n scale functions, that includes scalar multiplication of vectors collection, thus, these collections consist of Euclidean Space. In our case, as a scalar multiplication

$$(f,g)=\int_0^1 f(t)g(t)\,dt \quad (4)$$

we obtain the view that the coefficients are determined using this formula,

in that case $\phi_{n,j}(t)=\sqrt{2^n}\phi(2^n t-j),\quad j=0,1,\ldots,2^n-1$

Using Figures (3) and (4), find the coefficients of the Haar's wavelet:

$$C_n=\int_0^1 \phi_n(x)f(x)\,dx \quad (5)$$

The formula for finding the coefficients of the Haar's wavelet:

$$f(x)\cong\sum_{n=0}^{\infty}C_n\phi_n(x) \quad (6)$$

The Haar's scaling function draws a graph of the change in the different values of m and k (Figure 1).

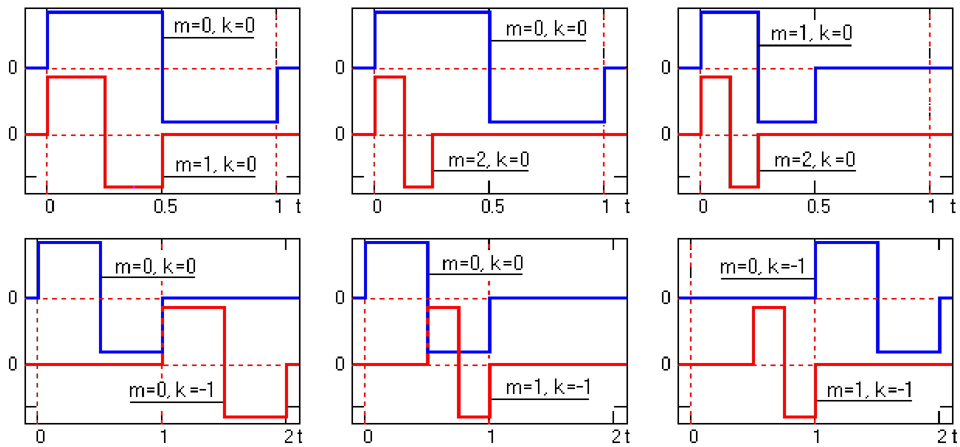

Figure 1. Graph of changing of the Haar's scaling function

Based on the model of Gastroenterology signal, in the first experimental information of invariable-piece wavelets is carried out digital processing (Figure2).

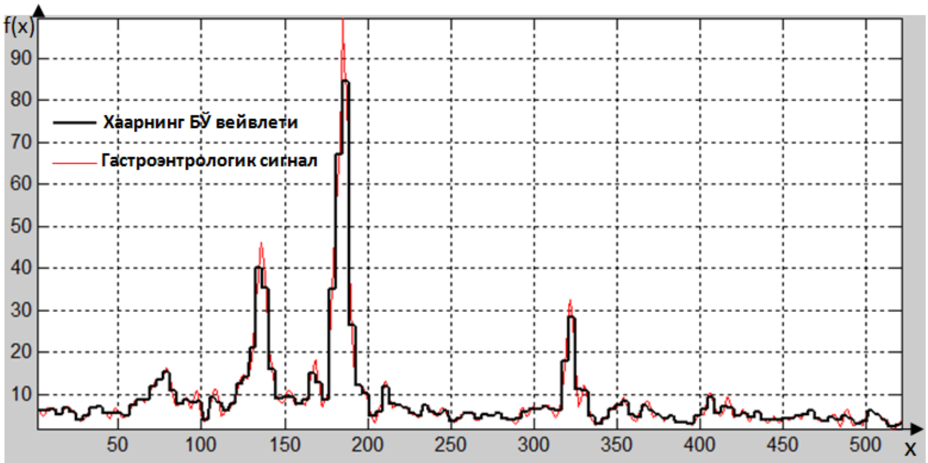

Figure 2. Digital processing in the analysis of Gastroenterology signal of the Haar's scaling wavelets

Construction of Doubechi wavelets

Wavelet conversion is expressing giving function to the wavelet function images[8]. Wavelet is the small wave or the wave that suddenly jump. Today wavelet has been using widely for conversion to digital signal processing, image, audio compression and many other areas. In the 80 years of the last century, Grossman and Morley carried out scientific research on the theory of the wavelet cconversiong. Except it, there are available Furen and DKC (discret kosinus conversion) methods, the main drawback of these methods are the basic harmonic components function of wavelet conversion does not work appropriately when it is periodically sequence is not good and in the result, the opportunity to restore a part of the information is lost, for this reason, in order to eliminate these defects, the perfect way is to move on Doubechi wavelet. In 1988 Doubechi called the attention of specialists in the analysis orthogonal wavelet change. It should be noted that, Doubechi wavelet is built on the basis of scaling for a limited number of coefficient indicators[7].

To build the Doubechi wavelet, we write the scaling and wave equation:

$$\varphi(t) = \sqrt{2}\sum_k h_k \varphi(2t-k)$$

$$\psi(t) = \sqrt{2}\sum_k g_k \varphi(2t-k) \quad (7)$$

The wave function $\psi(t)$ of a Doubechi wavelet is usually denoted by the letter D, and is formed by adding a number corresponding to the Doubechi wavelet scale, i.e., D2, D4, D6.

Here are the conditions of orthogonality and smoothness of the wavelet change[10]:

$$\left|m_0(\omega)\right|^2 + \left|m_0(\omega+\pi)\right|^2 = 1 \tag{8}$$

here,

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

$$\frac{d^l \psi\omega}{d\omega}\Big|_{\omega=0} = 0, \qquad l = 0,1,\dots,N-1 \tag{9}$$

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

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

here,

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

h_n to find the coefficients to be used , $m_0(\omega)$ and P polynom's view will be as follows:

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

The form h_k and g_k formula (7) are the coefficients of the scaling and wave equations, respectively, h_k for which g_k the following equation is appropriate according to formula (8):

$$\begin{cases} h_0^2 + h_1^2 + h_2^2 + h_3^2 = 1 \\ h_2h_0 + h_3h_1 = 0 \\ h_3 - h_2 + h_1 - h_0 = 0 \\ 0h_3 - 1h_2 + 2h_1 - 3h_0 = 0 \end{cases} \tag{10}$$

Solve 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 the h_k–coefficients are determined, with the help of h_k we identify g_k according to the following relationship[11]:

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

$$g_0 = h_3,\ g_1 = -h_2,\ g_2 = h_1,\ g_3 = -h_0 \tag{9}$$

To change the wavelet of the function $\varphi(t)$,it is necessary to calculate the coefficients$\{a_i,\ d_i\}$.These coefficients will be found through the following integral [8]:

$$a_k = (f, \varphi_k) = \int_R f(x)\overline{\varphi_k(x)}dx \tag{10}$$

$$d_k = (f, \psi_k) = \int_R f(x)\overline{\psi_k(x)}dx \tag{11}$$

It should be noted that in (10) and (11) there is a problem of calculating a large number of integrals to find the coefficients $\{a_i,\ d_i\}$. To solve this enigma is used proposed the rapid change wavelet method by Malla [13]. Malla's algorithm allows the use of calculating by using algebraic operations of changed wavelet coefficients:

$$a_i = h_0 f_{2i} + h_1 f_{2i+1} + h_2 f_{2i+2} + h_3 f_{2i+3}$$

$$d_i = g_0 f_{2i} + g_1 f_{2i+1} + g_2 f_{2i+2} + g_3 f_{2i+3} \tag{12}$$

a_i Doubechi scaling coefficients, d_i Doubechi Wavelet coefficients. These equations (12) provide fast algorithms for calculating wavelet coefficients. (12) According to the formula Doubechi wavelet changes based on the following links:

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

When the fourth regularly wavelet of Doubechi changes out, for the scaling function $\varphi(t)$ two coefficients turn into a zero[7].

If N=4 state (D4- the fourth regularly wavelet of Doubechi changes)

The mother Doubechi[9] wavelet and scaling wavelet are shown in the in Figure 3.

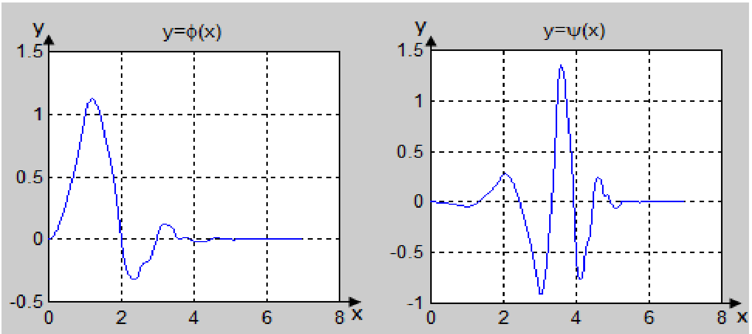

Figure 3. For the case of N=4 Doubechi scaling and mother wavelet functions(D4-the fourth Doubechi regularly conversion wavelet)

Based on the model of Gastroenterological signal, the first experimental tick of information of b N= 4 case is carried out digital processing for the fourth Doubechi regularly conversion (D4) wavelet. (Figure 4).

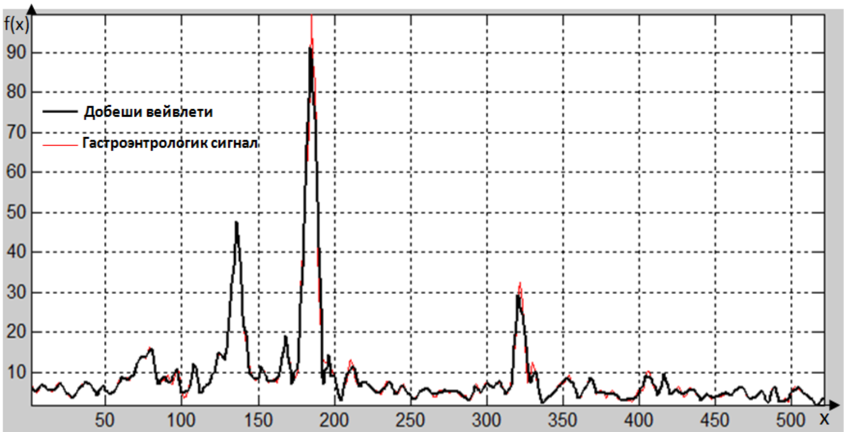

Figure 4. Digital processing of gastroenterological signal in Doubechi wavelets(D4)

Error Evaluation

Here are the digital processing errors in the Haar's fragmentary -unchanged and Doubechi wavelets.

Revealing on $[a,b]$ continuous function $f(x)$ in [2], segment $[a,b]$ we can divide the node into dots.

$$a \le x_0 < x_1 < \ldots < x_i < \ldots < x_n \le b$$

$$h = x_{i+1} - x_i = const \quad (15)$$

h - the distance between nodes.

There are formulas for determining the methodological errors of interpolation for polynomials of different levels. For example, for zero-level polynomials (for fragmentary -unchanged wavelets), the error estimation formula is:

$$\left|P(x)-f(x)\right| \leq \frac{1}{2}\max\left|f^{'}(x)\right|h$$

Here is an assessment of the relative errors of digital processing of the gastroenterological signal in Haar's fragmentary-unchanged wavelets:

$$\delta_1 = \frac{\left|f(x_i)-har(x_i)\right|}{f(x_i)} \cdot 100\% = 0{,}087679\,\%$$

δ_1 - Relative error of Haar's fragmentary-unchanged wavelets.

Here is an assessment of the relative errors of interpolation of the gastroenterological signal in Doubechi wavelets:

$$\delta_2 = \frac{\left|f(x_i)-D_i\right|}{f(x_i)} \cdot 100\% = 0{,}030609\,\%$$

δ_2 - The relative error of the Doubechi wavelet

Using formulas of (16) and (17), we evaluate relative errors according to the table (Table 1).

Table 1

No	Evidence of ECG signal	Interpolization on the Haar's fragment unchanged wavelet	ECG - Haar's $\left|f(x_i)-har(x_i)\right|$	Relative error on the Haar's fragment-unchanged wavelet %	Interpolization on the Doubechi wavelet	Doubechi - ECG $\left|f(x_i)-D_i\right|$	Relative error on the Doubechi wavelet %
0	6,370065	6,322574	0,047491	0,087679	6,370065	0	0,030609
1	6,370065	6,329703	0,040362		6,370065	0	
2	5,835327	5,843876	0,008549		5,767959	0,067369	
3	5,30059	5,322287	0,021697		5,467959	0,167369	
4	4,765852	4,381673	0,384179		4,666906	0,098946	
5	5,567959	5,461979	0,10598		5,466906	0,101054	
6	6,637434	6,401045	0,236389		6,771119	0,133685	
7	6,904803	6,99168	0,086877		6,771119	0,133685	
8	6,904803	6,784235	0,120568		6,837434	0,067369	
9	6,370065	6,29328	0,076785		6,374340	0,004275	
10	6,370065	5,992511	0,377554		6,302696	0,067369	

Conclusion

Using the Haar's-wavelet modification, the gastroenterological signal was evaluated by constructing a digital operation model in the Haar's fragmentary-unchanged and Doubechi wavelets and evaluating its errors. Based on the results of the analysis, in the process of evaluation the number of Gastroenterology signal node points for 521, the process of digital on the Haar's fragmentary-unchanged wavelets indicated of 0,087679% relative errors, and digital processing of

Doubechi wavelet indicated 0,030609% relative errors. Based on the results, digital processing on the Doubechi wavelets estimated the smallest errors as well. To conclude, it is possible to present that, in the process of digital signals Doubechi wavelets are able to make good results.

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