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THE PROBLEM OF APPROXIMATING SIGNALS BASED ON MODELING OF WAVELET - HAAR TRANSFORMATION

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ANNOTATION

This paper discusses the problem of digital processing of signals and images in computer networks, in the process of signal transmission, expressing them as an unknown function and approximation using a discrete Wavelet-Haar basis function. The calculation of the spectral coefficients of the signals and the mathematical expressions of the signal recovery are given. In order to increase the speed of operation, the law of derivation of coefficients from each other by grouping and systematization of spectral coefficients has been identified.

KEYWORDS: ***Signal, basic function, Wavelet-Haar, algebraic polynomial, approximation, spectral coefficient, systematization, register.***

INTRODUCTION

As a result of the rapid development of computer technology in the world, new issues of digital processing of signals and images are emerging. Alternatively, effective mathematical methods and algorithms are needed to transmit signals and images over a network and allocate them less space in memory. In solving these problems, a number of results have been obtained using basic functions such as Fure, Walsh-Adamar, Haar, Wavelet.

A number of scientific studies have been conducted around the world on the modeling of digital processing of signals and images using basic functions, compression of signals, filtering, modification, recovery and creation of effective calculation algorithms for noise isolation from signals. A.Haar, S.Mallat, I.Daubeschie, Ch.Chui, James Walker, A.Spanias, Bill Lewis, M.Vetterli, Plamen Krastev, A.N.Yakovlev, N.M.Astafeva, L.A.Zalmanzon, M.A.Ivanov, M.A. Klochkov and other scientists engaged on the creation and improvement of mathematical models of digital signal processing in computer systems, their rapid algorithms and software. In the Republic of Uzbekistan, scientists like F.B. Abutaliev, H.N. Zaynidinov, M.M. Musaev, U. Hamdamov, F. Rakhmatov and others conducted research.

This paper discusses the problem of approximating signals using the discrete Wavelet-Haar variation in solving the problems listed above. The main purpose is to express the unknown $f(x)$ incoming signal in the form of a function, to bring it to the following form

$$F(x)=\sum_{j=0}^{k} A_j \cdot x^j \qquad (1)$$

and to show certain advantages in the approximation process by comparing the changes. [4].

Wavelet-Haar direct and inverse variation is in the $[0, 2^n-1]$ interval range:

$$v_s = 2^{-n+m}\sum_{x=0}^{2^n-1}\varphi(x)\psi_{m,s}(x),$$

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$$\varphi(x)=v_{0,0}\psi_{0,0}+\sum_{m=0}^{n-1}\sum_{s=1}^{2^m}v_{m,s}\psi_{m,s}(x)$$

herein $0 \le n < \log_2 N$ and $m=0,1,2,\dots n-1$, $1 \le s \le 2^m$.

$\psi_{m,s}(x)$ - The basic function of the Wavelet-Haar transformation:

$$\psi_{0,1}(x)=\begin{cases}1, & 0 \le x < \frac{1}{2},\\ -1, & \frac{1}{2} \le x < 1,\\ 0, & x<0, \quad x \ge 1.\end{cases}$$

or

$$\psi_{0,1}(x)=\begin{vmatrix} 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1\\ 1 & 1 & 1 & 1 & -1 & -1 & -1 & -1\\ 1 & 1 & -1 & -1 & 0 & 0 & 0 & 0\\ 0 & 0 & 0 & 0 & 1 & 1 & -1 & -1\\ 1 & -1 & 0 & 0 & 0 & 0 & 0 & 0\\ 0 & 0 & 1 & -1 & 0 & 0 & 0 & 0\\ 0 & 0 & 0 & 0 & 1 & -1 & 0 & 0\\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & -1 \end{vmatrix}$$

$f(x)$ the signal spectra given in an unknown form are calculated using the following formula for N values of the signal spectra on the basis of Wavelet-Haar[4]:

$$v_s=\sum_{j=0}^{k}b_s\cdot A_j\ , \qquad (2)$$

herein $s=0,1,2,\dots,N-1,$

k – Algebraic polynomial level; v_s – signal spectral coefficient;

b_s – base function matrix; A_j – algebraic polynomial coefficient.

Using this expression (2), the following expressions for finding the Wavelet-Haar spectral coefficients for N=8 and $k=2$ are obtained:

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$$
\begin{aligned}
&v_0 = \frac{35}{2^7} A_2 + \frac{7}{2^4} A_1 + A_0 && v_4 = -\frac{1}{2^7}\left(A_2 + 2^3 A_1\right) \\
&v_1 = -\frac{7}{2^5} A_2 - \frac{1}{2^2} A_1 && v_5 = v_4 - \frac{A_2}{2^5} \\
&v_2 = -\frac{1}{2^6}\left(3A_2 + 2^3 A_1\right) && v_6 = v_5 - \frac{A_2}{2^5} \\
&v_3 = v_2 - \frac{A_2}{2^3} && v_7 = v_6 - \frac{A_2}{2^5}
\end{aligned} \qquad (3)
$$

Since a number of elements of the Wavelet-Haara base matrix form a group

$v_0 = v_{00}$, $v_1 = v_{01}$, $v_2 = v_{11}$, $v_3 = v_{12}$, $v_4 = v_{21}$, $v_5 = v_{22}$, $v_6 = v_{23}$, $v_7 = v_{24}$

it is possible to obtain a general expression of the coefficients depending on the groups, using the following definitions and expressions of the Wavelet-Haara spectral coefficients above:

$$
v_{mj} = -2^{-(m+2)} A_1 + 2^{-(m+5)}\left(1 + 2^{3-m}(1 - 2j)\right) A_2 \qquad (4)
$$

herein m-group (m=0,1,2,…), j- m- the order of the coefficients in the group (j=1,2,...). Wherein v_{00} – the coefficient is found from expression (6). This can be seen from expression (4), v_{mj} – it follows that the coefficients are structured, i.e. it is possible to generate one from the other. In the presence of a spectral coefficient, the restoration of the function is performed by the expressions in Table 1.

Table 1
Find the algebraic polynomial coefficients

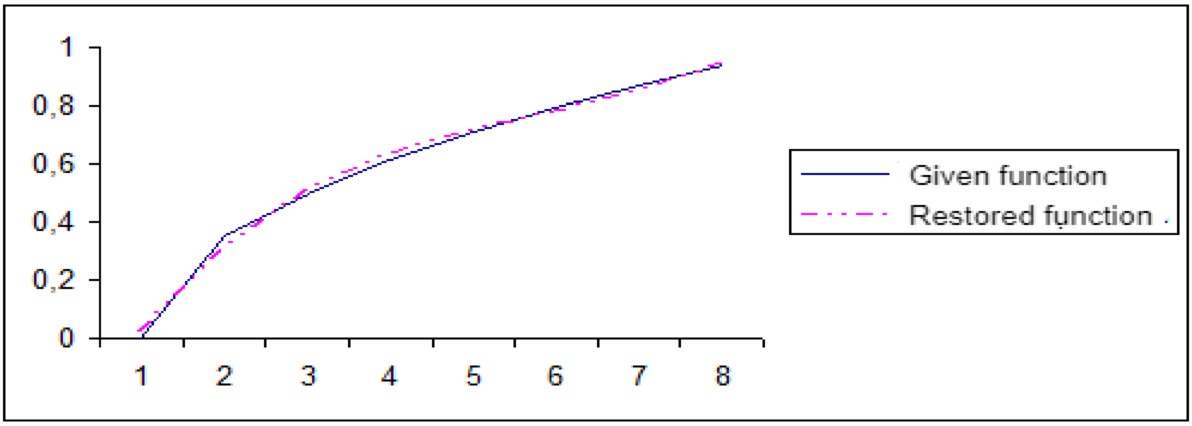
for $k = 2$	for $k = 3$
$A_0 = v_0 - \frac{35}{2^7} A_2 - \frac{7}{2^4} A_1$	$A_0 = v_0 - \frac{49}{2^8} A_3 - \frac{35}{2^7} A_2 - \frac{7}{2^4} A_1$
$A_1 = -\frac{9}{2^3} A_2 - 2(2v_1 - v_2 + v_3)$	$A_1 = -\frac{89}{2^7} A_3 - \frac{7}{2^3} A_2 - 2^2 v_1$
$A_2 = 2^4(v_2 - v_3) - 2^3(v_4 + v_5 - v_6 - v_7)$	$A_2 = 2^3(v_3 - v_2) - \frac{2^4}{21} A_3$
	$A_3 = \frac{2^7}{3}(v_1 - v_2 - v_3)$

As an example, the function $\varphi(x) = \sqrt{x}$ in the interval range [0; 1] the expression in the form of an algebraic polynomial for N = 8 when k = 3 is given in Table 2.

Table 2

calculation of spectral and polynomial coefficients of function $\varphi(x)=\sqrt{x}$

№	x	$\varphi(x)$	v_k	A_k	$\overline{\varphi}(x)$	max δ (%)	σ (%)
0	0	0	0,5956	0,68006	0,01899	0,5	0,2
1	0,125	0,35355	-0,229	0,081	0,31123		
2	0,25	0,5	-0,19	-0,016	0,50814		
3	0,375	0,61237	-0,076	0,00421	0,635		
4	0,5	0,70711	-0,177		0,71707		
5	0,625	0,79057	-0,056		0,7796		
6	0,75	0,86603	-0,042		0,84787		
7	0,875	0,93541	-0,035		0,94714		



Pic1. $\varphi(x)=\sqrt{x}$ function and its approximation

CONCLUSION

It can be seen that the Wavelet-Haar base matrix consists of the numbers -1 and 1. In addition, the use of (2^n) in the grouping of spectral coefficients by expression (4) makes it possible to replace the multiplication operation with the pushing of numbers within registers. This increases the processing speed.

Given the spectral coefficients, in the calculation of polynomial coefficients by expression (4), the law of derivation of coefficients from each other was determined, reducing the reference to systematized memory within the group. It is advisable to use this method in digital processing of stationary signals. The use of these expressions leads to the effective solution of issues such as signal approximation, filtering and compression, as well as transmission over the network.

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