A Simulink-Model of Specialized Processor on the Piecewise-Polynomial Bases

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Abstract— **The structure of the specialized processor of signal processing in piecewise-polynomial bases was developed and tested. By using MATLAB environment with application standard Simulink we were able to model the algorithms and structure of the specialized processor.**

Keywords— signal, basis, spectrum, fast transformations, effect of compression, piecewise-polynomial bases

I. INTRODUCTION

The major problem is finding-out the thin structure of signals, quick identification of local features, forecasting the development of processes and also during time aspiration to use the limited number of processing processors in parallel-conveyor computing systems for the purpose of cost reduction by researches.

For construction of patterns of the signals received from actual objects, traditional harmonious functions are widely applied. It explains that many signals received from actual objects can be easily presented by a set of sine wave and cosine fluctuations for which the device of Fourier analysis is used. The result is the transition from time to frequency functions. However, representation of time function sine and cosine functions is a few of many representations. Any full system of orthogonal functions can be applied for the decomposition in numbers which correspond to Fourier series.

II. THEORETICAL DATA

Elementary functions which are decisions of the simple differential equations have very wide application in practical engineering problems. Usually in engineering this terminology is basically understood as simple functions of one or two variables with limited quantity of continues extrema and limited stepness within the given change of argument [1]. They serve for construction of mathematical models of the signals received from real objects.

In the first case, frequency is defined by the periods of transmitted signal, which particularly in gravimetric prospecting lies within the range, from a few seconds to about several seconds [2] [3].

In the second case, the duration of the signal is -10-400мs with frequency -10-1700 kHz. Usually frequency range of precursor-signal divides at low frequency from 10 up to 50 kHz and high frequency rom 50 up to 1700 kHz.

Orthogonal system of basic functions which are given on a valid axis, for which there also exist algorithm of fast transformation have received wide circulation in technical appendices. They can be divided into two classes:

1) Global basic functions - such whose values are not equal to zero on one subinterval. Walsh Functions [4] [5], numerical [4] [6] [7], sawtooth are in this category;
2) allocative basic functions, nonzero values which are set on the enclosed segment. Examples are Haar functions [4] [5] [6] and Harmut's [5] [6] [8].

Splitting of the valid axis is usually doubled rational. Later we shall consider the interval [0,1] or [0,1) and will use the concept of a binary piece, which is as a result of division of a given interval 2^p equal parts (P = 1, 2...):

$$h_k = h_{pj} = \left[\frac{j}{2^{p-1}} \quad \frac{j+1}{2^{p-1}} \right] \qquad (1)$$

Where $j = 0,1,...,2^{p-1}, \quad k = j + 2^{p-1}$

For example, binary pieces can serve as intervals

[0;1); [1/2; 3/4], [3/8; 4/8]

The length of a binary piece hpj equals

$$\left| h_{pj} \right| = \left| \overset{+}{h}_{pj} \right| + \left| \overset{-}{h}_{pj} \right| = 2^{1-p};$$

Where $\overset{-}{h}_{pj}$, $\overset{+}{h}_{pj}$ are its left and right half respectively and also represent binary pieces:

$$\overset{+}{h}_{pj} = \left[\frac{j-1}{2^{p-1}}; \frac{2j-1}{2^p} \right], \quad \overset{-}{h}_{pj} = \left[\frac{2j-1}{2^p}; \frac{j}{2^{p-1}} \right] \qquad (2)$$

The system of un-rationed Haar functions to the form is defined as

$$har_k(x) = har_{pj}(x) = \begin{cases} +1 & x \in \overset{-}{h}_{pj} \\ -1 & x \in \overset{+}{h}_{pj} \\ 0 & x \in h_{pj} \end{cases} \tag{3}$$

It is necessary to note that: $har_0(x) \equiv 1$

Where P is the order of Haar's function. It is known as that Haars series can provide as uniform (including the uniform

$$f(x) = \sum_{k=0}^{\infty} C_k \cdot har_k(x) \tag{4}$$

best),and mean-square approximation. All depends on the method of calculating the factors.

Harmut [13] [14] [15] examined a system of piecewise-constant orthogonal basic functional occupying the position between Walsh and Haar systems. The most simple are functions of system $\{harm_k(x)\}$, obtained from Haar functions by double accession precisely same under the form, but on an adjacent binary piece on the right, and one of them joins with a "+ " sign, and another with a "-" sign. As a result, a system of evens and odds relative to the middle of the binary interval functions, whose integration leads to a system of piecewise-linear functions and also even and odds:

$$h\tilde{i}n_k(x) = 2^p \int_0^x hrm(r)dr \tag{7}$$

In many practical appendices connected with recovery of functions between readouts, the possibilities of continuous piecewise - linear bases are not enough.

This can be explained by two basic reasons:

1) Because of low speed of convergence of the approximations caused by comparatively big error of piecewise-linear interpolation which often leads to significant loss on factors;
2) Because of non smoothness's of approximation (the first derivative of disruptive functions of basis) – there is the absence of the concept of curvature which causes essential restrictions. For example, it is possible to skip the maxima and minima of functions.

III. THE STRUCTURE OF THE SPECIALIZED PROCESSOR

Studies on graphs of fast spectral transformations in localized bases show that their various modifications define sets of versions of special-purpose computing structures. A number of works were devoted to issues of development of structures and principles of their construction, in them opportunities of work in real time are marked, but the problem of achieving the maximal speed which is a major factor in problems DSP is not considered.

The structure of the specialized processor in parallel-conveyor-based, carrying out fast transformation of Haar on algorithm Cooley-Tukey is shown on Figure 1. The structure consists of the block of buffer registers for storage N/2 of readout data (where N is the quantity of entrance readout), four processor blocks and an ultrafast operative memory (RAM) for storage of both intermediate and final factors.

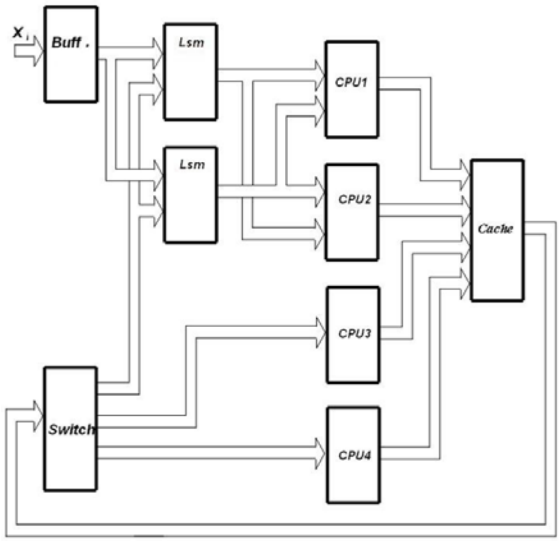

Figure 1. Structure of the specialized processor for digital signal processing.

The degree of universality of the proposed computing structure is caused by the application of the piecewise-quadratic basic functions, allowing approximation with required accuracy of category of signals under research. High speed and relative simplicity of hardware realization are reached, in many respects, owing to use of principles of parallelization, conveyorization calculations and overlapping of operations of input with processing.

Transition to piecewise-quadratic functions Haar and Harmut and development of the computing structures which are carrying out transformations on piecewise-quadratic functions, allow to improve accuracy of approximation, to reduce quantity of the factors necessary for approximation, and by that to save memory size.

Application of principles of parallelization and conveyorization, and also overlapping of operations of input with processing promote increase in the speed of specialized computing structure.

High-speed parallel – conveyor structure of the specialized processor was developed for performance of fast transformations in piecewise–polynomial the bases, differing by wide introduction of principles parallelization, conveyorization and overlapping of operations of input with processing.

IV. SIMULINK-MODEL OF THE SPECIALIZED PROCESSOR

In Figure 2, the Simulink-model of the specialized processor is shown. For modeling of the proposed structure in the environment of MATLAB with application of resources, Simulink blocks are used as shown below:

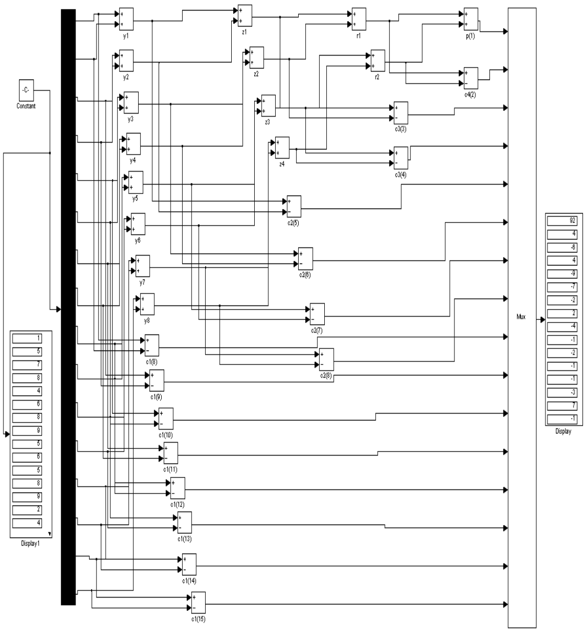

Figure 2. Example of an unacceptable low-resolution image

From the figure, the two blocks of Display are and Constant for feigning of an entry signal; Zero-Order Hold block for simulation of digitization and quantization of input analogue signal. Display block is used for numeric display for input values; constant block is for constant value parameters. A demux block is used to split vector signals into scalars or smaller vectors. In the process, there are several add and subtract inputs blocks. Later, a mux block is used for multiplex scalar signals. Finally the output signal is display for the control of signals at various stages of processing and for link with MATLAB environment.

V. EXPERIMENTAL RESULTS

Series of numerical experiments have been carried out on the research of piecewise-quadratic bases. With use of the offered algorithm of calculation of coefficients in Haar and Harmut's piecewise-quadratic bases, Table-1 is achieved. Here the factor of compression K_c is defined by the formula:

$$K_c=N/(N-N_1),$$

Where N = Quantity of readout of function
N_1 = Quantity of the zero factors received as a result of use of offered algorithm.

TABLE 1. RESULTS OF RESEARCH OF FAST TRANSFORMATIONS HARMUT IN PIECEWISE-QUADRATIC.

№	Function	Harmut's Fast transformation	
		K_c	Zero coefficients
1	$Y=e^x$	3.76	73.4%
2	$Y=e^{-2x}\cdot cos(4\pi x)$	2.28	56.2%
3	$Y=arcth(x)$	3.46	71.0%
4	ABT	1.21	17.2%
5	AME	1.29	24.2%

The numerical experiments allow us to draw a conclusion that the number of zero coefficients at digital processing of signals received as a result of bench tests in Haar and Harmut's piecewise-quadratic bases ranges from 5 % up to 17 %, when processing the geophysical signals received as a result magnetic exploration we get values ranging from 5 % up to 25 %, and while processing elementary functions (and also functions consisting of their combinations) this parameter gives us value from 10 % up to 70 % with an accuracy of 10^{-4}-10^{-6}. It is established, that decomposition (3) allows receiving high speed in Haar's basis and the big factor of compression in Harmut's basis. Also as a result of researches it is revealed, that with increase in quantity of readout function N, the values of factors decreases on exponential law.

VI. CONCLUSION

Application of results of researches in various systems of modeling, the control and management has shown that developed piecewise-polynomial methods of approximation of signals can be successfully realized algorithmically in the form of a system of program components, and also in hardware in the form of subsystems of digital signal processors.

ACKNOWLEDGMENT

This work was supported by NAP of Korea Research Council of Fundamental Science & Technology and also by ETRI SoC Industry Promotion Centre, Human Resource Development Project for IT SoC Architect.

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