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Application of wavelet analysis algorithms for digital control an electromagnetic exciter

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I. INTRODUCTION

At controlling of the electromagnetic exciter (EVV) complex design, consisting of the mechanically interconnected elements, the tract EVV-product will be nonlinear where arise the various vibration-strike processes that lead to significant enrichment spectrum of control signal at the output of the actuator [1]. In this case the output signals of inductive displacement sensors will be complex distorted form, for the processing of which the most effective is the use of digital control systems of parameters mechanical vibrations.

Of great interest is the use of computers not only for the processing of information, but also to define and control the vibration mode of the tested construction. From the point of view of the technical implementation, a digital system based on the use of serial control computers with minimal use of non-standard equipment will look like most simple. The latter requirement means that the task of generating, analyzing and control should be solved by the personal computer with appropriate software [2].

Block diagram of the digital control system is shown in Fig.1. At the outputs of the sensors D_1, $D_2,\ldots,D_n$ appear $y_1, y_2,\ldots,y_n$ response of object that are converted into machine code by analogue-digital converters (D converter) and directly come into the computer memory. Arrays of numbers, which represent of the implementation of the output vector process $\{y_1, y_2, \ldots, y_n\}$, then subjected to wavelet analyze. Algorithm of wavelet analysis calculates the evaluations of own and mutual signal spectra of sensors, which are elements of the spectral matrix $\Sigma_{yy}(j\omega)$ of vector process $Y(t)$. Control Unit (CU) detects a mismatch between the actual $\Sigma_{yy}(j\omega)$ and the given estimates $\Sigma^{**}_{yy}(j\omega)$ of the spectral components of the matrix and corrective action for the regulator (RG) are formed on this basis. Then the cycle repeats as long as while the calculated assessments of spectra will not coincide with the predetermined values.

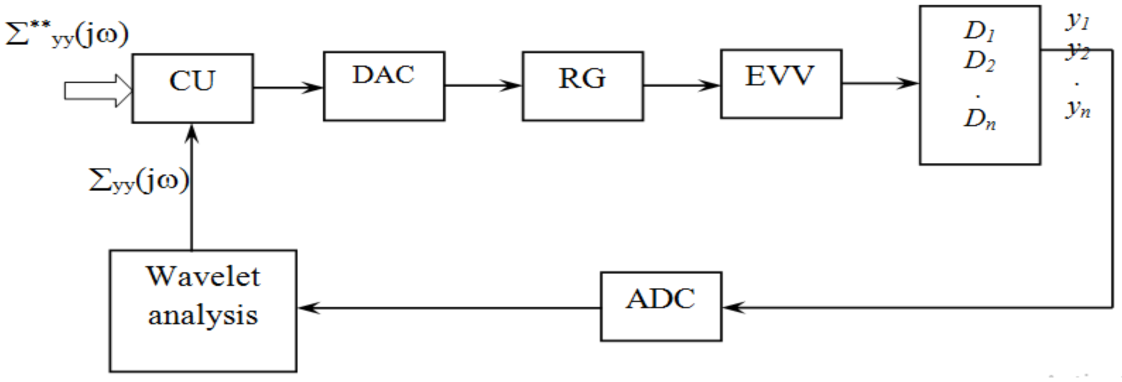

Fig.1. Block diagram of the digital control system

Let us now consider the algorithms of wavelet analysis, which are reduced to the calculation of estimates of own and mutual spectra signal of sensors. This requires processing of an array of numbers representing a discrete time coordinates of output parameters $y_1, y_2, \ldots, y_n$ of the control object, which are coming to computer via an ADC.

It is known that at digital signal processing usually perform a certain transformation on it, to identify characteristics of the signal, and then after to perform certain actions (e.g., noise reduction), performed the reverse conversion. A classic example is the Fourier transform that transforms the signal from the time domain into the frequency domain and vice versa. The both direct and inverse conversion is realized by calculating the convolution of the signal at its each point by a function called a filter. In discrete version the filters are specified via simple listing their values (coefficients) at the sampling points. Given the statistical features of most signals (useful information is located in the low-frequency part of spectrum of the signal and the interference or noise - in the high frequency domain) and signal is usually converted by two complementary each other filters - low and high pass filters. The wavelets belonging to the class of the quadrature mirror filters (QMF), characterized in that the high-pass filter is obtained from the corresponding simple low-pass filter arrangement of the coefficients in reverse order and by changing the sign of half of them (only the even or only the odd). In this case wavelet allocates local features of signal at each point and thus is the high-pass filter, and the corresponding low-pass filter is described by the so-called scaling function [3, 4].

Let us represent sensor output signal as a vector with length N, where N - number of samples. Then signal conversion process can be written in matrix form:

C_0	C_1	C_2	C_3	0	0	…	0	0	0	0		F_0
0	C_0	C_1	C_2	C_3	0	…	0	0	0	0		F_1
0	0	C_0	C_1	C_2	C_3	…	0	0	0	0		F_2
0	0	0	C_0	C_1	C_2	…	0	0	0	0		F_3
…	…	…	…	…	…	…	…	…	…	…	x	…
0	0	0	0	0	0	…	C_0	C_1	C_2	C_3		F_{n-3}
C_3	0	0	0	0	0	…	0	C_0	C_1	C_2		F_{n-2}
C_2	C_3	0	0	0	0	…	0	0	C_0	C_1		F_{n-1}
C_1	C_2	C_3	0	0	0	…	0	0	0	C_0		F_n

Here C_0, C_1, ... C_n mean filter coefficients of length n, F_0, ... F_n - value signal samples, a symbol *x* - operation matrix-vector multiplication. The last four rows of the filter matrix mean that we continue our signal on the straight line periodically (i.e. we think that value F_0 comes again after value F_n). As a result, multiplication matrix of dimension *NxN* to vector length N we obtain vector of the same length, and in view of the fact that the two filter involve in the transformation, even two vector length instead of *N* - seemingly we have not received any advantage. However Daubechies wavelets have following property: a smoothed representation of the signal (i.e. processed by the scaling function), and its local features (obtained resulting from the wavelet transform) have redundancy twice. In other words, for a length of 2N wavelet transform result signal at each point is a certain "averaging" of the signal and a set of "details" which distinguish the averaged signal from the original - and the averaged signal is 2 times "smoother" than the original. Thus, every even or every odd conversion sampling may be excluded from consideration, and after conversion obtain two vectors with 2 times small length a one of which contains a smoothed version of the signal (or signal representation at half scale), and the other - a set of local features (i.e. interferences at this level of detail). As a result, the analysis of the smoothed signal is simplifying the identification of its characteristic properties. Besides, analysis of local characteristics of the signal makes it possible not only to determine the nature and parameters of noise, but also clearly locate the "critical points" of signal - such as the emissions, missing values, sharp leaps of level, etc. In addition, if the received signal is still not cleared of noise, we can re-apply the wavelet transform and obtain a smoother version of the signal (now four times shorter than the original) and local features of the signal already at the next level detailing.

With that said, we can perform the signal conversion not at every point, but only in those which will take part in the further consideration, i.e., only in even or only in odd points. Note, this phrase means only that the convolution is calculated for half points, but in calculations take part all successive points M, where M - filter length. Then the transformation matrix will have a dimension of (N/2)xN (N - even) and will take the following form:

C_0	C_1	C_2	C_3	0	0	…	0	0	0	0		F_0
0	0	C_0	C_1	C_2	C_3	…	0	0	0	0		F_1
0	0	0	0	C_0	C_1	…	0	0	0	0		F_2
0	0	0	0	0	0	…	0	0	0	0		F_3
…	…	…	…	…	…	…	…	…	…	…	x	…
0	0	0	0	0	0	…	0	0	0	0		F_{n-3}
0	0	0	0	0	0	…	C_2	C_3	0	0		F_{n-2}
0	0	0	0	0	0	…	C_0	C_1	C_2	C_3		F_{n-1}
C_2	C_3	0	0	0	0	…	0	0	C_0	C_1		F_n

C_3	$-C_2$	C_1	$-C_0$	0	0	…	0	0	0	0		F_0
0	0	C_3	$-C_2$	C_1	$-C_0$	…	0	0	0	0		F_1
0	0	0	0	C_3	$-C_2$	…	0	0	0	0		F_2
0	0	0	0	0	0	…	0	0	0	0		F_3
…	…	…	…	…	…	…	…	…	…	…	x	…
0	0	0	0	0	0	…	0	0	0	0		F_{n-3}
0	0	0	0	0	0	…	C_1	$-C_0$	0	0		F_{n-2}
0	0	0	0	0	0	…	C_3	$-C_2$	C_1	$-C_0$		F_{n-1}
C_1	$-C_0$	0	0	0	0	…	0	0	C_3	$-C_2$		F_n

To find the values of the coefficients of the matrix, can be use the following properties of the Daubechie wavelets:

1. Shifts wavelet form an orthonormal basis of the space, i.e. $\sum_i c_i c_{i+j} = \begin{cases} 1, & j = 0 \\ 0, & j \neq 0 \end{cases}$, in other words, when multiplication of paired rows of the transformation matrix must get 0, and for multiplying the line on itself - 1. Property of orthonormality of basis means that the matrix inverse transform is the transposed matrix of the direct transform.

2. $\sum_i x_i^p c_i = 0,\ 0 \le p \le \frac{M}{2}$ The wavelet with length M (M - even) has M/2 zero initial moments, i.e.. Since the initial moments of the wavelet invariant to determination domain, can take an arbitrary sequence of values xi - for example, 0, 1, 2 ... M. The number of zero moments of the wavelet means that if the source signal is approximated by polynomial splines of degree M, then the wavelet-transform will "repay" all the polynomial components with degree between 0 and M/2 (i.e., wavelet transform of the polynom with certain "smoothness" will give a zero response) (Figure 2).

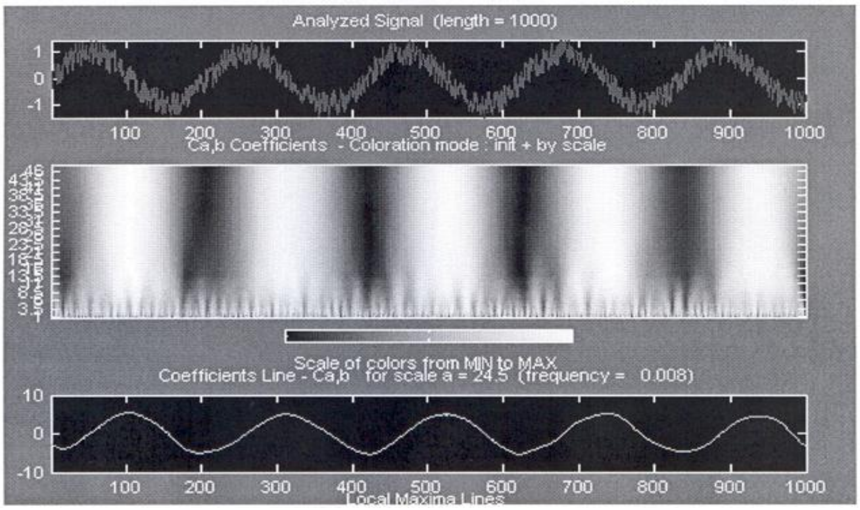

Fig.2. Output signal of the sensor, its wavelet spectrum and the filtered signal.

Thus, finding the coefficient values of the wavelet filter with length n is a solution of the system of n algebraic equations.

It should be noted that this approach may be successfully implemented as for vibration control process, and for carrying out vibration testing of various products, object, etc.

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RESUME

Application of wavelet analysis algorithms with digital control electromagnetic exciter

The problems of digital control solenoid virovozbuditelem. With the application of wavelet analysis algorithms, which are reduced to the computation of estimates of the self and mutual spectra. Wavelets, are a class of quadrature mirror filters. They secrete local signal characteristics at each point and is thus a high frequency filter, and an appropriate low-pass filter is described by the so-called scaling function.