НЕЙРОІНФОРМАТИКА ТА ІНТЕЛЕКТУАЛЬНІ СИСТЕМИ

NEUROINFORMATICS AND INTELLIGENT SYSTEMS

НЕЙРОИНФОРМАТИКА И ИНТЕЛЛЕКТУАЛЬНЫЕ СИСТЕМЫ

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OPERATIVE RECOGNITION OF STANDARD SIGNAL TYPES

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ABSTRACT

Context. Recognizing the type of function regardless of its parameters is an urgent task.

Objective. To develop methods for the operational quantitative measurement of deviations of the type of the analyzed function, representing the analyzed process, from the standard types of functions: power, polynomial, exponential and sinusoidal according to the data obtained at the current time.

Method. To solve the problem, methods based on disproportion functions have been developed. The existing disproportion functions and their application for the recognition of power and polynomial functions are given. To recognize the exponential and sinusoidal functions at the current time, the disproportion over the first-order derivative with respect to its derivatives is used. With the parametric specification of functions, it is the difference between the ratios of the values of two functions and the ratio of their first derivatives for a given parameter value. In the case of a proportional relationship between two functions, this disproportion function is equal to zero for any value of the proportionality coefficient. It is shown that if for a given value of the argument the disproportion over the first-order derivative of the analyzed function with respect to its first derivative is zero, this is a sign that the function is exponential at this point regardless if it's parameters.

To control the sinusoidality at the current time, the disproportion over the first-order derivative of the analyzed function with respect to its second derivative is calculated. If it is zero, this is a sign that the function is sinusoidal at a given point regardless of its amplitude, frequency and phase of the oscillations. It is shown that in this way it is also possible to control the sum of sinusoids with different amplitudes and phases, but with the same frequency. You can also control second-degree sine waves.

Results. The effectiveness of the proposed methods is shown by computer simulation of the decay of radioactive isotopes, as well as simulation in violation of the sinusoidal nature of the controlled process.

Conclusions. Based on the disproportion functions, methods have been developed for the operative recognition of the type of function that describes the analyzed process. These methods can be used to analyze chemical-technological processes, control the purity of radioactive isotopes, and also to control the sinusoidality of processes in electrical networks.

KEYWORDS: disproportion functions, type of numerical function, sinusoid distortion, exponential function, polynomial function, power function.

NOMENCLATURE

A is a sine wave amplitude;

b is a decay rate constant;

$c(x)$ is a $\cos(\omega x + \varphi)$;

d is a means disproportion over the derivative . In parentheses indicate its order (n). It is read: "At d n $y(x)$ with respect to x";

$N(t)$ is a relative disproportion of the current mass with respect to their first derivatives;

$m_1(t)$ is a current mass of iodine-131;

$m_\Sigma(t)$ is a sum of current masses;

m_{10} is a initial mass of the radioactive iodine-131;

m_{20} is a initial mass of the radioactive iodine-133;

$s(x)$ is a $\sin(\omega x + \varphi)$;

t is a time;

$v(t)$ is a disproportion over the first-order value;

$y(x)$ is a function to be analyzed;

$z(t)$ is a disproportion over the first-order derivative;

@ is a disproportion function calculation symbol;

$@d_x^{(n)}y$ is a disproportion over the n-th order derivative of $y(x)$ with respect to x;

$@d_{y'}^{(n)}y$ is a disproportion over the n-th order derivative of $y(x)$ with respect to dy/dx;

$@d_{y''}^{(n)}y$ is a disproportion over the n-th order derivative of $y(x)$ with respect to d^2y/dx^2;

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$@d_{y''}^{(1)}y'$ is a disproportion over the 1st order derivative of dy/dx with respect to d^3y/dx^3;

$@N_x^{(n)}y$ is a relative n-th order disproportion $y(x)$ with respect to x;

$@N_{y'}^{(n)}y$ is a relative n-th order disproportion $y(x)$ with respect to dy/dx;

$@N_{y''}^{(n)}y$ is a relative n-th order disproportion $y(x)$ with respect to d^2y/dx^2;

$@v_x^{(n)}y$ is a disproportion over the n-th order value of $y(x)$ with respect to x;

$@v_{y'}^{(n)}y$ is a disproportion over the n-th order value of $y(x)$ with respect to dy/dx;

$@v_{y''}^{(n)}y$ is a disproportion over the n-th order value of $y(x)$ with respect to d^2y/dx^2;

φ is a sine wave phase;

ω is a sine wave frequency.

INTRODUCTION

There are problems for which solution it is necessary to recognize the form of a numerical function that describes the analyzed process. In this case, recognition should be invariant with respect to the parameters of the function that describes the process. For example, in chemical industry, vibratory granulators are widely used. They are used to produce granules from melts or solutions. To improve the quality of the product in a granular medium, harmonic oscillations are excited, which must have strictly sinusoidal form [1]. The appearance of harmonics leads to a sharp deterioration in product quality. If we take into account the fact that vibration granulators are usually used in large-scale production, untimely detection of non-sinusoidal oscillations leads to significant losses. If the vibratory granulator is operating at a variable level of melt, the vibration frequency must be smoothly varied [1].

Thus, it is necessary to determine instantly, whether the vibrations excited in the melt or solution are sinusoidal, regardless of their frequency and amplitude.

Strict requirements for the sinusoidal shape of the output voltage are also required for DC to AC converters, especially for powering on-board equipment. In this case, it is also necessary to apply the system of current diagnostics of the sinusoidal voltage generator, invariant to its amplitude and frequency.

The task of current non-sinusoidality monitoring of the current and voltage in the electric network is relevant for the electric power industry [2].

In addition to non-sinusoidality, there are many examples when it is necessary to control other types of functions. For example, many chemical reactions and the decay of radioactive materials are described by an exponential function. Deviation of the controlled function type from the exponential one can indicate the simultaneous occurrence of several reactions or other events that need to be diagnosed. Therefore, the task of identifying deviations of the function type from the given one regardless of their parameters is relevant.

In this case, the system should detect deviations at the moment of measurement using current data only. In addition, it should be invariant with respect to the amplitude of the analyzed signal.

1 PROBLEM STATEMENT

A finite set of standard functions is given

$$y = ca^{bx},\ y = A\sin(\omega x + \varphi),$$
$$y = \sum_{i=1}^{n} A_i \sin(\omega x + \varphi),\ y = A\sin^2(\omega x + \varphi). \quad (1)$$

The coefficients in these functions are of real type. Their values are unknown.

The analyzed signal is described by a smooth, continuous function $y = f(x)$. For a given value of x, the type of the function may relate to the type of one of the listed standard functions (1) and differs from it in amplitude and other parameters whose values are unknown.

Using the current values of $y(x)$ and their derivatives $y^{(1)}, y^{(2)}, \ldots, y^{(n)}$, it is necessary to determine to which type it belongs specifically for a given x.

2 LITERATURE REVIEW

There are many works on the control of non-sinusoidality of voltage and current. In most cases, the methods based on the expansion of the analyzed signal in a Fourier series, for example, [3], are used for this. Typically, using Fourier analyses a harmonics coefficient is measured to quantify the distortion of a sinusoidal signal [4]. However, for this, it is necessary to observe a signal during at least one period. In practice, this may be unacceptable decision, especially if the process is low-frequency and one period of oscillation lasts an unacceptably long time.

Also, neural networks are used to evaluate the voltage non-sinusoidality on the buses of substations of an electric network with non-linear loads [2].

In [5] the structure of construction and the principle of operation of a neural network based on adaptive resonance theory are described. A specific example of the recognition of wavelet images of non-sinusoidal distortions in networks of 0.38 / 0.22 kV using a neural network is shown.

A comparative analysis of the application of the mathematical apparatus Fourier and wavelet transforms is made in [6] to determine the type of non-sinusoidal distortion in distribution network.

The centroid based signal similarity evaluation method was proposed in [7]. The paper proposes a novel approach to reform the projection signal by adding its centroid at the end. This method has been tested using traffic sign recognition.

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There is a known Distribution Function Method (DFM) [8, 9, 10]. This method uses normalized integrals for the compared signals. Both signals must be represented by positive continuous functions of the real variable. The method allows to solve a number of problems, in particular, arising in spectrograph and chromatography. However, for its application, it is necessary to control signals during a certain time interval.

In [11], it was proposed to use the disproportion functions [12] to solve the problem. These functions allow you to create cryptosystems on a new basis, as well as to do an on-line recognition the state of dynamic objects [13–15].

3 MATERIALS AND METHODS

To solve the problem, the disproportion functions are used. There are several disproportion functions. The following is a summary of some of them.

The n-th order derivative disproportion of the function $y(x)$, with respect to x ($x \neq 0$), is defined as follows:

$$@d_x^{(n)} y = \frac{y}{x^n} - \frac{1}{n!} \cdot \frac{d^n y}{dx^n} \quad (2)$$

This disproportion allows us to recognize the power function $y=kx^n$, since in this case it is equal to zero regardless of the factor k. Here, $n \geq 1$ is an integer.

The coefficient k is unknown. It can randomly change over time. We assume that the rate of change $\frac{dk}{dx} \to 0$.

For $n = 1$:

$$@d_x^{(1)} y = \frac{y}{x} - \frac{dy}{dx}. \quad (3)$$

The @ symbol is chosen to indicate the operation of calculating disproportion, d means “derivative”. The left-hand side for (3) is read “at d one y with respect to x”.

Disproportion (3) allows to recognize the function

$$y = kx. \quad (4)$$

It is obvious that for (4) the disproportion (3) is equal to zero regardless of the value of the coefficient k.

For the functions $y = \psi(t)$ and $x = \varphi(t)$ defined parametrically (t is a parameter), the n-th order derivative disproportion (2) of the function $y(x)$ with respect to x is calculated taking into account the rules of finding $\frac{d^n y}{dx^n}$ with the parametric dependence of y on x.

In particular, for n=1

$$@d_x^{(1)} y = @d_{\varphi(t)}^{(1)} \psi(t) = \frac{y}{x} - \frac{y'_t}{x'_t} = \frac{\psi(t)}{\varphi(t)} - \frac{\psi'(t)}{\varphi'(t)}. \quad (5)$$

Obviously, if $\psi(t) = k\varphi(t)$, then disproportion (5) is equal to zero in the entire area of existence $x = \varphi(t)$, regardless of the value of k.

The disproportion (3) is the difference of two speeds. The first term is the speed, which could be in the case of proportional coupling (4). The second term is the real speed for the current value of x.

Often, it is more convenient to evaluate disproportion not in the form of a difference in speeds, but using the same units in which $y(x)$ is measured. In this case, the disproportion over value should be used.

This disproportion over the n-th order value is defined as the product of n-th order derivative disproportion (2) by x^n.

It has a form

$$@v_x^{(n)} y = y - \frac{x^n}{n!} \frac{d^n y}{dx^n}. \quad (6)$$

The symbol “v” (“value”) is used instead of “d” one in (2).

In the particular case of n=1 (order 1) the value disproportion is reduced to:

$$@v_x^{(1)} y = y - x\frac{dy}{dx}. \quad (7)$$

The left-hand side of (7) is read: “at v one y with respect to x”.

The expression (7) is the difference between y and its possible value, found on the assumption of a proportional relationship between y and x, with a proportionality factor equal to $\frac{dy}{dx}$ in the exploration point.

Often there is a need to recognize a polynomial dependence

$$y = k_m x^m + k_{m-1} x^{m-1} + ... + k_1 x. \quad (8)$$

This type of function can be recognized if the disproportion (3) is computed sequentially m-times with respect to x. From the outset, the disproportion (3) $y(x)$ with respect to x is calculated. Then, the disproportion (3) of the newly obtained disproportion with respect to x is calculated. Thus, m is determined in accordance with the polynomial order. Such disproportion is called as sequential disproportion function (SDF) with respect to the first order derivative. It was shown in [8, 9] that it is equal to zero for arbitrary values of the coefficients $k_m, k_{m-1}, ..., k_1$ in (8), which makes it possible to recognize the polynomial dependence.

If the disproportions (2), (3), (5), (6), (7) are not equal to zero, we need to remember that in this case their values depend not only on the value of deviation of the type of the function in comparison with the given one, but also on the scale factor before the analyzed function, when

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$$y = kf(x), \tag{9}$$

where k is unknown.

In order to assess disproportion regardless of the scale factor, the relative disproportion functions can be used [11]. They are obtained as a result of dividing the disproportions (6), (7) by $y(x)$ (9). Below the first-order and the n-th order relative disproportions are shown:

$$@N_x^{(1)}y = 1 - \frac{x}{y}\frac{dy}{dx} \tag{10}$$

$$@N_x^{(n)}y = 1 - \frac{x^n}{n!\,y}\frac{d^n y}{dx^n} \tag{11}$$

All these disproportion functions can be used to recognize the type of the functions specified in (1).

To recognize the exponential function, the disproportion (7) of the function $y=f(x)$ with respect to its first derivative is used.

$$@d_{y'}^{(1)}y = \frac{y}{dy/dx} - \frac{dy/dx}{d^2y/dx^2}. \tag{12}$$

In [11] it was proved that the equality to zero of the disproportion (12) indicates that $y=f(x)$ is exponential. This assertion is valid for the exponential function in the general form

$$y = ca^{bx}, \tag{13}$$

where $a > 0$ and $a \neq 1$ for arbitrary values of c, b, x.

Thus, if the equation (12) is equal to zero for the current value of x, then the function $y= f(x)$ is exponential at this point.

Obviously, in the case when $y=f(x)$ is the sum of exponential functions with unequal parameters, then the disproportion (12) will not be zero.

The corresponding disproportion upon the value of the first order according to (7) has the form:

$$@v_{y'}^{(1)}y = y - y'\frac{y'}{y''} \tag{14}$$

The relative disproportion function according to (14) is

$$@N_{y'}^{(1)}y = 1 - \frac{y'}{y}\frac{y'}{y''} \tag{15}$$

A proportional relationship exists also between the sinusoid and its second derivative. This allows us to recognize the sinusoidal type of the function being analyzed based on the current values of the function itself and its first three derivatives, regardless of frequency, amplitude and phase shift. In this case, expression (5) has the form

$$@d_{y''}^{(1)}y = \frac{y}{\frac{d^2y}{dx^2}} - \frac{\frac{dy}{dx}}{\frac{d^3y}{dx^3}}. \tag{16}$$

Indeed, if we substitute $y = A\sin(\omega x + \varphi)$ and the corresponding derivatives in (16), the result will be zero regardless of the values A, ω, φ.

According to (7), the disproportion (16) has the form:

$$@v_{y''}^{(1)}y = y - y'\frac{y''}{y'''}. \tag{17}$$

There will be the same result for the general case when

$$y = \sum_{i=1}^{n} A_i \sin(\omega x + \varphi_i). \tag{18}$$

It is easy to see that for (18) the disproportions (16) and (17) are equal to zero too.

Any deviation of the type of the function being analyzed from (18) will lead to a nonzero of these disproportions.

Sometimes it's necessary to compare the analyzed function with function (19):

$$y = A\sin^2(\omega x + \varphi) \tag{19}$$

In this case the disproportion (5) may be used for its first and third derivatives:

$$@d_{y'''}^{(1)}y' = \frac{dy/dx}{d^3y/dx^3} - \frac{d^2y/dx^2}{d^4y/dx^4}. \tag{20}$$

Indeed:

$$\begin{aligned}
y' &= 2A\omega\sin(\omega x + \varphi)\cos(\omega x + \varphi) = \\
&= A\omega\sin[2(\omega x + \varphi)], \\
y'' &= 2A\omega^2\cos[2(\omega x + \varphi)], \\
y''' &= -4\omega^3\sin[2(\omega x + \varphi)] = -4\omega^2 y', \\
y^{(4)} &= -8A\omega^4\cos[2(\omega x + \varphi)] = -4\omega^2 y''.
\end{aligned}$$

Substituting the derivatives to (20), we obtain a result equal to zero.

When using disproportions (16, 17, 20), it is needed to keep in mind, that they will not be equal to zero if the amplitude of sinusoid changes in time (21).

$$y(t) = A(t)\sin(\omega x + \varphi). \tag{21}$$

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Let's consider the disproportion (16) for this case. To avoid long formulas, we introduce the notation:

$$s(x) = \sin(\omega x + \varphi),$$
$$c(x) = \cos(\omega x + \varphi).$$

Substituting (21) and its derivatives in (16), we obtain

$$@ d_{y''}^{(1)} = \frac{A(x)s(x)}{\left(A''(x) - A(x)\omega^2\right)s(x) + 2A'(x)\omega c(x)} -$$
$$- \frac{A'(x)s(x) + A(x)\omega c(x)}{\left(A'''(x) - 3A'(x)\omega^2\right)s(x) + \left(3A''(x)\omega - A(x)\omega^3\right)c(x)}.$$

Obviously, this expression is zero only if the amplitude of the sinusoid is constant.

4 EXPERIMENTS

Three numerical experiments were performed in order to investigate possibilities of the proposed methods.

First experiment is about recognition and quantitative evaluation of the deviation of the type of the function from the exponential one.

It is required to quantify the purity of the radioactive iodine – 131 with a half-life of T_1 = 8.04 days with the possible presence of the iodine-133 isotope, in which the half-life of T_2 = 0.87 days.

For a pure radioactive substance, the change in mass in time t has the form [16]:

$$m_1(t) = m_{10} e^{-b_1 t}. \quad (22)$$

For the case when two substances break up, the mass changes according to the formula:

$$m_\Sigma(t) = m_{10} e^{-b_1 t} + m_{20} e^{-b_2 t}, \quad (23)$$

where m_{10}, m_{20} are the initial masses; $m_1(t)$, $m_\Sigma(t)$ is a current masses; b_1, b_2 are the decay rate constants.

According to [16] the decay rate constants are defined as b_1=ln (2)/T_1=0,0825, b_2=0,796721

For both cases (22) and (23), the disproportion (12) $z_1(t)$, $z_2(t)$, the corresponding disproportions (14) $v_1(t)$, $v_2(t)$ and (15) $N_1(t)$, $N_2(t)$ were calculated. The observations were made during 10 days. An increment is one day. The initial masses are m_{10}=10*g*., m_{20} =0,01*g*.

Second experiment is related to detection of distortion of a sinusoidal function.

Consider the example when, in a certain time interval, in addition to the fundamental frequency, its second harmonic appears. The circular frequency of the fundamental harmonic is 314 rad/s, its amplitude is 10 volts, the phase shift is 0.25. The second harmonic has an amplitude 100 times smaller. In order to avoid processing large numbers, the frequencies of both harmonics are taken relative to the maximum frequency of 1000 rad/s.

The third numerical experiment was carried out in order to show that the proposed methods should be used only if the amplitude of the analyzed signal is constant. The amplitude of the sinusoid varies over a certain time interval. Disproportion behavior (16) was investigated.

5 RESULTS

The results for the first computer simulation are given in the Table 1.

For a pure isotope (the first case), the disproportions $z_1(t)$, $v_1(t)$ and $N_1(t)$ are equal to zero.

At the same time, in spite of the fact that the initial mass of iodine-133 is 1000 times smaller than the mass of the iodine-131 isotope, the first-order derivative disproportion $z_2(t)$ and the first-order value disproportion $v_2(t)$ are not equal to zero. The disproportion N_2 (t) allows us to quantitatively evaluate the deviation of the type of the analyzed function from the exponential one, regardless of its magnitude.

Table 1 – Disproportions changes over the time

t	z_1	z_2	v_1	v_2	N_1	N_2
0	0	1,5309	0	–2,6486	0	–0,1318
1	0	5,1674	0	–8,0382	0	–0,4354
2	0	8,0455	0	–11,3882	0	–0,6708
3	0	9,9136	0	–12,8455	0	–0,8222
4	0	10,9804	0	–13,0632	0	–0,9083
5	0	11,5462	0	–12,6304	0	–0,9539
6	0	11,8346	0	–11,9123	0	–0,9771
7	0	11,9786	0	–11,0986	0	–0,9887
8	0	12,0499	0	–10,2786	0	–0,9945
9	0	12,0849	0	–9,4912	0	–0,9973
10	0	12,1021	0	–8,7516	0	–0,9987

According to the obtained results, proposed method allows to detect the simultaneous decay of more than one substance. Therefore, if any disproportion function is equal to zero, it means that the radioactive isotope is clear. It can be used in the preparation of extremely pure radioactive substances.

The results of the second experiment are shown in Figure 1.

A graph of the change of the disproportion (16) over the time is shown. From 1st count to the 20th one as well as from 55th to 100th counts, the analyzed function is sinusoidal. In this case, the disproportion (16) is equal to zero. On the interval from 20 to 55, the second harmonic appeared. Despite the fact that the amplitude of the second harmonic is only 1% of the amplitude of the fundamental frequency, disproportion (16) deviates from zero significantly and varies from –38,1651 to 36,7351.

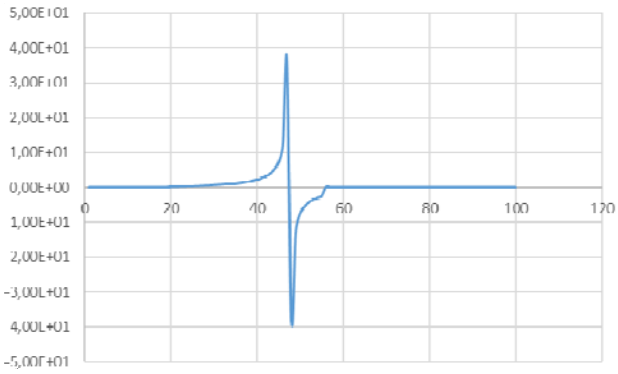

Figure 1 – Graph of disproportion (16) when a sinusoid distortion appears

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The given example shows the possibility of operative control of the non-sinusoidality of the analyzed signal.

On the Figure 2 the time variation of the disproportion (16) as a function of the amplitude of the sinusoid is shown. As we can see, after the amplitude reaches a new constant value, the disproportion is zero again.

The results of the third experiment are shown in Figure 2. Here the time variation of the disproportion (16) with a gradual change of the sinusoid amplitude in the range of time from 30 to 60 is shown. In this interval, the disproportion (16) is not equal to zero. As we can see, after the amplitude reaches a new constant value, the disproportion is again equal to zero.

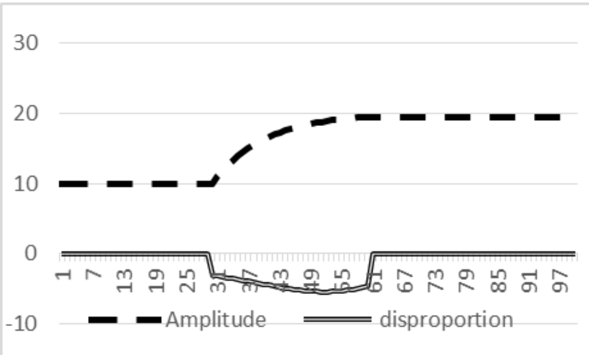

Figure 2 – Variation of disproportion (16) with amplitude change in time

Thus, it is possible to control transients in the object, at the output of which there is an analyzed signal.

6 DISCUSSION

The best known method for recognizing the type of a function is the least squares method. However, its application requires the implementation of the analyzed process at a certain time interval. That is, this method is not suitable for operational control.

To measure nonsinusoidality, special devices are used: spectrum and harmonic analyzers. The main elements of such devices are filters. These devices are an integral part of the operational system for monitoring the quality of electricity.

As a rule, these devices require the control of signal during at least one period of the first harmonic. In fact, it is not operative control also.

Non-sinusoidal voltage is characterized by a distortion factor of the sinusoidal voltage curve; and the coefficient of the n-th harmonic component of the voltage.

In this paper, it is proposed to measure the non-sinusoidality by the disproportion value of the analyzed signal with respect to its second derivative. The choice of the disproportion used depends on the units in which to evaluate. In any case, instead of special equipment, it is enough to connect a conventional computer to the electric network through a voltage divider and an analog-to-digital converter.

On the contrary of previous methods the proposed methods are operative.

If necessary, you can enter a scale of correspondence between the values of disproportion and the currently used distortion coefficient of the sinusoidality of the voltage curve.

To implement the methods, you need to calculate the first two or three derivatives. In the case of using analog computing devices, the signal value and its derivatives can be obtained simultaneously. This allows you to quantify the deviation of the type of the analyzed signal from the above types at the current time. However, when using digital devices, derivatives must be calculated numerically, for example, using the Newton-Stirling formula [17].

To estimate the sinusoidal waveform, as can be seen from (16), the current values of the first three derivatives are required.

Table 2 shows the values of the first three derivatives for sin (0.6) calculated by the Newton-Stirling formula, and their exact values. The values sin(x) calculated on the interval $x \in [0, 1.8]$ with a step of 0.2.

Table 2 – Exact and calculated values of 1st, 2nd and 3rd derivatives of sinusoidal signal

Derivatives	y'(0.6)	y''(0.6)	y'''(0.6)
Exact values	0.82534	–0.56464	–0.82534
Calculated values	0.82534	–0.56428	–0.82720

The table 2 shows that for the current measurement with high accuracy of the first three derivatives, it is sufficient to use the last 10 discrete values.

In any case, this number of measurements is less than what is required for existing methods for recognizing the type of the function.

CONCLUSIONS

In this paper, the actual problem of the operational recognition of some standard types of a numerical function is solved.

Scientific novelty lies in the fact that the recognition of the type of function that describes the process is carried out promptly from data obtained at the current time. For this, the current values of the analyzed process and its derivatives are used. It should be emphasized that it is recognition of exactly the form of a numerical function, regardless of its parameters.

The problem is solved using disproportion functions.

Depending on the requirements, disproportion over the n-th order derivative or disproportion over the n-th order value or relative disproportion is calculated.

To verify the power function any disproportion with respect to a time is calculated.

For this case, all of them are equal to zero, regardless of the scale factor and exponent.

For an exponential function, any of the disproportions of the analyzed function calculated at the current moment of time with respect to its first derivative is equal to zero.

If the disproportion of the function with respect to its second derivative is equal to zero, this is a sign that this function is currently sinusoidal.

Once again, it should be emphasized that these signs do not depend on the parameters of the function.

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If the disproportion is not equal to zero, its value allows you to quantify the deviation of the type of the analyzed function from one of the considered standard types. This estimate will be presented in different units of measure, depending on which disproportion is used.

In fact, new quantitative estimates of the deviation of the type of the function from the given have been developed.

The proposed methods were verified as a result of computer simulation of the decay of isotopes of a radioactive substance, as well as modeling of distortion of a sinusoidal signal during a limited time interval. The results obtained indicate a high sensitivity of the proposed methods.

The practical significance of the results of the work lies in the fact that the developed methods can be used to control the purity of radioactive isotopes, to control chemical-technological and other processes in production. Particularly, it should be pointed out that the proposed operational control of the sinusoidality of current and voltage in electric networks can be widely applied, regardless of amplitude, frequency, and phase. Such control is an actual practical task.

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ОПЕРАТИВНЕ РОЗПІЗНАВАННЯ ЕТАЛОННИХ ТИПІВ СИГНАЛІВ

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АНОТАЦІЯ

Актуальність. Розпізнавання типу функції незалежно від її параметрів є актуальним завданням.

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Мета. Розробити методи оперативного кількісного виміру відхилень типу функції, що представляє аналізований процес, від стандартних типів функцій: степеневих, поліноміальних, експоненційних і синусоїдальних за даними, отриманими в поточний час.

Методи. Для вирішення проблеми розроблені методи, засновані на функціях диспропорції. Приведені існуючі функції диспропорції та їх застосування для розпізнавання степеневих і поліноміальних функцій. Для розпізнавання експоненційної і синусоїдальної функцій в поточний момент використовується диспропорція по похідній першого порядку аналізованої функції по її похідним. При параметричному представленню функцій це різниця між відношенням значень двох функцій і відношенням їхніх перших похідних для даного значення параметра. У разі пропорційного зв'язку між двома функціями ця функція диспропорції дорівнює нулю для будь-якого значення коефіцієнта пропорційності. Показано, що якщо для заданого значення аргументу диспропорція по похідній першого порядку аналізованої функції по відношенню до її першої похідної дорівнює нулю, це ознака того, що функція є експоненціальною в цій точці незалежно від її параметрів.

Для контролю синусоїдального типу в поточний момент часу обчислюється диспропорція по похідній першого порядку аналізованої функції по відношенню до її другої похідної. Якщо вона дорівнює нулю, це ознака того, що функція є синусоїдальною в даній точці незалежно від її амплітуди, частоти і фази коливань. Показано, що таким способом можна також контролювати суму синусоїд з різними амплітудами і фазами, але з однаковою частотою. Також можна контролювати синусоїди піднесені в другу степінь.

Результати. Ефективність запропонованих методів показана в результаті комп'ютерного моделювання розпаду радіоактивних ізотопів, а також моделюванням спотворення синусоїдального характеру контрольованого процесу.

Висновки. На основі функцій диспропорції розроблені методи для оперативного розпізнавання типу функції, яка описує аналізований процес. Ці методи можуть бути використані для аналізу хіміко-технологічних процесів, контролю чистоти радіоактивних ізотопів, а також для контролю синусоїдальності процесів в електричних мережах.

КЛЮЧОВІ СЛОВА: функції диспропорції, тип числової функції, спотворення синусоїди, експоненціальна функція, поліноміальна функція, степенева функція.

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ОПЕРАТИВНОЕ РАСПОЗНАВАНИЕ ЭТАЛОННЫХ ТИПОВ СИГНАЛОВ

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АННОТАЦИЯ

Актуальность. Распознавание типа функции независимо от ее параметров является актуальной задачей.

Цель. Разработать методы оперативного количественного измерения отклонений типа анализируемой функции, представляющей анализируемый процесс, от стандартных типов функций: степенных, полиномиальных, показательных и синусоидальных по данным, полученным в текущее время.

Методы. Для решения проблемы разработаны методы, основанные на функциях диспропорции. Приведены существующие функции диспропорции и их применение для распознавания степенных и полиномиальных функций. Для распознавания показательной и синусоидальной функций в текущий момент используется диспропорция по производной первого порядка анализируемой функции по ее производным. При параметрическом представлении функций это разница между отношениями значений двух функций и отношением их первых производных для данного значения параметра. В случае пропорциональной зависимости между двумя функциями эта функция диспропорции равна нулю для любого значения коэффициента пропорциональности. Показано, что, если для заданного значения аргумента диспропорция по производной первого порядка анализируемой функции по отношению к ее первой производной равна нулю, это признак того, что функция является показательной в этой точке независимо от ее параметров.

Для контроля синусоидальности в текущий момент времени вычисляется диспропорция по производной первого порядка анализируемой функции по отношению к ее второй производной. Если она равна нулю, это признак того, что функция является синусоидальной в данной точке независимо от ее амплитуды, частоты и фазы колебаний. Показано, что таким способом можно также контролировать сумму синусоид с разными амплитудами и фазами, но с одинаковой частотой. Также можно контролировать синусоиды во второй степени.

Результаты. Эффективность предложенных методов показана в результате компьютерного моделирования распада радиоактивных изотопов, а также моделирования нарушения синусоидального характера контролируемого процесса.

Выводы. На основе функций диспропорции разработаны методы для оперативного распознавания типа функции, которая описывает анализируемый процесс. Эти методы могут быть использованы для анализа химико-технологических процессов, контроля чистоты радиоактивных изотопов, а также для контроля синусоидальности процессов в электрических сетях.

КЛЮЧЕВЫЕ СЛОВА: функции диспропорции, тип числовой функции, искажение синусоиды, показательная функция, полиномиальная функция, степенная функция.

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