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TECHNOLOGIES OF COMPUTER CONTROL

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INFORMATION TECHNOLOGIES OF PARALLEL ALGRITHMS OF IDENTIFICATION AND IMITATION MODELLING ON THE BASIS OF SYMBOLICAL COMBINATORY MODELS

PARALĒLO IDENTIFIKĀCIJAS UN IMITĀCIJAS MODELĒŠANAS ALGORITMU INFORMĀCIJAS TEHNOLOĢIJAS UZ SIMBOLISKO KOMBINATORISKO MODEĻU PAMATA

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1. Introduction

The reliability of the results of identification and imitation modelling depends on the accuracy of consideration of the mathematical relations between the information spaces in which computing processes are realized. Besides that, the validity of algorithms depends on the degree of dynamism of the processed signals and that puts forward additional requirements to the algorithms. As it is required to process large amounts of information, the use of computers working in parallel modes of calculations is necessary and that demands the application of computing algorithms with parallel architecture.

2. Requirements to parallel algorithms of identification

Traditional computing algorithms are not appropriate for realization in modern computers as their architecture is not coordinated with the parallel architecture of computers. To solve the problem of coordination, it is necessary to use formalized mathematical models. Yet the questions of hardware realization of computers and the computing problems appear to be related by deep mutual relations and, consequently, the development of such models is complicated. It demands the application of non-conventional mathematical apparatus connected to symbolical analytical calculations. This problem can be solved using symbolical combinatory (SC) models [8, 9, 10, 11].

Application of the procedures for checking the reliability of received results is an obligatory condition for the development of information technologies. Results of identification should reflect the physical properties of the identified object. Therefore, it is necessary to decode the results of numerical calculations, which have an abstract content, into the results with a clear physical interpretation. Only then, they can be used for the control of the object and for the diagnosis of its condition.

The algorithms created on the basis of SC models should possess high noise tolerance in relation to degenerate situations arising during solving of the equation systems. The traditional methods of regularization appear to be inefficient. Therefore, it is required to develop new methods and they can be created on the basis of SC models. In conditions when numerical stability of algorithms can change over a wide range, it is necessary to take measures for reducing the influence of errors with methodical character. Their value can be excessive if in the algorithms the mathematical relations between information spaces, in which they are realized, are distorted.

That demands using the aprioristic information in the mathematical form, and not just in the form of verbal descriptions. The specified above requirements to the algorithms can be fulfilled only under the condition if the relations between information spaces are described in determined mathematical form. Application of the algorithms based only on the basis of intuitive assumptions of associative character leads to false results.

3. Mathematical relations between information spaces in algorithms of identification and imitation modelling

The aprioristic information used for the identification of parameters of a dynamic analog technical object is usually written down in the form of a transfer function

$$W(p)=\frac{R(p)}{Q(p)}=\frac{p^{n}+q_{n-1}p^{n-1}+q_{n-1}p^{n-2}+\ldots+q_{1}p+q_{0}}{b_{m}p^{m}+b_{m-1}p^{m-1}+b_{m-1}p^{m-2}+\ldots+b_{1}p+b_{0}} \tag{1}$$

Its coefficients and their variations are specified in the technical documentation of the object. They are obtained during the design and industrial manufacturing stages. On the basis of these data, a set of various operators (1) that model the various conditions of the object can be generated. Discrete processing of information leads to the necessity to use discrete operators

$$D(z)=\varphi\, Z(T)*W(p)\Rightarrow\frac{A(z)}{B(z)}=\frac{\alpha_{m}z^{m}+\alpha_{m-1}z^{m-1}+\ldots+\alpha_{1}z+\alpha_{0}}{z^{n}+\beta_{n-1}z^{n-1}+\beta_{n-2}z^{n-2}+\ldots+\beta_{1}z+\beta_{0}}\,. \tag{2}$$

instead of the operators (1).

Their coefficients have an abstract content and depend on the sampling rate of the signals *T*. However, there is a determined unequivocal mathematical relation between the parameters of operators (1) and (2). Hence, between the information spaces *IS1* and *IS2*, in which numerical processing is made, this relation has the same character. It determines the structure of the algorithms for solving the systems of difference equations formed from the results of measurements of the input $x(iT)$ and the output $y(iT)$ signals

$$[X]\cdot\bar{\alpha}+[Y]\cdot\bar{\beta}=\bar{y}\,. \tag{3}$$

For this purpose, various modifications of such algorithms [8, 9]. can be used. In a test mode, when the mathematical description of the input signal is known, it is desirable to apply a system of smaller dimension

$$[Y]\cdot\bar{\hat{\beta}}=\bar{y}\,;\quad [Y]_{i\,j}=y[t+(i+j-1)T]\,;\quad [\bar{y}]_{i}=y[t+(n+i)T]\,. \tag{4}$$

Its conditionality is better than that of the system (3). First, the system (4) is solved and an estimation of the coefficients of the characteristic polynomial of operator (2) is found. Then, an estimation of the coefficients of the polynomial-numerator of operator (2) is calculated [4]. The vector

$$\bar{\hat{\beta}} \Rightarrow H \cdot \bar{y}; \quad H = [Y]^{-1} \tag{5}$$

in general can be considered as the vector of the spectral factors of Fourier transform in the basis that has a form of a Toeplitz matrix *Y*. Finding its inverse matrix *H* using numerical methods can possibly result in large errors, as the Toeplitz matrices have an extremely bad conditionality. This demands the application of non-conventional methods for maintaining the numerical stability of algorithms for inversion of such matrixes.

Clearly, in such conditions, the application of any intuitive descriptions of the model (5) is completely unreasonable. It has already been proved by the example of application of traditional regularization methods, based on the introduction of auxiliary functionals in the solution of the problem.

The vector (5) is connected to the operator *D(z)*. In the works [4, 6, 8, 9, 12, 13], the mathematical relations between information spaces $IS_1\{W(p)\}$ and $IS_2\{D(z)\}$ have been investigated. They have a determined unequivocal character and are described by the operations of direct and inverse discrete transform

$$\varphi Z(T) * W(p) \Rightarrow D(z), \; \varphi Z^{-1}(T) * D(z) \Rightarrow W(p). \tag{6}$$

It has been proved, that the mathematical relation between the poles of operators (1) and (2) does not depend on the character of used interpolation approximation. It has the following form

$$\{\xi_i = \exp(-a_i T)\} \Leftrightarrow \left\{a_i = -\frac{Ln(\xi_i)}{T}\right\}; \; [\bar{\beta}]_i = \varphi Sum * \left(\varphi KC(i) * \bigcup_{j=1}^{n} \xi_j\right). \tag{7}$$

The expressions (7) are determined by the character of the arrangement of analog and discrete poles on the complex plane. Mapping of the analog poles into the discrete ones occurs by the principle of mapping the infinite left complex half-plane into the area of the unit right half-circle. Therefore, the numerical values of distances between the discrete poles, which are used in the algorithms, can become comparable in size with the methodical errors. Their negative influence shows in the solution of the systems of difference equations. From here, it is clear that, if the difference equations are chosen on the basis of intuitive assumptions, as it is done in the associative method by its authors Y. Merkuryev, L. Rastrigin, and G. Vulf [14, 15, 16, 17], getting reliable results is impossible.

The determined character of the relations between the poles of operators (1) and (2) determines the same character of the relations between the coefficients of their characteristic polynomials

$$\{\varphi Z^{-1} * B(z)\} \Leftrightarrow \left\{Q(p) = \prod_{i=1}^{n} (p + a_i)\right\}. \tag{8}$$

The coefficients of the polynomial *B(z)* for a real, steady object must have alternating signs and their value must be in the range of the binomial coefficients, but should not exceed them by the absolute value. This condition is a characteristic attribute for the real physical objects. In the associative method, it is not observed. The difference equations, arbitrarily chosen by the authors, characterize the objects of virtual character that do not existing in the nature [12]. Y. Merkuryev in [16] does not deny it, advertising this method as an achievement in the field of information technologies. He is confident in its efficiency and universality and proves it by the example of imitation modelling the plots of Russian national fairy tales [16]. Therefore, the authors failed to show any numerical proof of validity of the method, as it mathematically incorrect.

The expression (3) shows, that the relations between the information space of the output signals $IS_3\{Y(t))\}$ and the spaces $IS_1\{W(p)\}$ and $IS_2\{D(z)\}$ also have a mathematically determined character. The decoding operation is reduced to mapping the objects from IS_3 into the objects $IS_4\left\{\left(\bar{\hat{\beta}}; \bar{\hat{\alpha}}\right); H\right\}$ with the use of algorithms of Fourier transform. It is realized in the feedback loop

$$IT_4\left\{\left(\bar{\hat{\beta}};\bar{\hat{\alpha}}\right)\right\} \Rightarrow IT_1\left\{\hat{W}(p);\varepsilon\right\}. \tag{9}$$

For the optimization of the results of identification and imitation modelling, any known method can be applied, for example, the gradient method. For this purpose, iterative procedures with the use of mathematical criteria are used. As such, the loss function, calculated for *m* cycles can be used

$$\hat{J}(m;W) \Longrightarrow \frac{1}{m}\sum_{j=1}^{m} \frac{\left\|W-\hat{W}_j\right\|}{\|W\|}. \tag{10}$$

One of the variants of the information loop can be represented in the following form

$$x(t) \to \left(IS_1 : \begin{matrix} W(p) = A(p,\bar{a})/Q(p,\bar{b}) \\ x(t) \end{matrix} \right) \Rightarrow \left(IS_2 : \begin{matrix} D(z,T) = C(z,\bar{\alpha})/B(z,\bar{\beta}) \\ y(iT) \end{matrix} \right) \Rightarrow$$

$$\Rightarrow \left[IS_3 : \begin{matrix} Y\cdot\bar{d} = \bar{y}_n\ ;\ \bar{d} = (\bar{\alpha},\bar{\beta}) \\ \left(Y^T\cdot Y\right)\cdot\bar{d} = \left(Y^T\cdot\bar{y}\right) \end{matrix} \right] \Rightarrow \left[IS_4 : \begin{matrix} \bar{d} = Y^{-1}\cdot\bar{y}_n\ ;\ \bar{d} = (\bar{\alpha},\bar{\beta}) \\ \bar{d} = \left(Y^T\cdot Y\right)^{-1}\cdot\left(Y^T\cdot\bar{y}\right) \end{matrix} \right] \Rightarrow$$

$$\Rightarrow \left[IS_5 : \begin{pmatrix} \bar{\alpha} \\ \bar{\beta} \end{pmatrix} \Rightarrow \hat{W}(p) = \begin{pmatrix} \bar{\hat{a}} \\ \bar{\hat{b}} \end{pmatrix} \right] \Rightarrow \left(IS_1 : \left[IS_6 : \bar{\varepsilon} = F\left\{ \begin{pmatrix} \bar{\hat{a}} \\ \bar{\hat{b}} \end{pmatrix} - \begin{pmatrix} \bar{a} \\ \bar{b} \end{pmatrix} \right\} \right] \right). \tag{11}$$

The aprioristic information should be represented in the mathematical form. The fact of the presence of determined relations between information spaces, in which the processing of experimental data is made, should be established.

The procedure of identification and imitation modelling is reduced to the estimation of the parameters of dynamic process at the output of the object

$$y\ (t) = \sum_{i=1}^{n}\ C_i \exp(a_i\cdot t)\cdot\sin(\omega_i\cdot t)\,. \tag{12}$$

The character of the relations between information spaces and their quantitative indicators are determined with the help of spectral factors of Fourier transform

$$\varphi F\ :\left\{BasW_j, w_i\right\} \to Cw_{j,i}\ ;\ \varphi F\ :\left\{BasY_j, y_i\right\} \to Cy_{j,i}\,. \tag{13}$$

Between the systems of Fourier transforms in different information spaces there should be the conformity

$$\varphi F\ :\left\{BasW\ _j, w_i\right\} \Leftrightarrow \varphi F\ :\left\{BasY\ _j, y_i\right\}. \tag{14}$$

The information technologies of algorithms of identification and imitation modelling should be developed on the basis of the feedback principle with the use of discrepancies

$$\varepsilon = N^{-1}\sum_i \left\|Cy_i - Cw_i\right\|.$$

4. Numerical example of identification of dynamic process

The problem of identification of the parameters of dynamic process

$$y\ (t) = \sum_{i=1}^{3} C_i \exp(a_i \cdot t) \cdot \sin(\omega_i \cdot t)\,. \tag{15}$$

is considered. The parameters of the processes, chosen for the formation of Fourier bases during the imitation modelling, are given in Tables 1 and 2.

From the realizations of signals, combinations were made for the formation of 3rd order Fourier bases, in which the vectors of spectral coefficients of Fourier transform were obtained for 3 test signals with parameters

$$y0_1[t;\, a_i = (0.8;1.4;1.7);\, \omega_i = (2.8;3;3.2)];\quad y0_2[t;\, a_i = (2.8;3.2;3.8);\, \omega_i = (3.8;4.3;4.5)]$$

$$y0_3[t;\, a_i = (5.7;6.2;7);\, \omega_i = (6.8;6.2;7)]\,.$$

Table 1

Parameters $\omega_{i,j}$ of the dynamic processes

j	1	2	3	4	5	6	7	8	9	10	11	12	13
$\omega_{1,j}$	2.6	2.1	2.4	2.3	3.8	2.4	3.3	3.8	3.8	2.3	3.1	3.9	3.2
$\omega_{2,j}$	3.5	3.7	4.6	3.1	4.2	3.4	4.3	4.2	3.9	3.8	4.2	4.9	3.8
$\omega_{3,j}$	6.4	7.1	7.3	6.1	6.5	7.8	7.5	6.8	7.8	6.8	6.7	7.5	7.5

Table 2

Parameters $a_{i,j}$ of the dynamic processes

j	1	2	3	4	5	6	7	8	9	10	11	12	13
$a_{1,j}$	1.8	2.4	1.8	2.2	1.8	1.7	1.9	0.6	1.3	2.1	2.3	2.1	2.4
$a_{2,j}$	3.6	4.1	2.9	4.1	4.2	3.8	3.7	3	4.1	3.9	2.7	4.2	3.1
$a_{3,j}$	5.9	5.4	7	6.3	5.3	5.5	6.7	5.7	5.5	5.5	6.9	5	5.3

The change of the identification errors, depending on the number of used bases, using the signal $y0_3(t)$, is shown in Fig.1. The average values of the errors obtained for the first 8 bases, for all test signals, were accordingly $\varepsilon\omega_j(\%) = (63.2;\ 19.6;\ 15.3)$, $\varepsilon a_j(\%) = (63.2; 19.6;\ 15.3)$. For other bases, non-reliable results were obtained, as they exceeded 200%, so they were rejected. In Fig.2, the change of the errors for the 1st basis is shown depending on the sampling rate of the signals T (sec).

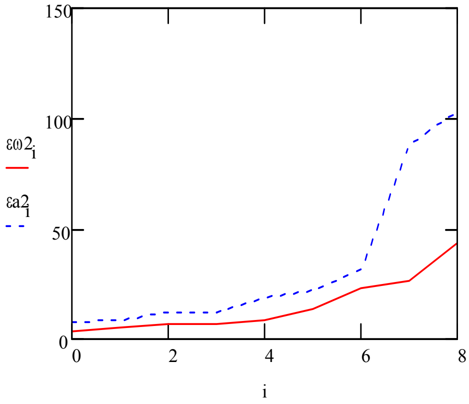

Fig.1. Identification error, depending on the number of used bases

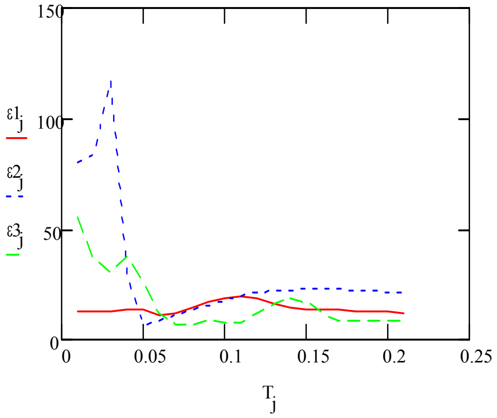

Fig.2. Identification error, depending on the sampling rate

These numerical results confirm the conclusions from the Section 3. The big values of the errors specify the necessity of more careful description of mathematical relations for the algorithms of identification. They confirm the necessity of application of procedures for checking the reliability of the obtained results. The authors of the associative approach believe that such check is not obligatory. They confuse the value of the discrepancy of the system of difference equations with the numerical criteria for checking the reliability of the results of identification. The discrepancy of the system of simultaneous equations, if their solutions are substituted in them, will always be zero, but it will not characterize the accuracy of the method.

5. Symbolical combinatory model of algorithms of identification and imitation modelling

The SC model we shall present in the form of address lexicographic combinatorial configurations. In it, we use the combinatorial operators developed in the articles [5, 6, 7, 8, 9, 10, 11]. The elements of the matrix (4) are formed from the parameters of the mapping of output signal in the form of a rational function (1). Therefore, they can be expressed using the degrees of the discrete poles of the operator *D(z)* as in expression (7)

$$[Y]_{rL} = \sum_{k=1}^{n} C_k q_k{}^{r} \cdot q_k{}^{L}; \quad q_k = \exp(-a_i T). \tag{16}$$

The elements of the matrix H (5) we shall find using the SC model of the elements of the attached matrix V. According to [1], it can be found with the help of the operator φDpv that operates on the sub-matrix $H(\bar{r}, \bar{L})$. Here the vectors of the coordinates $\bar{r}$ and $\bar{L}$ of the allocated sub-matrix are used:

$$V(\bar{r}, \bar{L}) \Rightarrow \varphi Dpv(\bar{r}, \bar{L}) * \bar{q}^{(n)}; \quad \bar{q}^{(n)\,T} = (q_1, q_2, \cdots, q_n). \tag{17}$$

The elements of (16) we shall present as

$$[Y]_{rL} \Rightarrow \left[\bar{q} * Arang(r)\right]^{T} \cdot Diag(\bar{C}^{(n)}) \cdot \left[\bar{q} * Arang(L)\right]; (r, L) \in \left[\operatorname{Im} s = (\bar{r} \times \bar{L})\right]; \tag{18}$$

$$\left[\bar{q}^{(n)^T} * Arang(k)\right]^{T} \Rightarrow \left[q_1{}^{k}; q_2{}^{k}; \cdots, q_n{}^{k}\right]. \tag{19}$$

Here the designation of the system of coordinates of allocated sub-matrix *Ims* in the form of the Kronecker product of vectors is introduced. The operator $\varphi Dpv(\bar{r}, \bar{L}) * \bar{q}^{(n)}$ according to [5] can be represented in the form of position oriented graph

$$\begin{aligned} \varphi Gr(\bar{r}, \bar{L}) :\ & \tilde{q}_1{}^{(n)} \Rightarrow \varphi Dpv * \left[\varphi Kc(m_1) * \tilde{q}_1\right] \times \varphi Dpv * \left[\varphi Kc(m_2) * \tilde{q}_2\right] \times \cdots \\ & \cdots \times \left[\varphi Dpv * \left[\varphi Kc(m_k) * \tilde{q}_k\right]\right]; \quad \sum_{i=1}^{k} m_i = n \end{aligned} \tag{20}$$

Its partitions are formed from the subsets of the components of vector (17) using the residual principle. They represent the decompositions of the vector (17), which can be represented in the index form as

$$\bigcup_{i=1}^{k} \bar{q}_i^{(n_i)} \Rightarrow \bigcup_{i=1}^{k} i \circ \{\varphi Kc(v) : [(i+1), (i+2), \ldots, n)]\}; \quad k = n - (v-1). \tag{21}$$

The expression (20) describes the graph as a branching tree. Therefore, the SC model of the algorithm for finding the elements of H has the form of a decomposition of independent fragments as graph branches. Thus, it is a symbolical expression of the algorithm with parallel architecture.

For finding the SC model of the graph (20), we shall find additional properties of the operator φDpv, which are based on the previous results [5, 6, 7, 8, 9, 10, 11]. The components of *Ims* containing the coordinates of the elements of allocated sub-matrix, we use as arguments of φDpv. Due to this, the operations related to the inversion of Y can be transferred into the index information space

$$\varphi Dvp(\operatorname{Im} s) * \tilde{q}^{(n)} \Rightarrow \tilde{q}^{(n)} * Arang\left[\varphi Dvp(\bar{r}^{(n)} \times \bar{L}^{(n)})\right]. \tag{22}$$

Then we shall have

$$\varphi Dvp\left\{(\varphi Perm * \bar{r}^{(n)}) \times \bar{L}^{(n)}\right\} * \tilde{q}^{(n)} \Rightarrow \tilde{q}^{(n)} * Arang\left[\left(\varphi Dvp * \bar{r}^{(n)}\right) \oplus \bar{L}^{(n)}\right]. \tag{23}$$

On the basis of $\operatorname{Im} s = \left[\left(\overline{0.n-1}\right) \times \circ \left(\overline{0.n-1}\right)\right]$, the difference operators φFg [1, 4] can be introduced into the SC model:

$$\varphi Fg * \tilde{q}^{(n)} \Rightarrow \coprod_{i,j(i \neq j)} q_i - q_j \,; \tag{24}$$

$$\varphi Dvp\left\{(\varphi Perm * \overline{r}^{(n)}) \times \overline{L}^{(n)}\right\} * \tilde{q}^{(n)} \Rightarrow \left[\varphi Fg(\overline{r}^{(n)}) * \tilde{q}^{(n)}\right] \cdot \left[\tilde{q}^{(n)} * Arang\left(\left(\overline{L^{(n)}}\right)\right)\right]; \tag{25}$$

$$\varphi Dvp\left\{\overline{r}^{(n)} \times (\varphi Perm * \overline{L}^{(n)})\right\} * \tilde{q}^{(n)} \Rightarrow \left[\varphi Fg(\overline{L}^{(n)}) * \tilde{q}^{(n)}\right] \cdot \left[\tilde{q}^{(n)} * Arang\left(r^{(n)}\right)\right]; \tag{26}$$

$$\begin{aligned} &\varphi Dvp\left\{(\varphi Perm * \overline{r}^{(n)}) \times \overline{(\varphi Perm * \overline{L}^{(n)})}\right\} * \tilde{q}^{(n)} \Rightarrow \\ &\qquad \Rightarrow \left[\varphi Fg(\overline{r}^{(n)}) * \tilde{q}^{(n)}\right] \times \left[\varphi Fg(\overline{L}^{(n)}) * \tilde{q}^{(n)}\right]. \end{aligned} \tag{27}$$

If $\overline{r}^{(n)} = \overline{m.\, m + (n-1)}$, the following common multiplier is extracted:

$$\varphi Dvp\left\{\varphi Perm * \left[\left(\overline{0.n-1}\right) \oplus m^{[n]}\right]\right\} * \tilde{q}^{(n)} \Rightarrow \left[\tilde{q}^{(n)} * Arang(m^{[n]})\right] \cdot \left[\varphi Fg * \tilde{q}^{(n)}\right]. \tag{28}$$

The conjugate property of the decomposition is observed:

$$\begin{aligned} &\varphi Dvp(\varphi Perm * \overline{r}^{(n)}) * \left[\tilde{q}^{(n)} * Arang(\overline{r}^{(n)} \oplus \overline{L}^{(n)})\right] \Rightarrow \\ &\Rightarrow \left[\tilde{q}^{(n)} * Arang\left(\varphi Dvp * \overline{r}^{(n)}\right)\right] \cdot \left[\tilde{q}^{(n)} * Arang\left(\overline{L}^{(n)}\right)\right]; \end{aligned} \tag{29}$$

$$\begin{aligned} &\varphi Dvp(\varphi Perm * \overline{L}^{(n)}) * \left[\tilde{q}^{(n)} * Arang(\overline{r}^{(n)} \oplus \overline{L}^{(n)})\right] \Rightarrow \\ &\Rightarrow \left[\tilde{q}^{(n)} * Arang\left(\varphi Dvp * \overline{L}^{(n)}\right)\right] \cdot \left[\tilde{q}^{(n)} * Arang\left(\overline{r}^{(n)}\right)\right]. \end{aligned} \tag{30}$$

The expression (21) specifies that the SC model possesses the recursive properties that allow to apply the methods of reduction of algorithm complexity. For this purpose, we shall present the product in the branches of the graph in the form of a numerical ordered sequence *R(m, n)* [6]:

$$\begin{aligned} &R(m,n) \Rightarrow \sum_{v=1}^{m} \varphi Perm * \left\{\left[\varphi KC(v) * \overline{1.n}\right] * \varphi Arng(Z_v)\right\}; \\ &Z_v \Rightarrow \varphi Perm * \left[\varphi Part(v) * m\right]. \end{aligned} \tag{31}$$

For it, the following property is observed:

$$G(m,n) \Rightarrow (\overline{0.m-1}) \oplus R(m,n). \tag{32}$$

On their basis, the lexicographic forms for the Kronecker product of vectors can be generated as

$$\varphi \Pi r(m) * \left(\overline{1.n}\right) \Rightarrow R(m,n); \;\; \varphi \Pi r(m) * \left(\overline{1.n}\right) \Rightarrow \varphi KC(m) * \left[\left(\overline{1.n}\right) - (\overline{0.m-1})\right]. \tag{33}$$

Using abovementioned properties, we get

$$\begin{aligned} &\varphi Dvp(\varphi Perm * \overline{r}^{(n)}) * G(m,n) \Rightarrow \varphi Dpv(\varphi Perm * \overline{r}^{(n)}) * \left[\varphi KC(m) * \left(\overline{1.n}\right)\right]; \\ &\varphi Dvp\left\{(\varphi Perm * \overline{r}^{(n)}) \times \overline{L}^{(n)}\right\} * G(m,n) \Rightarrow \tilde{q}^{(n)} * Arang\left\{\begin{matrix} \varphi Dpv(\varphi Perm * \overline{r}^{(n)}) \\ * \left[\varphi KC(m) * \left(\overline{1.n}\right)\right] \end{matrix}\right\} \end{aligned} \tag{34}$$

Using the property of decomposition of the operator φDpv, we shall find

$$\varphi Dvp * \left[Q^{(n \times m)} \cdot P^{(m \times n)}\right] \Rightarrow \overline{u}^{T} \cdot \overline{h}\,; \tag{35}$$

$$\left[\overline{u}\right]_i \Rightarrow \varphi Dvp * Q_i^{(n \times n)}; \;\; \left[\overline{h}\right]_i \Rightarrow \varphi Dvp * P_i^{(n \times n)}. \tag{36}$$

The coordinates of the sub-matrices are used as arguments of the operator φDpv.
As such, we use vectors made from the components of ordered numerical sequences $\overline{G(n,m)} = (\overline{0.n}) \oplus \overline{R(n,m)}$ [6]:

$$\left[\bar{u}\right]_i \Rightarrow \varphi Dvp\left[\left(\overline{1.n} \times \circ\, G(n,m)_i\right)\right] * Q;\ \left[\bar{h}\right]_i \Rightarrow \varphi Dvp\left(G(n,m)_i \times \overline{1.n}\right) * P \tag{37}$$

Then the expression (1) can be written down in the following form:

$$\varphi Dvp * \left[Q^{(n\times m)} \cdot P^{(m\times n)}\right] \Rightarrow \varphi Sum * \left\{\left[\varphi Dvp(\overline{\arg}_1) * Q\right] \otimes \left[\varphi Dvp(\overline{\arg}_2) * P\right]\right\}; \tag{38}$$

$$\overline{\arg}_1 \Rightarrow \left[\overline{1.n}\right] \times \circ\, \overline{G(n,m)}^{\,T};\quad \overline{\arg}_2 \Rightarrow \overline{G(n,m)} \times \circ \left[\overline{1.n}\right]. \tag{39}$$

Let's find the argument set for the φDpv, operating on the product $\left[Q^{(n\times m)} \cdot M^{(m\times m)} \cdot W^{(m\times n)}\right]$. With the help of the vector $\overline{ims}_i \Rightarrow \overline{G(n,m)}_i \times \circ\, \overline{G(n,m)}$ we shall extract the sub-matrix $S^{(n\times m)}{}_i \in M^{(m\times m)}$. Using (4), we find

$$\overline{\arg}\left[\varphi Dpv * (S_i \cdot W)\right] \Rightarrow \left[\overline{G(n,m)}_i \times \circ\, \overline{G(n,m)}^{\,T}\right]_M \otimes \circ \left[\overline{G(n,m)} \times \circ \left(\overline{1.n}\right)\right]_W; \tag{40}$$

$$Arg\left(\varphi Dpv * M^{(m\times m)}\right) \Rightarrow \left\{\overline{G(n,m)} \times \circ\, \overline{G(n,m)}^{\,T}\right\}_M. \tag{41}$$

The result of the action of the operator φDpv we shall write down as

$$\varphi Dpv * \left[Q^{(n\times m)} \cdot M^{(m\times m)} \cdot W^{(m\times n)}\right] \Rightarrow \bar{d}^{\,T} \cdot Z \cdot \bar{w}; \tag{42}$$

$$\bar{d}^{\,T} \Rightarrow \varphi Dpv\left\{\left[\left(\overline{1.n}\right) \times \circ\, \overline{G(n,m)}\right]\right\} * Q;\ \bar{w} \Rightarrow \varphi Dpv\left\{\left[\left(\overline{1.n}\right) \times \circ\, \overline{G(n,m)}\right]\right\} * W; \tag{43}$$

$$\left[Z\right]_{ij} \Rightarrow \varphi Dpv\left\{\overline{G(n,m)}_i \times \circ\, \overline{G(n,m)}^{\,T}_j\right\} * M^{(m\times m)}. \tag{44}$$

Using the result (42) and the expression (33 [1], we find the SC model of the inverse matrix of the dynamic process as

$$\begin{aligned} Y^{-1} &\Rightarrow \varphi Dpv\left\{\left(\overline{G(n,m)} \times \circ\, \overline{G(n,m)}\right)\right\} * Y \Rightarrow \left[\varphi Dpv * W(\overline{G(n,m)})\right] \cdot \\ &\cdot \left[\varphi Dpv\left\{\left(\overline{G(n,m)} \times \circ\, \overline{G(n,m)}\right)\right\} * M^{(k\times k)}\right] \cdot \left[\varphi Dpv * W(\overline{G(n,m)})\right]. \end{aligned} \tag{45}$$

Here the outer multipliers are formed on the basis of matrices consisting of the powers of discrete poles, and the middle matrix is formed from the weight factors of the dynamic process C_i. In this expression, the diagonal matrices, which elements are generated using the operator φFg [2], can be extracted:

$$Y^{-1} \Rightarrow Diag\left[\overline{\alpha\ (FG)}\right] \cdot \left[\varphi Dpv * M^{(k\times k)}\right] \cdot Diag\left[\overline{\alpha\ (FG)}\right]. \tag{46}$$

From the expressions (42-46), it follows that they can be generated as decompositions which fragments can be processed independently. Thus, the SC model of the computing algorithm has a parallel architecture. Its structure can be changed flexibly by changing the parameters of the operators of combinatorial operations that are included in the model. It allows to coordinate the architecture of the algorithm with the parallel architecture of the computer using software methods.

6. Conclusions

The development of information technologies of algorithms of identification and imitation modelling should be based on the observance of the mathematically determined relations between the information spaces in which the processing of experimental data is done. As these relations cannot be described precisely and the algorithms do not possess the guaranteed numerical stability, checking the reliability of the obtained results is an obligatory condition for the development of information technologies. Therefore, the algorithms of imitation modelling should be formed with the application of the principle of information feedback. In the Y. Merkuyev, L. Rastrigin, and G. Vulf's associative method, these conditions are not observed. Therefore, the method is mathematically incorrect and cannot work. It is a dead-end way in the development of information technologies. For a long time, there were no sufficient bases for the priority financing of this direction.

Modern information technologies should be connected to the realization of algorithms in modern computers working in parallel modes of calculation. Therefore, the development of formal models for coordinating the architecture of algorithms with the parallel architecture of computers is necessary. Such problem can be solved with the application of symbolical combinatory models. They allow developing computing algorithms with parallel architecture that have higher noise tolerance to degenerate situations arising during calculations. Efficiency of the obtained theoretical results is confirmed by a numerical experiment on the example of polynomial approximation. The inverse 20^{th} order Hilbert's matrix was calculated with the 100% accuracy, though it was considered earlier that over 10^{th} order it is impossible to calculate.

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Burovs G. Paralēlo identifikācijas un imitācijas modelēšanas algoritmu informācijas tehnoloģijas uz simbolisko kombinatorisko modeļu pamata
Identifikācijas un imitācijas modelēšanas algoritmu informācijas tehnoloģijas rada nepieciešamību ievērot matemātiski determinētas sakarības starp informācijas telpām un izmantot procedūras iegūto rezultātu ticamības pārbaudei. J.Merkurjeva, L.Rastrigina un Ģ.Vulfa asociatīvajā metodē matemātiskās sakarības ir aizstātas ar patvaļīgām, vienkāršotām sakarībām ar intuitīvu raksturu, un rezultātu ticamība netiek pārbaudīta. Tādēļ šī metode ir matemātiski kļūdaina, tā nevar darboties un ir strupceļš informācijas tehnoloģiju attīstībā. Uz simbolisko kombinatorisko modeļu pamata analītiskā formā ir iegūts algoritms identifikācijas matricas invertēšanai. Tas ļauj izmantot principiāli jaunas algoritmu regularizācijas metodes. Izstrādātajam algoritmam ir paralēla arhitektūra, kas ļauj to realizēt datoros, kas darbojas paralēlā skaitļošanas režīmā. Algoritma efektivitāte ir pārbaudīta skaitliskā eksperimentā, kā piemēru izmantojot polinomiālo aproksimāciju. Tika aprēķināta 20.kārtas inversā Hilberta matrica ar 100% precizitāti, kaut gan agrāk tika uzskatīts, ka to nevar aprēķināt, ja kārta ir lielāka par 10.

Burov G. Information technologies of parallel algorithms of identification and imitation modelling on the basis of symbolical combinatory models
Information technologies of algorithms of identification and imitation modelling are considered from the positions of necessity to observe the mathematically determined relations between information spaces and the application of procedures for checking the reliability of obtained results. In the associative method of Y. Merkuryev, L. Rastrigin, and G.Vulf, the mathematical relations are replaced with arbitrary, simplified relations with an intuitive character and the reliability of results is not checked. Therefore, such method is mathematically incorrect. It cannot work and represents a dead-end way in the development of information technologies. On the basis of symbolical combinatory models, the algorithm for calculating the inverse matrix of identification in an analytical form is created. It allows to apply essentially new methods of algorithm regularization. The developed algorithm has a parallel architecture that allows to realize it on computers working in modes of parallel calculation. Efficiency of the developed algorithm was checked by a numerical experiment on the example of polynomial approximations. The inverse 20th order Hilbert's matrix was calculated with the 100% accuracy, though it was considered earlier that over 10th order it is impossible to calculate.

Буров Г. Информационных технологии параллельных алгоритмов идентификации и имитационного моделирования на основе символьных комбинаторных моделей
Информационные технологии алгоритмов идентификации и имитационного моделирования рассмотрены с позиций необходимости соблюдения математических детерминированных связей между информационными пространствами и применения процедур проверки достоверности получаемых результатов. В ассоциативном методе Ю Меркурьева, Л Растригина , Г Вульфа математические связи заменены произвольными упрощенными соотношениями интуитивного характера и достоверность результатов не проверяется. Поэтому такой метод математически несостоятелен и неработоспособен и представляет собой тупиковый путь в развитии информационных технологий. На основе символьных комбинаторных моделей получен алгоритм получения обратной матрицы идентификации в аналитическом виде. Это позволяет применить принципиально новые методы регуляризации алгоритмов. Разработанный алгоритм имеет параллельную архитектуру. Это позволяет его реализовать в ЭВМ, работающих в режимах параллельных вычислений. Эффективность полученного алгоритма проверена численным экспериментом на примере полиномиальной аппроксимации. Была найдена обратная матрица Гильберта 20 порядка со 100% точностью, хотя ранее считалось что выше 10 порядка ее получить невозможно.