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Identification of Linear Dynamic Objects and Control Tasks

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ABSTRACT: Presents the results of a structural and parametric identification of mathematical models of linear technological facilities management if there is noise in the input and output signals in a priori uncertainty in an unknown Act distribution of noise. Discusses the way the structural and parametric identification object model that enables you to assess the differential equations of linear order without using transfer function or impulse control in complex systems interference-signal conditions.

KEYWORDS: structural-parametric synthesis of control systems, identification of mathematical models, technological management objects, noise on the input and output of the object, linear difference equations.

I. INTRODUCTION

Currently, methods of identification of mathematical models of real dynamic management objects are an important part of the solution to the problems of automatic control of technological objects liable to operate in conditions of uncontrollable perturbing influences. If prior information about the research facility there is no known methods to build mathematical models of technological objects prone to random noise in the input and output signals of the system [1]. However, these methods do not provide answers to questions about the essential characteristics of an object and clarify only some guidance in choosing a class of mathematical models.
One of the most common dynamic model is a mathematical description of a class of linear differential equations. However, in this case, the determination of the parameters and structure models (order on input and output) linear-differential equation is sufficiently challenging.
The task of identification of technological objects control with input and output disturbances is more complex than the problem in the classic formulation of regression analysis. Of particular interest were the methods of identification of dynamic systems that allow to evaluate the parameters of an object model in real-time.
Now you can observe the intensive development of the wealthy identification methods of technological objects Office operating in complex interference – signal conditions. In [2] the identification method control objects using the method of least squares estimation for linear differential operators. Methods of instrumental variables and their recurrent modifications discussed in [3.4]. Methods, compensating the offset squares are dedicated to work [5.6].
In the vast majority of publications on the subject of disturbing noise are stationary white noise. However, in practice, often the interference is not only auto correlated but also transient.
When the object is not assumed a priori, there are methods to determine the order of mathematical models of process control systems in the presence of noise in the output signal [1], for example, the use of the quadratic function loss, information criterion (AIC), Akaike criterion for smallest model Rissanena (MDL), the use of a matrix of points. You can also use information on transfer functions for pulse characterization of the dynamic system.
This paper provides an algorithm for structural and parametric identification models of linear technological objects control when disturbances in the input and output signals with unknown laws of distribution of noise monitoring.

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II. STATEMENT OF A PROBLEM

Consider a linear differential equation of multi-dimensional with input and output disturbances with the infinite in both discrete time $i = \ldots,-1, 0,1,\ldots:$

$$z_i - \sum_{m=1}^{r} b_0^{(m)} z_{i-m} = \sum_{j=1}^{d} \sum_{m=0}^{rj} a_0^{(mj)} x_{i-m}^{(j)} \qquad (1)$$

Inlet and outlet variables are observed with additive noise in the form of

$$y_i = z_i + \xi_1(i), w_i^{(j)} = x_i^{(j)} + \xi^{(j)}(i) \qquad (2)$$

Demanded to define by $y_i, w_i^{(j)}$ the vectors a, b and orders $r,\ r_j$.

As a function of the parameter estimates for linear differential equations in terms of interference is used the following criteria [10]:

$$\min_{\binom{b}{a}} \omega^{-1}\left(b, a^{(1)}..a^{(d)}\right) U_N\left(b, a^{(1)}..a^{(d)}\right), \qquad (3)$$

where (.,.) is scalar product;

$$U_N\left(b, a^{(1)}..a^{(d)}\right) = \left(Y - A_{Y,W}\begin{pmatrix} b \\ a \end{pmatrix} * Y - A_{Y,W}\begin{pmatrix} b \\ a \end{pmatrix}\right),$$

$$\omega\left(b, a^{(1)}..a^{(d)}\right) = \bar{\sigma}_1^2\left[1 + b^T b + \gamma^{(1)}\left(a^{(1)}\right)^T a^{(1)}..\gamma^{(d)}\left(a^{(d)}\right)^T a^{(d)}\right],$$

$\bar{\sigma}_1^2$ - the average variance of the noise monitoring; $\xi_1(i); \left(\bar{\sigma}^{(j)}\right)^2$ - the average variance of the noise monitoring $\xi_2^{(j)}(i), \gamma^{(j)} = \dfrac{\left(\bar{\sigma}^{(j)}\right)^2}{\bar{\sigma}_1^2};$

$$a = \left(a^1..a^d\right)^T, a^{(j)} = \left(a^{a,j}..a^{r,j,j}\right)^T,\ b = \left(b^1..b^r\right)^T,\ Y = \left(y_1..y_N\right)^T$$

$$A_{y,w} = \left| \begin{array}{ccc:ccc:c:ccc} y_0 & \cdots & y_{1-r} & w_1^{(1)} & \cdots & w_{1-r_1}^{(1)} & & w_1^d & \cdots & w_{1-r_d}^{(d)} \\ \vdots & & \vdots & \vdots & & \vdots & \cdots & \vdots & & \vdots \\ y_{N-1} & \cdots & y_{N-r} & w_N^{(1)} & \cdots & w_{N-r_1}^{(1)} & & w_{N-1}^d & \cdots & w_{N-r_d}^{(d)} \end{array} \right|.$$

The criteria to get highly consistent estimates, subject to the following conditions:

1. Set $\tilde{B}$ the a priori belong to the true parameter values stable linear system is compact.
2. Noise $\xi(i), \xi^{(j)}(i),\ j = \overline{1,d}$, statistically independent and meet the ones of the following conditions:

$$E\left(\xi_1(i+1) / \xi_1(i_0),\ldots, \xi_1(i)\right) = 0 \qquad (4)$$

where E is the expected value operator;

$$E\left(\xi_1^2(i+1) / \xi_1(i_0),\ldots\xi_1(i)\right) \le h$$

Here: h -random variable;

$$E(h) \le \pi < \infty;\ E\left((\xi_1)^4(i)\right) \le \pi_1 \text{ almost surely;}$$

$$E\left(\xi^{(j)}(i+1) / \xi_1(i_0),\ldots\xi^{(j)}(i)\right) = 0 \text{ almost surely;}$$

$$E\left(\left(\xi^{(j)}\right)^2(i+1) / \xi_1(i_0),\ldots,\xi^{(j)}(i)\right) \le h^{(j)},$$

$h^{(j)}$ - random variable;

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$$E\left(h^{(j)}\right) \le \pi^{(j)} < \infty;\ E\left(\xi^{(j)}(i)\right) < h^{(j)}1 < \infty .$$

3. $\left\{x_i^{(1)},\ldots, x_i^{(d)}\right\}$ statistically do not depend on the $\left\{\xi(i)\right\}, \left\{\xi^{(j)}(i)\right\}, j = \overline{1,d}$

4. Vector of the input variables and the true parameter values satisfy the conditions:

$$N^{-1}\sum_{i=i_0}^{N}\begin{pmatrix} z_r^T(i) \vdots \left(x_{r_1}^{(1)}(i)\right)^T \vdots \cdots \vdots \left(x_{r_d}^{(d)}(i)^T\right)^T \\ \times z_r^T(i) \vdots \cdots \vdots \left(x_{r_d}^{(d)}\right)^T \end{pmatrix} almost \underset{N\to\infty}{\to} surely^{H} \tag{5}$$

where

$$x_{r_j}^{(j)} = \left(x_i^{(j)} \ldots x_{i-r_j}^{(j)}\right)^T,\ z_r(i) = \left(z_{i-1} \ldots z_{i-r}\right)^T$$

Method of structural and parametric identification of linear dynamical system allows to evaluate the order linear differential equation, without applying the device transfer function or impulse characteristics of an object in terms of noise monitoring in the input and output signals of the system.

III. THE CONCEPT OF THE PROBLEM DECISION

The numerical realization of model structure selection based on heuristic search algorithm [7], which is used in the tasks of optimization by random selection, combining and variations of the desired parameters using the mechanisms of biological evolution. The difference between this genetic algorithm is to use the crossing operations by recombination of solutions.

The challenge comes down to coding as a vector, where each element represents a shift for itself and the task is formalized as a problem of integer programming.

Numerous genotypes primary population is randomly generated. If the population is uncompetitive, the algorithm with sufficient performance translates it into a viable population.

Each genotype is measured using a fitness function, parameter, where each genotype is associated a certain adaptability, which assesses how they described phenotype, good addresses this challenge.

From the resulting set of decisions ("generation") taking into account the significance of the "fitness" selected decisions, which are subject to the "crossing" and "mutation".

The "crossing" is to a descendant or child could inherit traits from both parents, "mix" them. Because an encoding is a vector, the genotypes for breeding operation, you can use the following method: select a random gene in genotype; data plots are exchanged by both parents. At the stage of "mutation" each gene has a genome is changed arbitrarily.

The end result of "crossing" and "mutation" is getting new solutions. They also calculated the value of fitness, and then are selected ("selection") of the best solutions to the next generation.

The selection phase of the entire population, you must select a share that will remain "alive" at this stage of evolution. The probability of survival of the species depends on the value of as fitness.

This set of actions is repeated iteratively. So the simulated "evolutionary process", for several generations, until the stopping criterion, namely: algorithm for several generations, the fitness function value for each individual in the population is "insignificant".

Thus, the following stages of the genetic algorithm: define the objective function(fitness) for individuals of a population, generate a random initial population. Then loops to make the following operations on the population reproduction (crossing),mutation, the calculation of the value of the criterion for this structure, stability and compliance check on dimension, the formation of a new generation (selective breeding) based on a selection of the best in the current. When the conditions of a stop to finish the loop, otherwise repeat the operation.

In general terms, the structural and parametric identification algorithm looks the following way:

1. Create a database for model structures: store-for all parametric identified structures, stab store-only for sustainable systems, store_p is the result a thesaurus for models with a minimum value of the criterion for each border complexity

$$p = r + \sum_{j=1}^{d} r_{j.} \tag{6}$$

2. Specify limitations for the algorithm: adequacy Δ, the maximum allowable complexity p .

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3. Set the starting boundary of complexity $p = 1$.
4. Run genetic algorithm for current restrictions on p.
5. For each structure on each iteration of the genetic algorithm in calculating the "fitness function" are the following:
- check whether the structure is already calculated in the store; If it was, then the values of criterion and passed in a genetic algorithm;
- parametric identification is made for the current structure-specimen r, r_j on the basis of criterion (5) and restrictions on the parameters in the form of algebraic criterion for sustainability Rous-Hurwitz;
- added model in the store;
- with the help of the characteristic equation are derived model parameters for stability and sustainability of the model are added it to stab store;
6. Sort stab store by value criterion from smaller to larger and add a model with a smaller output criterion in the thesaurus store_*p*.
7. Increased border search for genetic algorithm $p = (p+1)$.
8. If you change the search space p change the criteria for the optimal model of the current p there will be less than Δ compared with the previous optimal value, i.e. ($p-1$),in this case, the algorithm stops.
9. If the search space p reached maximum permissible complexity, then stop the algorithm.
10. go to step 4.

After stopping the algorithm displays a plot of the criterion of p as well as the resulting thesaurus *store*_ p, which models are already sorted by complexity (dimensionality) and specify a criterion for each model.
On the basis of this method is a software product that allows you to automatically produce structural and parametric identification of linear dynamical systems. As the environment in which the product is selected *Matlab*, one of the benefits of rich mathematical background ready-to-use functions and system components.
The software product consists of multiple modules (Fig. 1), each of which is responsible for a specific part of the algorithm.
To solve the problem of structural identification as a basis is taken *Genetic Algorithm Solver*, genetic algorithm method that implements and is part of the package *Matlab*.
This package is not adapted to solving integer programming (*Integer programming*). To adapt this tool, use the following method:

- set the upper and lower bounds of the area defined by the search;
- a derivative of the function generate an initial population, which is guaranteed to get an integer value for each individual. An example of a function:

function Population = int_pop (GenomeLength,FitnessFcn, options) to- talpopulation = sum(options. PopulationSize); range = options. PoplnitRange; low- er= range(1,:); span = range(2,:) - lower; Population = rep- mat(lower, totalpopulation,1) + round(repmat(span, totalpopulation,1). rand(totalpopulation, GenomeLength));*

a derivative mutation by mutate, is strictly an individual. An example of a function:

*function mutationChildren = int_mutation (parents,options, GenomeLength, FitnessFcn, state, thisScore, thisPopulation) shrink = .01; scale = 1; scale = scale - shrink * scale * state. Generation/options. Generations; range = options. Popln- itRange; lower = range(1,:); upper = range(2,:); scale = scale * (upper - lower); mutationPop = length(parents); mutationChildren = repmat(lower,mutationPop,1) + round(repmat(scale,mutationPop,1) .* rand (mutationPop, GenomeLength));*

In this approach, the genetic algorithm is implemented in *Matlab*, will produce a spatial search strictly bounds (*lower, upper*). The search will be strictly in an integer field.

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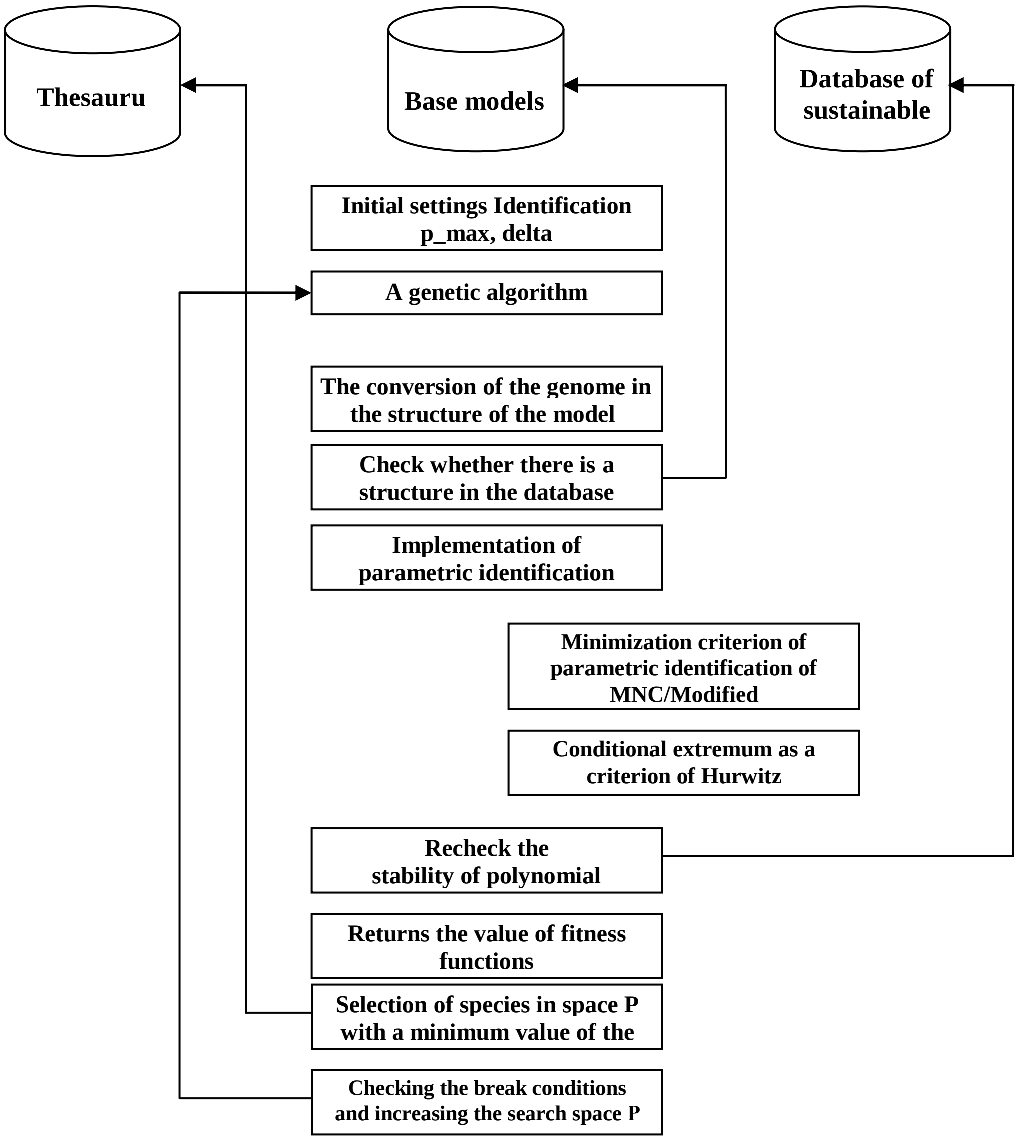

Fig.1.-a simplified outline of the programme of structural and parametric identification of linear dynamic management objects.

IV. REALIZATION OF THE CONCEPT

As for the test has been selected the next model. The number of input variables $x = 4$. The delay for each x will $r_1 = 3$, $r_2 = 1$, $r_3 = 1$, $r_4 = 2$, lag on exit $r = 2$. Our method for this model will look like in the form of a vector $r = [3;1;1;2;2]$, where each value r corresponds to the order of r_j for each x, but the last value-is the order of r on the exit.

Output ratios $b = [0,8,-0,5,0,2]$ moved to the right side of the model (1). This is necessary for the convenience of computing. The coefficients on the input $a = [0,4;-0,5;-1;03;-0,2;0,6;0,4;-0,5;-1;0,3;-0,2]$ match the shift r_j for each x. The complexity of the system $p = 9$. For all tests, the total volume of the sample $N = 10000$.

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The following methods are compared as a function of loss for parametric identification:
- the method of least squares ;
- method recurrences of instrumental variables with the following choice of instrumental variables:

$$\psi_i = \left| y_{i-r-1} \dots y_{i-2r} \mid w^{(1)}_{i-r_1} \dots w^{(1)}_{i-2r_1} \mid \dots \mid w^{(d)}_{i-r_d} \dots w^{(d)}_{i-2r_d} \right|^T; \quad (7)$$

-developed by criterion.
Results of the algorithms were compared for relative error modelling:

$$\delta z_N = \sqrt{\|\hat{z} - z\|^2 / \|z\|^2} \cdot 100\,\%, \quad (8)$$

Where $z = |z_i, \dots, z_N|^T$ -vector of the output of the non-observed variable, $\hat{z} = |\hat{z}_i, \dots, \hat{z}_N|^T$ - score vector output non-observed variable, obtained through the model.
As the result of the method is the thesaurus model, there is a problem of comparing models of various structures, and for the resulting evaluations will be models of the same complexity in each thesaurus and the model under which triggered a stopping criterion, i.e. $\Delta \le 1$.
As proof of this statement was about to hold a test system with the following settings: $\sigma_2 / \sigma_x = 0{,}2$; $\sigma_1 / \sigma_z = 0{,}2$ $\sigma_x^2 = [0{,}0396; 0{,}0403; 0{,}0415; 0{,}0396; 0{,}0397]$; $\sigma_y^2 = 0{,}3497$; $\gamma = \begin{bmatrix} 0{,}1132; 0{,}1152; 0{,}1186; \\ 0{,}1134; 0{,}1136 \end{bmatrix}$.

In fig. 2. and fig. 3. convergence of all three graphs to compare methods for the given conditions. On the charts: when increasing the search space p more reference model and increase the number of settings error Δ decreases slightly. In other words, if the changes Δ criterion value are insignificant and do not lead to a noticeable reduction in errors, then further steps to identify the make no sense. In the table 1 and table 2 shows test results.

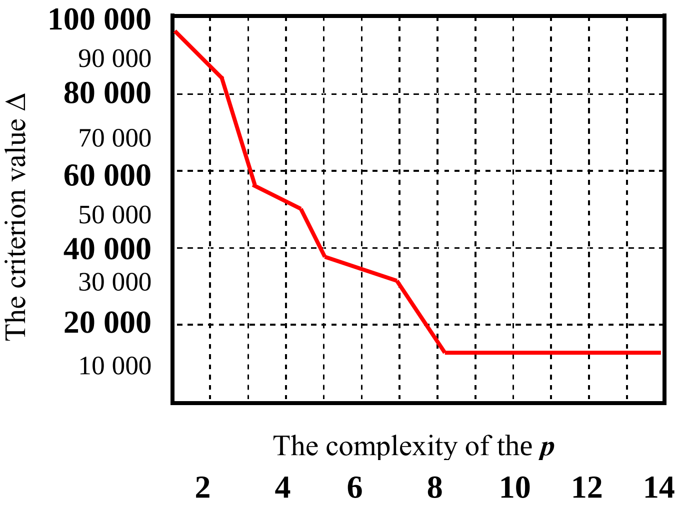

Fig.2-schedule of convergence of the proposed criteria.

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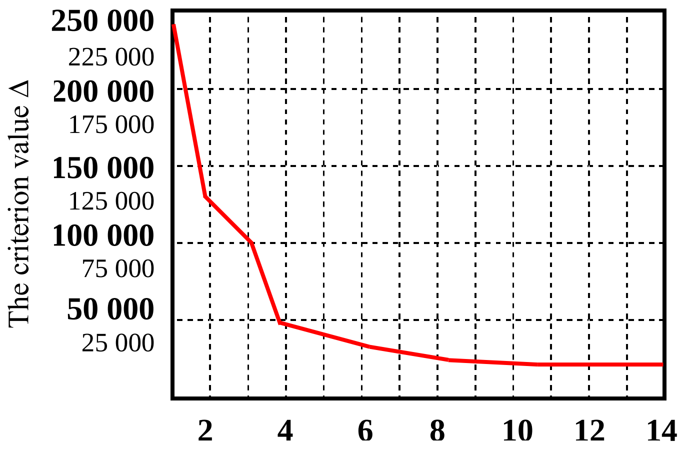
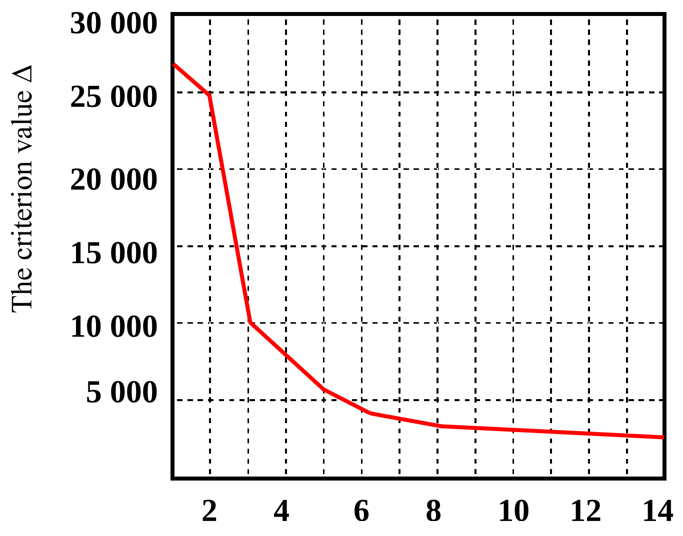


(a)



(b)

Fig. 3-schedule of convergence: (a) instrumental methods; (b) is the method of least squares.

Table 1

Comparison criteria (specified complexity models)

σ_2 / σ_x	σ_1 / σ_z	Error $\delta\theta, \%$		
		MLS	**The method of instrumental variables**	**Developed by criterion**
0,2	0,2	8,61	8,39	7,32
0,2	0,5	12,80	13,44	7,37
0,2	0,7	15,30	16,10	7,56
0,5	0,2	18,70	18,69	10,72
0,7	0,2	28,87	29,19	7,63

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σ_2 / σ_x	σ_1 / σ_z	**Error $\delta\theta, \%$**		
		MLS	**The method of instrumental variables**	**Developed by criterion**
0,5	0,5	23,13	24,09	10,21
0,5	0,7	25,11	22,89	10,35
0,7	0,5	33,15	33,26	12,42
0,7	0,7	31,31	31,65	10,76

Table 2

Comparison criteria $\Delta \le 1$

σ_2 / σ_x	σ_1 / σ_z	**Error $\delta\theta, \%$**		
		MLS	**The method of instrumental variables**	**Developed by criterion**
0,2	0,2	3,83	3,98	1,17
0,2	0,5	4,40	4,62	2,73
0,2	0,7	5,06	7,23	3,84
0,5	0,2	17,50	17,45	2,82
0,7	0,2	28,24	28,07	3,67
0,5	0,5	18,51	18,31	3,13
0,5	0,7	18,97	18,37	7,51
0,7	0,5	29,58	29,88	4,38
0,7	0,7	31,57	32,53	5,93

V. CONCLUSION

An approach to structural-parametric identification of linear dynamic management objects of any dimension on the model input and output and for the ultimate time be thesaurus model specified accuracy, in order of lowest complexity, where each model meets the criterion of sustainability.

Performed content staging and given the task of structural-parametric identification of multidimensional dynamic management objects in the presence of noise monitoring in the input and output signals in a priori uncertainty when you do not know the law distribution impediment.

A method of structural-parametric identification of linear dynamical systems to assess the order linear differential equation model is an object without using the transfer function, the impulse response system under noise monitoring in the input and output signals of the control object.

As a function of the parameter estimates for linear differential equations of the proposed criterion for more accurately to parametric identification with a very rich valuations in the face of interference on the inlet and outlet of the system.

A genetic algorithm of structural-parametric identification of multidimensional linear dynamic objects, which is a heuristic search algorithm on the task class modelling and optimization by random selection, combining and variations of the desired parameters using the mechanisms of biological evolution with an emphasis on the use of the crossing, which produces a recombination of candidate solutions, whose role is similar to the mating in nature.

Implemented software implementation of genetic algorithm of structural-parametric identification of linear dynamic systems, consisting of a set of modules, each of which is responsible for a specific part of the algorithm to automatically carry out structural-parametric synthesis of control systems of technological processes.

Method of adapting a software product to integer programming *(Integer programming)* in *Matlab*, which sets the upper and lower boundaries of the search scope integer; a derivative of the function generate an initial population, which are guaranteed to get the integer value of each individual, and a derivative of mutation in mutation and is strictly an individual. Genetic algorithm searches for the strict bounds (lower, upper) and strictly in an integer field.

The test tasks modelling genetic algorithm of structural-parametric identification of linear dynamic management objects smoothly in and out and performed a comparative comparison by simulation methods of relative error of least squares, the recurring method of instrumental variables estimation criterion dative parameters of linear difference equations object, which showed that increasing the search space is greater than the reference model and the number of parameters of error decreases slightly. This allows you to make the following conclusion: If you change the value criterion is insignificant, the further identification were not worth it. On the basis of the sharing method not dominated

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as alternatives and neuro-fuzzy approach for restoration of membership functions developed neuro-fuzzy model selection standard of network information management system to effectively formalize the process of engineering intuition and making design decisions.

REFERENCES

[1] Engelhard V.V. *Geneticheskiy algoritm strukturno-parametricheskoy identifikacii lineyny' dinamicheskih sistem s pomehami na vhode i vy'hode*. [Genetic algorithm of structural and parametric identification of linear dynamical systems with disturbances at the inlet and outlet]. Proceedings of higher educational establishments. Volga region, no. 4 (28), 2013, p. 5-18.

[2] Katsyuba O. A., Zhdanov A. I. *Avtomatika i telemekhanika* [Automation and remote control]. 1979, no. 8, pp. 86–96.

[3] Ivanov D. V., Katsyuba O. A. *Vestnik Samarskogo gosudarstvennogo tekhnicheskogo universiteta. Ser. Fiziko-matematicheskie nauki* [Bulletin of Samara State Technical University. Series: Physical and mathematical sciences]. 2011, no. 4 (25), pp. 102–109.

[4] Ivanov D. V., Uskov O. A. *Izvestiya Yuzhnogo federal'nogo universiteta. Ser. Tekhnicheskie nauki* [Proceedings of South Federal University. Series: Engineering sciences]. 2012, no. 6 (131), pp. 187–192.

[5] Tolcheek V. O., Yagotkina T. V. *Metody identifikatsii lineynykh odnomernykh dinamicheskikh sistem* [Methods of linear one-dimensional dynamic system identification]. Moscow: Moskovskiy energeticheskiy institut, 1997, 108 p.

[6] Yusupbekov N.R., Marakhimov A.R., Igamberdiev KH.Z., Gulyamov SH.M. Fuzzy modeling and integrated evaluation of the acceptability design solutions in the network design problems of avtomated control systems // Proceedings Eleventh International Conference on Application of Fuzzy Systems and Soft Computing – ICAFS-2014, September 2-3, 2014. Rouen, France. – p.119-130.

[7] Ljung, L. System Identification – Theory for the User / L. Ljung. – second edition. – Prentice Hall, Upper Saddle River N. J., 1999.