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MODEL OF SUPPORT OF DECISION-MAKING FOR DETERMINATION OF EFFECTIVE MANAGEMENT OF THE INDUSTRIAL ENTERPRISE

Annotation: *the model for economic indicators forecasting of the management efficiency on the industrial enterprise, which based on the joint application of interval forecast and fuzzy mathematics, is developed.*

Keywords*: management efficiency assessment, illegible sets, illegible forecasting, illegible interval estimation, linguistic variable, function of accessory*.

Introduction. The problem of an estimation of management efficiency of the enterprise is one of the sharpest, that subjects of managing face in the process of the functioning in the conditions of dynamically changing market environment.

Forecasting is a key moment in the process of making administrative decisions since efficiency of any decision depends on sequence of events which can arise after its acceptance. Opportunity to predict uncontrollable aspects of these events before decision-making allows to make the most expedient choice [1].

Problem definition. For an estimation and forecasting of indicators of effective management of the enterprise in case of considerable information uncertainty expert methods of forecasting get effective application. However, as a rule, various experts differently estimate value of indicators and therefore it is very difficult to set a dot estimation. For similar situations they use the device of illegible sets which operates with indicators in the form of illegible numbers.

Solution methods. In the unfolded form the situation of making the administrative decision is characterized by game model $\langle \mathrm{I}, \mathrm{J}, \mu \rangle$ [2], where:

- $\mathrm{I} = \{1; 2; \ldots \mathrm{i}; \ldots \mathrm{k}\}$ - known set of indicators of effective management of the enterprise;

- $\mathrm{J} = \{1; 2; \ldots \mathrm{j}; \ldots \mathrm{n}\}$ - known set of scenarios of conditions of efficiency (possible conditions of the economic environment);

- $\mu = \mu_{kxn} = (\mu_{ij})$ - completely or partly known matrix elements of which - set the corresponding values of estimates of accessory function of an **i** indicator to a set of the most reliable values in the conditions of **j** situation.

Let the situation of estimation and forecasting of indicators of economic efficiency of management be characterized by the following components:

1. $I = \{1;2;3;4\}$ - known set of indicators (criteria) of an estimation ;
2. $J = \{1;2;3;4;5\}$ - a known set of scripts of conditions of the economic environment considered by decision-makers ;
3. $\mu = \mu_{4x5} = (\mu_{ij})$ - partially known matrix which elements set the corresponding values of estimates of accessory function of an i indicator to set of the most reliable in the conditions of j script .

Exact true values of all elements of a payment matrix are unknown, but experts found intervals which possess their values:

$$\mu_{11} \in [0{,}0;0{,}1], \mu_{12} \in [0{,}15;0{,}25], \mu_{13} \in [0{,}35;0{,}45], \mu_{14} \in [0{,}55;0{,}65], \mu_{15} \in [0{,}75;0{,}85],$$
$$\mu_{21} \in [0{,}15;0{,}25], \mu_{22} \in [0{,}25;0{,}35], \mu_{23} \in [0{,}45;0{,}55], \mu_{24} \in [0{,}65;0{,}75], \mu_{25} \in [0{,}85;0{,}95],$$
$$\mu_{31} \in [0{,}25;0{,}35], \mu_{32} \in [0{,}35;0{,}45], \mu_{33} \in [0{,}55;0{,}65], \mu_{34} \in [0{,}75;0{,}85], \mu_{35} \in [0{,}95;1{,}0],$$
$$\mu_{41} \in [0{,}35;0{,}45], \mu_{42} \in [0{,}45;0{,}50], \mu_{33} \in [0{,}65;0{,}70], \mu_{34} \in [0{,}85;0{,}90], \mu_{35} \in [0{,}95;1{,}0]$$

The sence of a method of illegible forecasting consists in consecutive narrowing of interval expected value to the corresponding illegible number. The initial interval of possible values of an indicator on the period of forecasting is established on the basis of group examination by determination of the minimum and maximum values of the left and right border of an interval of the forecast. This interval is the input parameter of iterative procedure of receiving expected illegible number.

The algorithm of realization of a method of illegible forecasting of indicators of management efficiency has the following appearance [3]:

1. Forecasting problem definition.
2. Formation of expert N number group.
3. Definition on the basis of expert polling of a set A:

$A = \{(\underline{a_i}, \overline{a_i}), i = \overline{1,N}\}$, where $\underline{a_i}, \overline{a_i}$ – correspondingly left and right borders of an expected interval of i expert.

4. Finding of an initial group interval estimation of expected value:

$$(\underline{m}, \overline{m}), \underline{m} = \min\{\underline{a_i}, i = \overline{1,N}\}, \overline{m} = \max\{\overline{a_i}, i = \overline{1,N}\}$$

Definition of illegible number $\tilde{P}$ (approximately equals $(\underline{m}+\overline{m})/2$) and its interval β.

5. Check of an enclosure of an interval of expected values of a confidential interval of illegible number $(\overline{m}-\underline{m})\le\beta$. If the condition is carried out, transition to a step 12, else – to a step 7.

6. Formation of three alternatives of the interval forecast by breakdown of an initial group interval estimation of expected value into three equal blocked subintervals (with extent of overlapping -50%):

$$A_1=(\underline{a_1},\overline{a_1})=(\underline{m},\underline{m}+2\delta);$$
$$A_2=(\underline{a_2},\overline{a_2})=(\underline{m}+\delta,\overline{m}-\delta);\text{, where } \delta=(\overline{m}-\underline{m})/4$$
$$A_3=(\underline{a_3},\overline{a_3})=(\overline{m}-2\delta,\overline{m})$$

7. Formation by experts of individual matrixes of paired comparisons of alternatives in preference degree.

8. Definition of a group matrix of paired comparisons of alternatives by definition of its elements as average geometrical of the corresponding elements of equidistant matrixes of paired comparisons.

9. Calculation a vector of group priorities of alternatives $\overline{p}=(p_1,p_2,p_3)$

10. Definition of the interval forecast $(\underline{m},\overline{m}),\underline{m}=p_1\underline{a_1}+p_2\underline{a_2}+p_3\underline{a_3}$

11. Definition of the illegible forecast in the form of illegible number $\tilde{P}$ and its function of accessory.

The analysis of the received results. Lets consider application of this method for the solution the problem of an illegible estimation and forecasting of a financial state of the enterprise.

Stage 1. Creation of linguistic variables: A – "Management efficiency indicators", B – "Reliable states". Analyzing different types of conditions of the linguistic variable "Management efficiency indicators", we will be set by a set $\{\mu\}$, which is suited by five illegible T-numbers of $\{\beta\}$ type $\beta_1=(0{,}0;0{,}0;0{,}15;0{,}25)$; $\beta_2=(0{,}15;0{,}25;0{,}35;0{,}45)$; $\beta_3=(0{,}35;0{,}45;0{,}55;0{,}65)$; $\beta_4=(0{,}33;0{,}65;0{,}75;0{,}85)$; $\beta_5=(0{,}75;0{,}85;1{,}0;1{,}0)$.

To function of accessory $\mu(V)$ there corresponds the illegible number $\beta=(\alpha_1;\alpha_2;\alpha_3;\alpha_4)$, where $\alpha_1;\alpha_4$ - abscissaes of the lower basis of a trapeze, $\alpha_2;\alpha_3$ - abscissae of the top basis of the trapeze setting μ in area with nonzero accessory of the carrier V to the corresponding illegible subset. Numbers β are trapezoid numbers.

Stage 2. Definition of a set of expected values of indicators of management efficiency on the basis of expert polling:

$$\mu_{11} \in [0,0;0,1], \mu_{12} \in [0,15;0,25], \mu_{13} \in [0,35;0,45], \mu_{14} \in [0,55;0,65], \mu_{15} \in [0,75;0,85],$$
$$\mu_{21} \in [0,15;0,25], \mu_{22} \in [0,25;0,35], \mu_{23} \in [0,45;0,55], \mu_{24} \in [0,65;0,75], \mu_{25} \in [0,75;0,85],$$
$$\mu_{31} \in [0,25;0,35], \mu_{32} \in [0,35;0,45], \mu_{33} \in [0,55;0,65], \mu_{34} \in [0,75;0,85], \mu_{35} \in [0,95;1,0],$$
$$\mu_{41} \in [0,35;0,45], \mu_{42} \in [0,45;0,50], \mu_{33} \in [0,65;0,70], \mu_{34} \in [0,85;0,90], \mu_{35} \in [0,95;1,0]$$

Stage 3. Group interval estimation of expected value, definition of illegible number and its interval β:

$$\left(\underline{m_1}, \overline{m_1}\right) = [0,0;0,85], \ \tilde{P}_1 \approx 0,425, \ \beta_1 \in [0,0;0,75]$$

$$\left(\underline{m_2}, \overline{m_2}\right) = [0,15;0,85], \ \tilde{P}_2 \approx 0,5, \ \beta_2 \in [0,0;0,85]$$

$$\left(\underline{m_3}, \overline{m_3}\right) = [0,25;1,0], \ \tilde{P}_3 \approx 0,625, \ \beta_3 \in [0,15;1,0]$$

$$\left(\underline{m_4}, \overline{m_4}\right) = [0,35;1,0], \ \tilde{P}_4 \approx 0,675, \ \beta_4 \in [0,25;1,0]$$

Check of an enclosure in a confidential interval:

$$\left(\overline{m_1} - \underline{m_1}\right) = 0,85 > \beta_1$$

$$\left(\overline{m_2} - \underline{m_2}\right) = 0,8 \le \beta_2$$

$$\left(\overline{m_3} - \underline{m_3}\right) = 0,75 \le \beta_3$$

$$\left(\overline{m_4} - \underline{m_4}\right) = 0,65 \le \beta_4$$

Stage 4. As for indicators 2-4 condition of an enclosure carries out, then expected values remain for further calculations. For an indicator 1 condition of an enclosure isn't carried out therefore we will create three alternatives of the interval forecast in the form of three blocked subintervals:

$$A_1 = \left(\underline{a_1}, \overline{a_1}\right) = (0,0;0,425);$$
$$A_2 = \left(\underline{a_2}, \overline{a_2}\right) = (0,2125;0,6375);$$
$$A_3 = \left(\underline{a_3}, \overline{a_3}\right) = (0,425;0,85)$$

Stage 5. Definition of a group matrix of pair comparisons of experts' alternatives:

$$A_{эксп} = \begin{pmatrix} [0{,}285] \\ [0{,}345] \\ [0{,}625] \end{pmatrix}$$

Calculation of a vector of group priorities of alternatives:

$$\bar{p} = (0{,}23;0{,}27;0{,}5)$$

Stage 6. Definition of the interval forecast:

$$(\underline{m_1}, \overline{m_1}) = [0{,}2725;0{,}695],\ (\overline{m_1} - \underline{m_1}) = 0{,}4225 \le \beta_1$$

Thus, we received the illegible forecast of indicators of effective management of the enterprise:

$$\tilde{P} = \begin{pmatrix} [0{,}27;0{,}7] \\ [0{,}15;0{,}85] \\ [0{,}25;1{,}0] \\ [0{,}35;1{,}0] \end{pmatrix}$$

As result of calculations - an interval estimation, it is impossible to estimate unambiguously extent of influence of a concrete indicator on management efficiency. In this regard there is a problem of formalization of an interval indicator of effective management of activity.

It is possible to solve this problem by a quantitative estimation of indicators of efficiency by means of the theory of illegible logic. Illegible representation in structure of model appears in connection with illegible interpretation of level of efficiency.

Criterion of effective management of activity of the enterprise is some number from the range [0,1] which corresponds to "extent of achievement of goals". The more value of criterion is, the higher is effectiveness of activity management of the enterprise.

Effectiveness of the management of the enterprise is described by a linguistic variable X with the name "Effectiveness of the management of the enterprise". Then the four of the remained properties of a linguistic variable $\langle T, U, G, M \rangle$ can be defined so:

1. universal set of U=[0,1];

2. term set T= { "low", "average", "high" } with such functions by accessories:

$$\mu_{\text{"низкий"}} = \begin{cases} 1, \text{ если } 0 \le u < 0{,}15 \\ 10(0{,}25 - u), \text{ если } 0{,}15 \le u < 0{,}25 \\ 0, \text{ если } 0{,}25 \le u \le 1 \end{cases}$$

$$\mu_{\text{"средний"}} = \begin{cases} 0, \text{ если } 0 \le u < 0{,}35 \\ 10(u - 0{,}35), \text{ если } 0{,}35 \le u < 0{,}45 \\ 1, \text{ если } 0{,}45 \le u < 0{,}55 \\ 10(0{,}65 - u), \text{ если } 0{,}55 \le u < 0{,}65 \\ 0, \text{ если } 0{,}65 \le u \le 1 \end{cases}$$

$$\mu_{\text{"высокий"}} = \begin{cases} 0, \text{ если } 0 \le u < 0{,}75 \\ 10(u - 0{,}75), \text{ если } 0{,}75 \le u < 0{,}85 \\ 1, \text{ если } 0{,}85 \le u \le 1 \end{cases}$$

3. the syntactic rule G, generating new terms with use of quantifiers "higher", "or", "not", "below";

4. M will be the procedure putting to each new term in compliance an illegible set from X by rules: if terms A and B had functions of accessory $\mu_A(u)$ and $\mu_B(u)$ correspondingly, new terms would have the following functions of accessory set in tab. 1.

"Low" level of efficiency of the activity management of the enterprise means that there is a full confidence that efficiency of carrying out the work within all functional areas is low. Goals aren't achieved. Dynamics of growth is absent.

Level of efficiency of the activity management of the enterprise "below an average" means that it is quite possible,that separate kinds of activity (one or two) are characterized by the average level of efficiency. The enterprise partially achieved the goals. Dynamics of growth is observed, but growth rates are slowed down.

Level of effective management of activity of the "average" enterprise assumes that there is a full confidence, that efficiency of the works performed within functional areas of the enterprise has the average level. The enterprise achieved goals, but costs of their achievement exceeded the planned level. Dynamics of growth corresponds to growth rates.

Level of effective management of activity of the enterprise "above an average" means that the enterprise achieved goals, but the low level of efficiency on separate activities has to cause proper response of the management. Growth rates advance dynamics of growth.

Level of effective management of activity of the enterprise "high" means that the enterprise is effective in carrying out the functions and achieved goals. Constant dynamics of growth rates is observed.

Tab. 1

Functions of accessory for a linguistic variable

Quantifier	Function of accessory
Below average	$\mu_{\text{"ниже среднего"}} = \begin{cases} 0, \text{ если } 0 \le u < 0{,}15 \\ 10(u-0{,}15), \text{ если } 0{,}15 \le u < 0{,}25 \\ 1, \text{ если } 0{,}25 \le u < 0{,}35 \\ 10(0{,}45-u), \text{ если } 0{,}35 \le u < 0{,}45 \\ 0, \text{ если } 0{,}45 \le u \le 1 \end{cases}$
Above average	$\mu_{\text{"выше среднего"}} = \begin{cases} 0, \text{ если } 0 \le u < 0{,}55 \\ 10(u-0{,}55), \text{ если } 0{,}55 \le u < 0{,}65 \\ 1, \text{ если } 0{,}65 \le u < 0{,}75 \\ 10(0{,}85-u), \text{ если } 0{,}75 \le u < 0{,}85 \\ 0, \text{ если } 0{,}85 \le u \le 1 \end{cases}$

Thus, presence of a scale of levels of effective management of the activity of the enterprise created on the basis of the theory of illegible logic gives the chance by identification of a settlement indicator with its interpretations, to determine an actual level of effective management of activity of the enterprise. It, in turn, is justification for development of actions for providing and support the increase of dynamics of growth of effective management of the activity of the enterprise directed on achievement of the common and private goals [4].

The considered mathematical tools allow to estimate qualitatively effective management of the enterprise and it is rational to organize activity of the enterprise.

Conclusions. The device of illegible logic is effectively used for the solution of economic problems of estimation and forecasting of indicators of effective management of the enterprise.

Use of the offered model of an estimation and forecasting of economic indicators of the efficiency management of the industrial enterprise based on combined use of the interval forecast and illegible mathematics allows to resolve an objective correctly. This approach allows to model adequately decision-making process.

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TABLES OF DATA WITH GAPS RESTORATION USING MULTIVARIATE FUZZY EXTRAPOLATION

Annotation. *The problem of the missing values in the data tables filling by using the method of multivariate fuzzy extrapolation is proposed.*

Key words.*Data Mining, data with gaps, multivariable fuzzy extrapolation, neural networks.*

INTRODUCTION

In many Data Mining problems, associated with the processing of information presented as the table “object – property” data may contain missing values (gaps), information in which is lost. The problem of the missing values restoring has received sufficient attention [1-3], in this case as the most effective now are neural networks [4-8]. However, methods of missing values filling based on the restoring of hidden dependencies which are data in the table realization, i.e. explicitly or implicitly in the process of filling the "gaps" is synthesized mathematical model of the phenomena that are described by the table, i.e. solve the identification problem [9, 10].

In practice, the situations often occurs when the dimension of the feature vectors in the table and the number of observations are the same order, i.e., amount of date for mathematical model synthesis is not enough. In this case, the methods of space extrapolation [11] that allow to construct estimates of vector field values using little sets of individual observations can be successfully used.

As one of the most effective approaches based on space extrapolation method the multivariable linear extrapolation (MLE) [11, 12] can be used for recovery of linear functions in the case of insufficient number of observations. MLE can be used for the restoration of non-linear dependencies too, in this case the nonlinear function is determined for not all available observations, but using nearest situation in sense of adopted metrics.

The main disadvantage of MLE is its numerical complexity because the method is based on solving the optimization problem associated with finding the orthogonal projection onto the set of vectors undistorted by missing values. In this case it is necessary to solve the pseudoinversion task [13] for high-dimensional matrices. The following limitation of the method is the fact that in the original table “object - property” number of vectors of observations without missing values must exceed the number of “bad” vectors with gaps. If all the vectors of the table contain “missing values”, MLE is no effective.

In this situation, it seems appropriate to develop simple and effective method for recovering of missing values with a large number of gaps, and in this case instead of the traditional metrics if is convenient to use the concept of membership levels adopted in fuzzy systems and neural networks that are now form main direction in Computational Intelligence [14].

1. PROBLEM STATETMENT

Let we have usual table “object - property” that is shown in Table 1

Table 1

	1	...	*p*	...	*j*	...	*n*
1	x_{11}	...	x_{1p}	...	x_{1j}	...	x_{1n}
...	...	...	...	...	...	...	...
i	x_{i1}	...	x_{ip}	...	x_{ij}	...	x_{in}
...	...	...	...	...	...	...	...
k	x_{k1}	...	x_{kp}	...	x_{kj}	...	x_{kn}
...	...	...	...	...	...	...	...
N	x_{N1}	...	x_{Np}	...	x_{Nj}	...	x_{Nn}

that contain information about N − objects each of that is described by (1Чn) - row feature vectors $\underline{x}_i = (x_{i1},\ldots,x_{ip},\ldots,x_{ij},\ldots,x_{in})$. Let’s assume that N_G rows may have one or more missing values, and $N - N_G$ ones- completed in full. This does not exclude the situation when $N_G = N$ i.e. all vectors contain the missing values, the number of which in each row $n_i < n, i = 1,2,\ldots,N$.

During processing, the table must be filled in the missing values so that the recovered elements were in some sense the most "similar" or "nearest" to a priori unknown regularities hidden in this table.

2. THE MULTIVARIABLE FUZZY EXTRAPOLATION METHOD

Let's represent Table 1 in the form of $(N \times n)$ - matrix X, in which, in the simplest case are absent one element x_{ip} or more generally $\sum_{i=1}^{N} n_i$ elements. All data are previously centered and standartized by all features, so that all observations belong to the hypercube $[-1,1]^n$. Therefore, the data form array $\tilde{X} = \{\tilde{x}_1, \dots, \tilde{x}_k, \dots, \tilde{x}_N\} \subset R^n$, $\tilde{x}_k = (\tilde{x}_{k1}, \dots, \tilde{x}_{ki}, \dots, \tilde{x}_{kn})^T$, $-1 \le \tilde{x}_{ki} \le 1$, $1 < m < N$, $1 \le q \le m$, $1 \le i \le n$, $1 \le k \le N$. For each row $\underset{\rightarrow}{x}_i$, containing missing values we have to estimate distances between it and all the other rows using the concept of "partial distance" (PD), adopted in fuzzy clustering [15] and modified as

$$D_P^2(\underset{\rightarrow}{x}_i, \underset{\rightarrow}{x}_k) = \frac{n}{n_i + n_k - n_{ik}} \sum_{j=1}^{n} (x_{ij} - x_{kj})^2 \delta_j$$

where

$$\delta_j = \begin{cases} 0, \text{ if } \underset{\rightarrow}{x}_i, \text{ or } \underset{\rightarrow}{x}_k \text{ in } j \text{ position contains missing value,} \\ 1 \text{ otherwise,} \end{cases}$$

n_{ik} -total number of missing values in the same position in $\underset{\rightarrow}{x}_i$ and $\underset{\rightarrow}{x}_k$.

In this case we have to exclude from consideration $\underset{\rightarrow}{x}_k$ for which $\sum_{j=1}^{n} \delta_j = 0$.

Let us order further $\tilde{N} \le N - 1$ calculated distances so that

$$0 \le D_P^{2[\min]} = D_P^{2[1]} < D_P^{2[2]} < \dots < D_P^{2[\tilde{N}]} \le 4n$$

(here the index in square brackets indicates the rank) and save for further processing only $\hat{N} \le \tilde{N} \le N - 1$ observations, that satisfy inequality

$$\frac{D_P^{2[l]}}{4n} \le \varepsilon, \quad l = 1, 2, \dots, \hat{N},$$

where ε - a certain threshold $(0 < \varepsilon < 1)$.

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Using the concept of memberships, adopted in the standard fuzzy c-means method [16],let's calculate the membership level $\underset{\to}{x}_i$ to $\hat{N}$ still under consideration vectors $\underset{\to}{x}_l$ in the form

$$U_l(i) = \frac{D_P^{-2[l]}}{\sum_{q=1}^{\hat{N}} D_P^{-2[q]}}, \quad l = 1, 2, \ldots, \hat{N},$$

while if $D_P^{2[l]} = 0$, we automatically assume that $U_l(i) = 1$.

Thus, each vector $\underset{\to}{x}_i$ is approximated by the expression

$$\hat{\underset{\to}{x}}_i = \sum_{l=1}^{\hat{N}} U_l(i) \underset{\to}{x}_l. \tag{1}$$

Let's note too that MLE is used as an approximation of type (1), but instead of memberships levels $U_l(i)$ the weights obtained by solving the optimization problem, which is not always solvable are used.

And finally, the last stage - to fill missing values. It is easy to see that the estimate of missing element $\underset{\to}{x}_{ip}$ can be written as

$$\hat{\underset{\to}{x}}_{ip} = \sum_{l=1}^{\hat{N}} U_l(i) \underset{\to}{x}_{lp}.$$

The proposed method can be conveniently represented in the form shown in Figure 1.

3. EXPERIMENTALRESEARCH

The provided results are presented on the fig.2. On this picture shows a database that contains data connected with the X-ray plant. Real data has been corrupted and restored by the proposed method based on multivariate fuzzy extrapolation.

To estimate the quality of the algorithm we used the mean absolute percentage error (MAPE). When estimating the quality of the recovered data x-ray plant MAPE does not exceed 15 percent.

The problem of restoration of distorted data provided by the x-ray plant using the proposed method, making it possible speed up recovery hardware that is out of order.

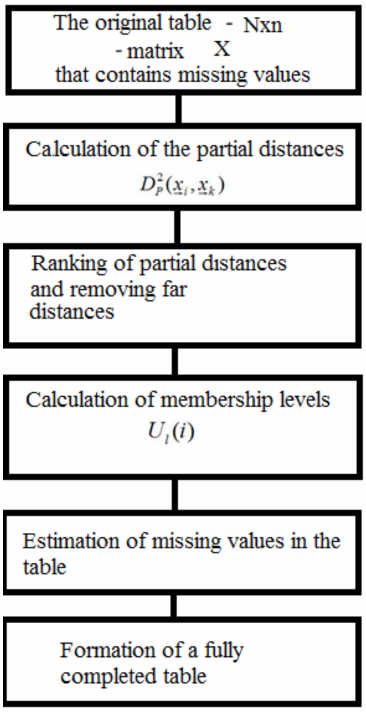
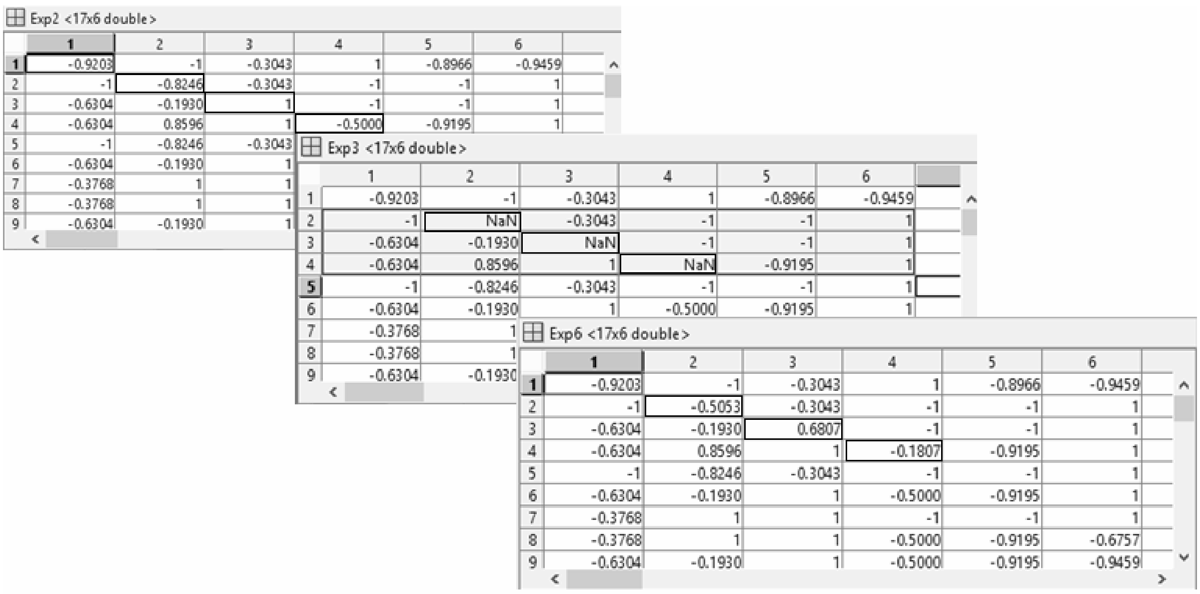


Fig. 1 - The method of multivariate fuzzy extrapolation in the task of restoring missing values



Exp2 <17x6 double>

	1	2	3	4	5	6
1	-0.9203	-1	-0.3043	1	-0.8966	-0.9459
2	-1	-0.8246	-0.3043	-1	-1	1
3	-0.6304	-0.1930	1	-1	-1	1
4	-0.6304	0.8596	1	-0.5000	-0.9195	1
5	-1	-0.8246	-0.3043			
6	-0.6304	-0.1930	1			
7	-0.3768	1	1			
8	-0.3768	1	1			
9	-0.6304	-0.1930	1			

Exp3 <17x6 double>

	1	2	3	4	5	6
1	-0.9203	-1	-0.3043	1	-0.8966	-0.9459
2	-1	NaN	-0.3043	-1	-1	1
3	-0.6304	-0.1930	NaN	-1	-1	1
4	-0.6304	0.8596	1	NaN	-0.9195	1
5	-1	-0.8246	-0.3043	-1	-1	1
6	-0.6304	-0.1930	1	-0.5000	-0.9195	1
7	-0.3768	1				
8	-0.3768	1				
9	-0.6304	-0.1930				

Exp6 <17x6 double>

	1	2	3	4	5	6
1	-0.9203	-1	-0.3043	1	-0.8966	-0.9459
2	-1	-0.5053	-0.3043	-1	-1	1
3	-0.6304	-0.1930	0.6807	-1	-1	1
4	-0.6304	0.8596	1	-0.1807	-0.9195	1
5	-1	-0.8246	-0.3043	-1	-1	1
6	-0.6304	-0.1930	1	-0.5000	-0.9195	1
7	-0.3768	1	1	-1	-1	1
8	-0.3768	1	1	-0.5000	-0.9195	-0.6757
9	-0.6304	-0.1930	1	-0.5000	-0.9195	-0.9459

Fig.2 – Results of experiments

CONCLUSION

The problem of the missing values in the data tables filling by using the method of multivariate fuzzy extrapolation is proposed. The method has clear physical sense, derived from the theory of fuzzy systems, and characterized by computing simplicity and high speed data processing.

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EVOLVING HIERARCHICAL NEURAL NETWORK FOR PRINCIPAL COMPONENT ANALYSIS TASKS AND ITS ADAPTIVE LEARNING

Annotation. *Evolving hierarchical neural network architecture and adaptive learning algorithms for processing of multi-dimensional stochastic non-stationary signals in on-line mode were proposed.*

Key words.*Data Mining, Text Mining, Web Mining, principal component analysis (PCA), principal components space, data compression, eigenvector.*

Introduction

In many tasks associated with the large data sets processing, often arises a problem of compression with minimal loss of information in order to select the most essential features that define the nature of the phenomenon under investigation, data visualization, their transmitting over channels with limited bandwidth, etc. In the cases where information that must be processed is given as a set of N $n-$dimensional vectors $x(1), x(2), \dots, x(k), \dots, x(N)$, $x(k) \in R^n$, the problem can be successfully solved by using principal component analysis (PCA) [1], consisting in the orthogonal projection of each vector-observation $x(k)$ to the first m $(m < n)$ orthogonal eigenvectors, corresponding to the largest eigenvalues of the correlation $(n \times n)$ data matrix. Actually, the input data compression is carried out by finding the mapping

$$x(k) \in R^n \to y(k) \in R^m$$

where $x(k) = (x_1(k), x_2(k), \dots, x_n(k))^T$, $y(k) = (y_1(k), y_2(k), \dots, y_m(k))^T$, and the principal component analysis task is reduced to finding an operator that implements this mapping.

Currently PCA methods are sufficiently researched and developed, but their use becomes much more complicated, when it is necessary to process multivariate stochastic signal $x(k)$, where k has the sense of the discrete current time and generally doesn’t restricted. Instead of conventional batch processing in this situation, the alternative to the standard PCA procedures is adaptive data compression based on neural network technologies.

A number of artificial neural networks [2-6], that implement principal component analysis ideas are known now. Either all of these systems could be conditionally divided into two classes: neural networks that implement sequential approach to the calculation of principal components and neural network that implement parallel approach.

In the sequential approach, the most known member is Sanger's neural network [7], where the first neuron calculates the first principal component and the corresponding eigenvector, then using a first component the next neuron calculates the second component, third neuron uses two already calculated principal components, and so on. The advantage of this approach is the possibility to variate dimension of the output signal m during the calculations. However, the disadvantage is the low speed, explained by the sequential nature of the calculations, which makes its inefficient when processing non-stationary signals.

In the parallel approach, whose typical representative is Karhunen-Oja's neural network [8, 9], data compression is carried out by the orthogonal projection onto the subspace spanned to the eigenvectors corresponding to maximal eigenvalues of the correlation matrix. This network has enough good performance and its architecture is extremely simple and coincides with the structure of self-organizing maps and unidirectional associative memories and contains one layer of adaptive linear associators. On the other hand, the Karhunen-Oja's network provides the not actually PCA, but so-called principal subspaces analysis (PSA), wherein dimension of these subspaces m in the calculation remains fixed.

The peculiar compromise between these two approaches implements a hierarchical Rubner-Schulten-Tavan's neural network, consisted of m neurons– adaptive linear associators, wherein the $j-$neuron output signal calculated according to the expression

$$y_j(k)=\sum_{i=1}^{n}w_{ji}(k)\tilde{x}_i(k)+\sum_{h=1}^{j-1}v_{jh}(k)y_h(k)=w_j^T(k)\tilde{x}(k)+v_j^T(k)\vec{y}_{j-1}(k)=y_j^x(k)+y_j^y(k),$$

$$j=1,2,\ldots,m;\ i=1,2,\ldots,n;\ h=1,2,\ldots,j-1,\ k=1,2,\ldots,N,\ldots$$

where $w_j(k)=(w_{j1}(k),w_{j2}(k),\dots,w_{jn}(k))^T$, $v_j(k)=(v_{j1}(k),v_{j2}(k),\dots,v_{j,j-1})^T-(n\times 1)$ и $((j-1)\times 1)$ – synaptic weights vectors,

$\vec{y}_{j-1}(k)=(y_{j1}(k),y_{j2}(k),\dots,y_{j-1}(k))^T-((j-1)\times 1)$ – previous neurons outputs vector, $y_j^x(k)=w_j^T\tilde{x}(k)$, $\tilde{x}(k)$ – centered relatively the current average vector $x(k)$, $y_j^y(k)=v_j^T(k)y_{j-1}(k)$. Its easy to see that this network is similar to the Fahlman-Lebir's cascade-correlation neural network architecture [12].

This network is trained using the gradient algorithms with constant learning rate parameter that doesn't provided the necessary speed in the processing of non-stationary signals, besides the number of calculated principal components m are given a priori.

The main goal of this work is the synthesis of evolving hierarchical neural network and its learning algorithms that have high speed and provide the possibility to tune architecture during information processing.

1. ADAPTIVE LEARNING ALGORITHMS

Synaptic weights w_{ji} are tuned using the standard Oja's self-learning rule [13], which is in fact Hebb's normalized algorithm and has the form

$$w_{ji}(k+1)=w_{ji}(k)+\eta_w(\tilde{x}_j(k)-w_{ji}(k)y_j(k))y_j(k)$$

or in vector form

$$w_j(k+1)=w_j(k)+\eta_w(\tilde{x}_j(k)-w_j(k)y_j(k))y_j(k), \tag{1}$$

where η_w – learning rate parameter that determines the speed of convergence.

During adjustment this algorithm minimizes the learning criterion (Lyapunov's function)

$$E_w^j(k)=\frac{1}{2}\left\|\tilde{x}(k)-w_jy_j(k)\right\|^2$$

whose gradient is determined by the expression

$$\nabla_w E_w^j(k)=-(\tilde{x}(k)-w_jy_j(k))y_j(k). \tag{2}$$

Synaptic weights v_{ji} are adjusted by using the antihebbian algorithm, that has the form

$$v_{jh}(k+1) = v_{jh}(k) - \eta_v y_j(k) y_h(k),\ j < h,$$

or in vector form

$$v_j(k+1) = v_j(k) - \eta_v y_j(k)\vec{y}_{j-1}(k) = v_j(k) - \eta_v (w_j^T(k)\tilde{x}(k) + v_j^T(k)\vec{y}_{j-1}(k))\vec{y}_{j-1}(k). \quad (3)$$

It can be shown, that learning criterion in this case has the form

$$E_v^j(k) = w_j^T(k)\tilde{x}(k)\vec{y}_{j-1}^T(k)v_j(k) + \frac{1}{2}\left\| v_j^T \vec{y}_{j-1}(k) \right\|^2 = y_j^x(k) y_j^y + \frac{1}{2}(y_j^y)^2$$

and its gradient –

$$\nabla_v E_v^j(k) = w_j^T(k)\tilde{x}(k)\vec{y}_{j-1}(k) + \vec{y}_{j-1}(k)\vec{y}_{j-1}^T(k)v_j = (y_j^x(k) + y_j^y)\nabla_v y_j^y = y_j \vec{y}_{j-1}(k). (4)$$

In the conditions of non-stationary signals processing when rate of convergence comes to the foreground, is advisable to use instead of gradient algorithms with a constant step the second order procedures or their approximations [14].

By introducing Levenberg- Marquardt's one-step algorithm version

$$\begin{cases} w_j(k+1) = w_j(k) - (\nabla_w E_w^j(k)\nabla_w^T(k) + \beta_w I_n)^{-1}\nabla_w E_w^j(k), \\ v_j(k+1) = v_j(k) - (\nabla_v E_v^j(k)\nabla_v^T(k) + \beta_v I_{j-1})^{-1}\nabla_v E_v^j(k) \end{cases}$$

(here β_w, β_v regularization parameters, I_n, I_{j-1} – identity matrixes of corresponding dimensions) and using the Sherman-Morrison's formula for matrix inversion, after simple transformations [15] with regard to (2), (4) we come to the simple form [16]

$$\begin{cases} w_j(k+1) = w_j(k) + \dfrac{\tilde{x}(k) - w_j(k) y_j(k)}{\beta_w + y_j^2(k)} y_j(k), \\ v_j(k+1) = v_j(k) - \dfrac{y_j(k)\vec{y}_{j-1}(k)}{\beta_v + y_j^2(k)\left\|\vec{y}_{j-1}(k)\right\|^2}. \end{cases} \quad (5)$$

It is easy to see that the recurrent procedures (5) are the modification of the adaptive Kaczmarz algorithm [17, 18], conceived for solving the principal component analysis tasks in on-line mode.

However, it's known that one-step algorithms are very sensitive to the various kinds of disturbances and noises that can be worsen the quality of the estimates. In connection with this it is necessary to provide both tracking (speed) and filtering (smoothing noise) properties for learning procedure. Applying the approach used in [19] for the learning algorithms synthesis, instead of (5) we can introduce the recurrent relations:

$$\begin{cases} w_j(k+1) = w_j(k) + r_{w,j}^{-1}(k)(\tilde{x}_j(k) - w_j(k)y_j(k))y_j(k), j = 1,2,\ldots,m, \\ r_{w,j}(k) = \alpha r_{w,j}(k-1) + y_j^2(k), 0 \le \alpha \le 1, \\ v_j(k+1) = v_j(k) - r_{v,j}^{-1}(k)y_j(k)\vec{y}_{j-1}(k), \\ r_{v,j}(k) = \alpha r_{v,j}(k-1) + y_j^2(k)\left\|\vec{y}_{j-1}(k)\right\|^2 \end{cases} \tag{6}$$

where α – smoothing parameter defining a compromise between tracking and filtering properties of the algorithm.

Using the algorithm (6) means that the quantitym of principal components m is given apriori and doesn't change in the learning process. At the same time the question remains: how big should be this quantity to provide the required compression level of input data with minimal information loss? In order to answer this question we can use the evolving connectionist systems ideas [20], where not only synaptic weights are learned, but architecture is also tuned.

2. EVOLVING NEURAL NETWORK ARHITECTURE FOR PRINCIPAL COMPONENT ANALYSIS TASK

Rubner-Schulten-Tavan's type evolving hierarchical neural network architecture for principal component analysis is shown in Fig. 1. Network nodes are adaptive linear associators with synaptic weights $w_j, v_j, j = 1,2,\ldots,m,\ldots$, and, moreover, it includes an adder $\sum$, designed for decompressing the compressed signal, and decision-making unit DM, in which assesses necessarity to add additional neurons to network.

The network starts with only one Oja's neuron, noted $w_1(k)$, and if the quality of the reconstructed signal

$$\hat{x}_1(k) = w_1(k)y_1(k)$$

is worse than a certain threshold ε_{EST}, in the network the second neuron is added with synaptic weights values $w_2(k)$, $v_2(k)$. It is easy to notice that the addition of the second, third, $w_3(k)$, $v_3(k)$ and the next nodes, as well as their removal does not affect the work of other neurons of network.

The number of neurons changing process continues until the recovered signal

$$\hat{x}(k) = \sum_{j=1}^{m} w_j(k) y_j(k)$$

accuracy will satisfy the inequality

$$E_{EST}^{k} = \frac{1}{k} \sum_{k} \frac{\left\| \tilde{x}(k) - \hat{x}(k) \right\|^2}{\left\| \tilde{x}(k) \right\|^2} \le \varepsilon_{EST}. \qquad (7)$$

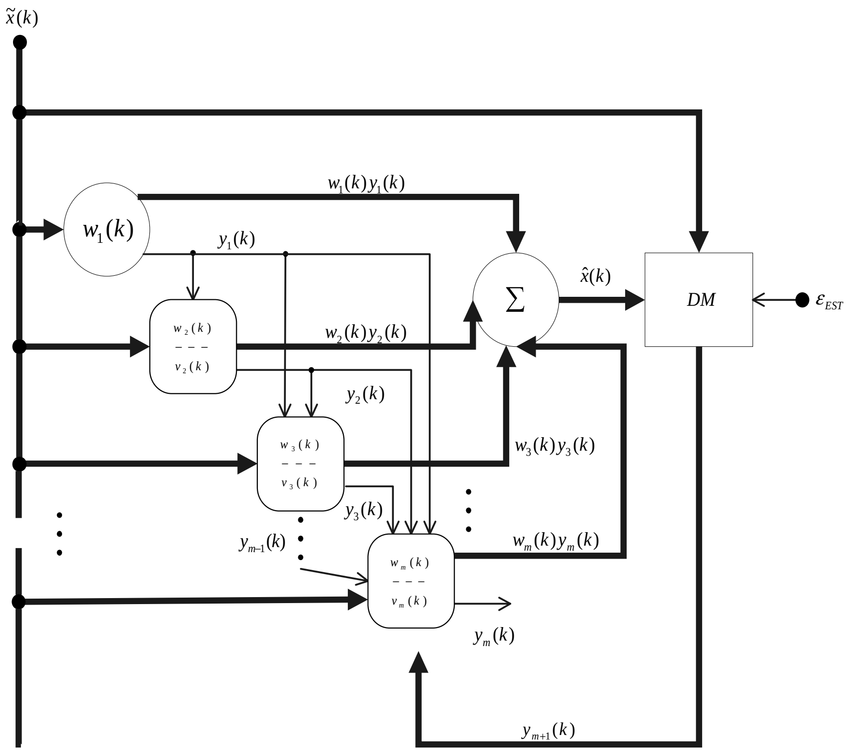


Fig. 1 – Evolving hierarchical neural network for principal component analysis

As soon as the value E_{EST}^{k} becomes smaller than the threshold value ε_{EST}, the architecture changes process stops in unit DM. Since the information processing occurs in on-line mode, the setup process architecture can also occur continuously.

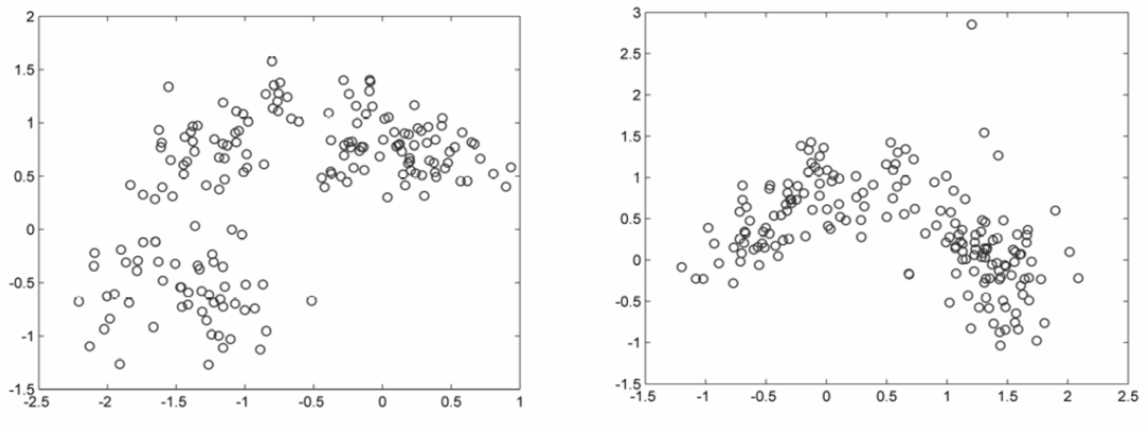
3. EXPERIMENT RESULTS

For demonstrating the work of optimal learning rules Rubner-Schulten-Tavan's hierarchical neural network data from dataset Wine [21], representing the performance of chemical analysis and tasting of three varieties containing 178 values (13 attributes) were used. Using neural networks two tasks have been solved: the major components have been found all and the dimension of the input data has been reduced to 2. For each task experiment was carried out at different initial conditions 100 times, the results were averaged. As estimates of the results mean absolute percentage error was used MAPE. Table. 1 shows the results of algorithm work that are compared with the results of the standard learning algorithm of Rubner-Schulten-Tavan's neural network.

Table 1

The results of the working of learning algorithms forRubner-Schulten-Tavan's hierarchical neural network

	Hierarchical neural network with gradient learning algorithm	Hierarchical neural network with adaptive learning algorithm
Finding all of the principal components		
Error	0,08	0,17
Time, sec	0,53	1,05
Finding all of the principal components		
Error	0,49	0,69
Time, sec	0,13	0,19



a) b)

Pic. 2. – Data for the "Wine" dataset after compression to the two-dimensional space: a) using the hierarchical neural network with adaptive learning algorithm, b) using the hierarchical neural network with gradient learning algorithm

From Table. 1 it can be concluded that a hierarchical neural network with adaptive learning algorithm in the dimension reduction task works on average 15% more accurate than a hierarchical neural network with gradient learning algorithm, while possessing the speed of convergence is 33% higher. In finding all the main components of a hierarchical neural network with adaptive learning algorithm works in an average of 12% more accurate and 49% faster.

Conclusions

Evolving hierarchical neural network architecture and adaptive learning algorithms for processing of multi-dimensional stochastic non-stationary signals in on-line mode were proposed. The neural network is characterized by simplicity of numerical realization and allows changing the number of estimated principal components during adjustment without retraining of existing neurons was introduced.

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IMAGE SEGMENTATION WITH FUZZY J-MEANS METHOD

Abstract. *The reason for novel method development consists in absence of existing ones that could quickly cope with undefined overlapping image segments without trapping into local extremum. As image segmentation is closely related to clustering, boundaries between image segments are decided to be presented using fuzzy clusters. Crisp and fuzzy solutions to image processing are observed in this paper along with matrix modification of fuzzy J-means clustering that is proposed based on modified fuzzy C-means algorithm.*

Keywords: *image segmentation, crisp clustering, fuzzy clustering, C-means, J-means matrix modification*

Introduction

Spatial segmentation is an important phase in many image and video processing applications. It assumes partitioning the whole field of view into uniform, in a sense, areas of interest. The union of such neighbouring partitions appears to be different from the specified point of view. Therewith, vector space may be presented using visual or geometric features obtained from image pixel information analysis. Among a large variety of image segmentation techniques, clustering is considered one of the most effective [1].

Clustering multidimensional observations is one of the key problems from a wide research area known as ‘data mining’. The challenges faced here are as follows: different distribution law of initial data that is a priori unknown, necessity in real time or near real time processing, variety of cluster shapes and their overlapping, existence of noise and outliers, without mentioning difficulties in initial partitioning and similarity metric choice. Many methods have been already developed for solving these problems, starting from strictly mathematically formalized and up to heuristic based ones [2, 3]. Despite huge efforts in this field, the aforementioned problems are left partially unsolved.

The most frequently used approach to clustering problem consists in partitioning feature vector space implemented by finding p vectors of centroids $C(l)$, $l = 1, 2, \dots, p$ around which clustered sample vectors are grouped. Well-known methods, there, with extended mathematical grounding are those connected with sum of squares minimization (in terms of Euclidean metric) of intra-cluster distances between vectors of observations and calculated centroids. Among centroid based methods, H-means, K-means, C-means, J-means and their modifications [2-7] have gained great popularity.

Despite of their effectiveness, centroid based methods (such as K-means, H-means and fuzzy C-means) possess the same drawback: they tend to stuck at local extremum during optimization process. This problem occurs quite often for multiextremal optimization, and to overcome it, there are several approaches: from simple search restart or global random search application [8] and up to using more complicated genetic or immune algorithms. Unfortunately, these approaches significantly increases time needed for multimedia information processing that is unallowable while working with video data bases containing huge amounts of visual information.

Vector clustering procedures with global properties are J-means method for crisp clustering [5] and its fuzzy case FJM (abbreviated from 'fuzzy J-means') [9]. When optimization procedure traps into a local extremum, these methods accomplish 'jumps' in the vicinity of the extremum, which leads the procedure out of the trap to the attraction of a more 'deep' extremum. In further sections, crisp and fuzzy image segmentation via clustering is observed along with matrix modification of fuzzy J-means method that is proposed and discussed in application to image segmentation.

1. Crisp and Fuzzy Image Segmentation

Boundaries between image segments may be of two types. They can be presented as strict separate objects and overlapping objects. The latter is even more practicable because real objects usually overlap each other and the background, i.e. they are not clearly defined. The same thing is true for crisp and fuzzy clustering. In the first case, cluster boundaries are strict and one observation (image pixel, for instance) is related to one and only one cluster, i.e. clusters are mutually exclusive. In fuzzy clustering, some observations may belong to more than one cluster with membership value specified [1].

Consider crisp form of image segmentation, during which an image given by $(M \times N)$-matrix containing pixel information is partitioned into uniform, in a sense, classes (segments or clusters). With this proviso, the initial image matrix is divided into ‘window’ blocks of size $(m \le M)\times(n \le N)$. Then, after each of these blocks is converted (vectorized) into $(mn\times 1)$-vectors of amount $N^* = MN(mn)^{-1}$, any of the aforementioned clustering algorithm is applied. From substantive and computational points of view, ‘windows’ $x(k) = \left\{x_{i_1 i_2}(k)\right\} \in R^{m\times n}$; $i_1 = 1, 2,\ldots, m$; $i_2 = 1, 2,\ldots, n$; $k = 1, 2,\ldots,$ $N^* = MN(mm)^{-1}$ are more preferable for processing than vectorized data. Among the whole multitude, the best partition $P_p = \left\{Cl_1, Cl_2,\ldots, Cl_p\right\}$ should be found in some accepted sense under condition of p non-overlapping clusters

$$Cl_l \cap Cl_q = \varnothing;\ l \ne q;\ l, q \in [1, p] \tag{1}$$

and matrix centroids $C = \{C(1), C(1),\ldots, C(p)\}$, providing minimum value of the objective function

$$\min_{P_p} E = \min_{P_p} E(x(k), C(l)) = \min \sum_{k=1}^{N^*}\sum_{l=1}^{p} \mu(x(k), C(l)) Sp(x(k) - C(l))(x(k) - C(l))^T \tag{2}$$

where $Sp(\circ)$ denotes the trace of matrix, $\mu(x(k), C(l)) = \begin{cases} 1, \text{ if } x(k) \in Cl_l, \\ 0, \text{ otherwise.} \end{cases}$

Solution to the optimization problem of objective function (2) can be simply presented as follows:

$$C(l) = \frac{1}{N_l}\sum_{x(k)\in Cl_l} x(k) = \frac{\sum_{k=1}^{N^*} \mu(x(k), C(l))x(k)}{\sum_{k=1}^{N^*} \mu(x(k), C(l))} \tag{3}$$

where N_l is the number of samples belonging to cluster Cl_l. In fact, the solution is reduced to finding matrix centers of weight in corresponding clusters.

Though, as it was already mentioned, condition (1) is not always held in real-world image processing applications, and cluster overlapping occurs very often. In other words, as a rule, it is impossible to set one-to-one correspondence of a ‘window’ with one or another particular segment. In vector space, such problems are successfully resolved with fuzzy cluster analysis where fuzzy C-means method (FCM) has gained the greatest popularity for pattern recognition and computer vision systems [1, 10-12].

FCM matrix modification was introduced in [13]. The following expression, there, was used as an objective function

$$E = E(x(k), C(l)) = \sum_{k=1}^{N^*} \sum_{l=1}^{p} \mu^{\beta}(x(k), C(l)) Sp(x(k) - C(l))(x(k) - C(l)) \tag{4}$$

with constraints

$$\sum_{l=1}^{p} \mu(x(k), C(l)) = 1; \; 0 < \sum_{l=1}^{m} \mu(x(k), C(l)) < N^*; \; l = 1, 2, \ldots, p. \tag{5}$$

Here, $\mu(x(k), C(l))$ is the value of sample $x(k)$ membership in cluster Cl_l, $\beta \geq 0$ is the parameter named 'fuzzifier' that specifies the level of edge overlapping for adjacent segments (usually $\beta = 2$).

The following result is obtained after optimization of objective function (4) under constraints (5):

$$\begin{cases} \mu(x(k), C(l)) = \dfrac{(Sp(x(k) - C(l))(x(k) - C(l))^T)^{\frac{1}{1-\beta}}}{\sum_{l=1}^{p} (Sp(x(k) - C(l))(x(k) - C(l))^T)^{\frac{1}{1-\beta}}}, \\ C(l) = \dfrac{\sum_{k=1}^{N^*} \mu^{\beta}(x(k), C(l)) x(k)}{\sum_{k=1}^{N^*} \mu^{\beta}(x(k), C(l))}, \end{cases} \tag{6}$$

and if $\beta = 2$, then the following simple expression is obtained [13] corresponding to popular J. Bezdek procedure generalization for the matrix case [14]:

$$\begin{cases} \mu(x(k), C(l)) = \dfrac{(Sp(x(k) - C(l))(x(k) - C(l))^T)^{-1}}{\sum_{l=1}^{p} (Sp(x(k) - C(l))(x(k) - C(l))^T)^{-1}}, \\ C(l) = \dfrac{\sum_{k=1}^{N^*} \mu^{2}(x(k), C(l)) x(k)}{\sum_{k=1}^{N^*} \mu^{2}(x(k), C(l))}. \end{cases} \tag{7}$$

2. Matrix Presentation of Fuzzy J-means

In connection with fuzzy image segmentation, fuzzy J-means method is reasonable to be extended to the matrix case. Moreover, it turns out that J-means significantly outperforms previously observed centroid based methods when many clusters and observations are present. Fuzzy J-means method consists in random movement of intermediary centroid (trapped into local extremum during optimization procedure) into empty points (that are not centroids) located in vicinity until reaching more 'deep' extremum being a centroid. Then, the obtained crisp solution is recalculated into fuzzy one by determining membership levels and refining all the cluster centroids.

FJM method is implemented in two main stages: finding local optimums using standard FCM with consecutive finding more 'deep' minimums via FJM-heuristic.

The first stage assumes the following sequence of steps.

Step 1. Specifying initial quite random partitioning $P_p = \{Cl_1, Cl_2, \ldots, Cl_p\}$ with centroids $C(1)$, $C(2), \ldots$, $C(p)$; fuzzifier β and threshold $\varepsilon > 0$ that determines condition of algorithm termination.

Step 2. Calculation of membership values $\mu(x(k), C(l))$ using the first relation from (6) (for arbitrary β) or the first relation from (7) (for $\beta = 2$) with centroids that are got from the previous step.

Step 3. Recalculation of centroids $C(1)$, $C(2), \ldots$, $C(p)$ using the second relation from (6) (for arbitrary β) or the second relation from (7) (for $\beta = 2$) with membership values got from the previous step.

Step 4. Estimation of spherical norm of difference between the previously obtained centroids and those calculated at the third step.

Step 5. Check for termination conditions. If the obtained norm is less than ε, the algorithm terminates; if the obtained norm is greater than ε, return to step 2 with centroids located as after applying step 3.

The algorithm proceeds iteratively until termination condition is reached, and the solution will be presented by coordinates of local optimum in linear programming problem for (4), (5).

The second stage is a phase of jumps when random moves are performed in vicinity to the obtained local minimum in order to reach more 'deep' extremum.

It was shown in [10] that the general optimization problem (4) with constraints (5) can be reduced to unconstrained optimization with a specific presentation of objective function which can be written in matrix form as follows:

$$E = E(x(k), C(l)) = \sum_{k=1}^{N^*} (\sum_{l=1}^{p} (Sp(x(k) - C(l))(x(k) - C(l))^T)^{1-\beta})^{1-\beta}, \qquad (8)$$

for arbitrary values of fuzzifier β and

$$E = E(x(k), C(l)) = \sum_{k=1}^{N^*} (\sum_{l=1}^{p} (Sp(x(k) - C(l))(x(k) - C(l))^T)^{-1})^{-1} \qquad (9)$$

for $\beta = 2$.

Then, jumps are performed from any of the obtained centroids $C(l)$, $l = 1, 2..., p$. In other words, the chosen centroid is replaced with any sample $x(r)$, and after that, the value of objective function (8) or (9) is calculated in the following view:

$$E = E(x(k), x(r)) = \sum_{k=1}^{N^*} (\sum_{l=1}^{p} (Sp(x(k) - x(r))(x(k) - x(r))^T)^{1-\beta})^{1-\beta} \qquad (10)$$

or

$$E = E(x(k), x(r)) = \sum_{k=1}^{N^*} (\sum_{l=1}^{p} (Sp(x(k) - x(r))(x(k) - x(r))^T)^{-1})^{-1}. \qquad (11)$$

If values (10), (11) turn out to be less than (8), (9) for some $x(r)$, the decision is made that a better centroid is found for cluster Cl_l. Then, all the membership values are recalculated using the first relation from (6) or (7). Such jumps are performed in vicinity of each centroid got at the first step. If it turns out that jumps in vicinity of all the centroids do not perfect the value of objective function (10), (11), then decision is made concerning termination of optimization process or jumps are performed again in vicinity of greater radius. Practically, this process may continue until empty points run to an end. The latest found local extremum is considered to be global one. Despite of seemingly bulky description, optimization process is quite simple from computational point of view.

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Conclusion

It has been stated that strict boundaries between neighbouring segments are not always determinable in an image. For the purpose of quick and efficient image segmentation under condition of overlapping classes, matrix modification of fuzzy J-means method has been proposed. The developed method is based on matrix modification designed for fuzzy C-means clustering with the mechanism of random jumps, which provides finding global extremum of the accepted objective function. Computational simplicity of the method ensures its application for large-scale multidimensional data and guarantees resolving wide range of fuzzy clustering problems in matrix spaces.

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15.

UDC 004.9

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DATA MININGMETHODSBASED ONSELF-ORGANIZINGMODELS

Abstract. The paper proposes analysis ofdata miningmethodsbased onself-organizingmodels. Reviewing the basic idea of the modified Group method of data handling (GMDH) known as the Group of Adaptive Models Evolution (GAME) network. Presents an original idea of active neurons (different activation function are sorted), this idea might be used to improve the efficiency of models based on the generalization of structures of iterative and combinatorial type algorithms.

Keywords: data mining, domain ontology, ontological information, generalized iterative algorithm , inductive modeling, structures of data, handling and storing of information.

Introduction

Problems of data mining complex systems can be solved using both the logical deductive methods and sorting-out inductive ones. Deductive methods have advantages in the case of simple modeling tasks, if there is known the theory of an object being modeled and therefore it is possible to build a model based on physically based principles using knowledge of processes in an object. But these methods can not give satisfactory results for complex systems. In this case, an approach of knowledge extraction directly from the data based on experimental measurements has an advantage. A priori information about the properties of such objects may be only minimal or even absent.

One of the most well-known modeling techniques devoid of problems described above is the group method of data handling that discovers knowledge about the object directly from the data sample.

Group method of data handling is currently widely used in solving various problems and actively applied in tasks where usage of conventional algorithmic solutions is ineffective or even impossible. To increase accuracy and expand horizons for GMDH application, many researchers have been studied some aspects of GMDH and proposed as well as developed hybrid-type algorithms. At present many domestic and foreign researchers like E.Bodyanskiy (Ukraine), P. Kordik (Czech Republic), T.Kondo (Japan) and others are actively developing GMDH-like systems based on multilayered algorithm. For instance, in [1] the use of genetic algorithm is described for optimization of multilayered GMDH structure, and factors are finding at that by the method of singular decomposition (SVD, Singular Value Decomposition).

1. GMDH as a polynomial neural network

Both the GMDH author Ivakhnenko and many users of his method, especially in the last 20 years when artificial neural networks have gained wide popularity, began to call its typical structure also as a neural network. Moreover, in recent years GMDH algorithm among the professionals abroad is called often as Polynomial Neural Network (PNN).

Here one of the main elements of iterative GMDH algorithms, namely any partial description, can also be considered as an elementary neuron of the neural network PNN GMDH. The structure of such neuron for the quadratic partial description is shown in Fig. 1. The originality of the neural network with such neurons consists in speed of the process of local adjustment of weights of neurons and automatic global optimization of the network structure (number of units and number iterations or hidden layers).

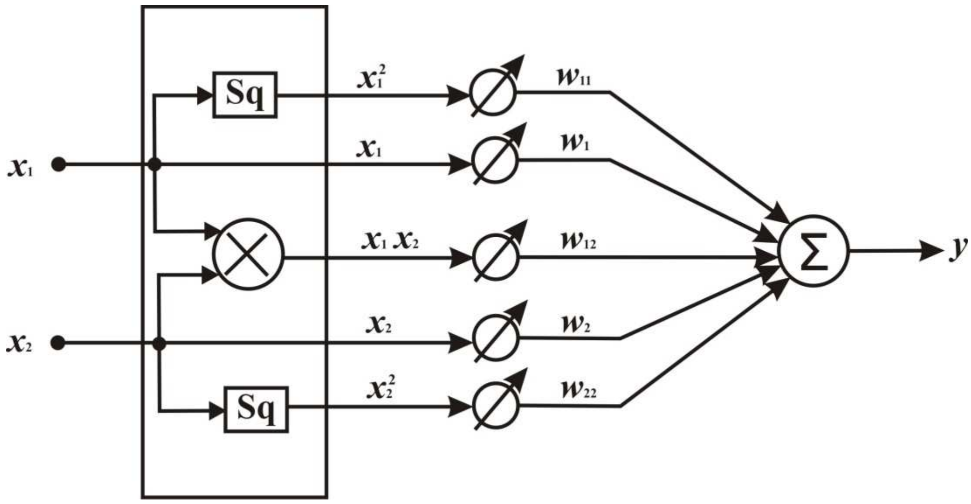

Fig. 1. Structure of GMDH neuron with the quadratic particular description [2]

Elements of polynomial GMDH neural networks and its use is discussed in [2-7] in details.

2. The idea of neural networks with active neurons

At the early stages of the GMDH theory development, the similarity between neural networks and multilayered GMDH algorithm was observed. O.Ivakhnenko in one of the articles stated that the differences between the perceptron and GMDH are not fundamental, so it is acceptable to call GMDH-systems as "perceptron-like systems".

Before explaining what the active neuron is like, there is a need to characterize firstly the passive neuron.

Mechanisms of optimization of the input variables set are not founded in all kinds of standard (passive) neurons. They are set in the complex process of self-organization of the whole system of many neurons in general. Structural optimization by an external criterion and receiving optimal non-physical models in the perceptron is not provided, only parametric optimization using e.g. inverse calculation of errors ("back propagation") is performed. Perceptron is almost not inferior to polynomial GMDH algorithms with respect to accuracy if the learning set is rather long, noise variance is small, and the set contains variables quantized on a small number of levels, i.e. when the physical model appears to be optimal. The advantage of GMDH models in accuracy is reached at short data samples of continuous noisy variables, i.e. if a non-physical model becomes optimal. Advantages of perceptron and polynomial GMDH algorithms are combined in Neural Network with active neurons.

The similarity between the structure of neural networks and GMDH algorithms inspired researchers to explore how they can be combined. O. Ivakhnenko et al. [3] propose the combined method that extends the theory of self-organization from fixed structures to active neural networks. Proposed algorithm known as "neural network with active neurons" is used instead of a passive neuron in the GMDH algorithm [4-6].

Both multilayered and combinatorial GMDH algorithm can be used as active neuron. O. Ivakhnenko [2] proposes to modify the combinatorial algorithm into the algorithm with active neurons that leads to increasing of accuracy and reducing of calculation time.

The advantage of GMDH neural networks with active neurons as compared with conventional neural network with binary neurons consists in that self-organizing of the network is simplified: each neuron finds necessary connections and its structure by itself in the process of self-organization.

Neural networks with active neurons were successfully used for prediction of the processes in economical and ecological systems [4, 5-9].

Idea of active neurons described above served also as the basis for generalization of the previous modifications in order to significantly improve the efficiency of iterative GMDH algorithms.

3. GMDH-type neural network with feedback

T. Kondo proposed a new multilayered GMDH-type neural network with feedback [7] which may by itself automatically choose the optimum neural network architecture using the idea of self-organization. Architecture of the GMDH-like neural network has a cycle of feedback. In this algorithm outputs of neurons are connected with the system inputs (feedback) for further calculation. Thus, the complexity of the neural network increases gradually. This GMDH-type neural network algorithm has an ability of self-selecting optimum neural network architecture from three variants such as sigmoid function, radial basis function (RBF) and polynomial neural network. In addition, structural parameters such as number of neurons in hidden layers and input variables are selected automatically by minimizing the error criterion defined as Akaike criterion:

$$AIC(s_f) = -2\ln\varphi(X, \hat{\theta}_f) + 2s_f, \tag{1}$$

whereφ is the likelihood function.

For each combination, optimum neuron architectures are automatically selected from the two type neurons: neuron architecture with two and with r inputs.

Proposed by T.Kondo the GMDH-type neuron network with feedback has been successfully used for the medical problem of recognizing 3-dimensional images of lungs [9].

It may be noted that this idea with submitting outputs to the input was partially implemented in the multilayered algorithm with selection of initial arguments. In this research the idea is also reflected in the developed generalized algorithm.

4. Group of Adaptive Models Evolution

An evolutionary algorithm based on GMDH and called GAME (group of adaptive models evolution) has developed in the Czech Technical University in Prague by P. Kordik [43]. The coefficients of unit transfer functions are estimated in GAME on the basis of the data set describing the system being modelled.

Major modifications of the GMDH-type system are [10]:

the transfer function of the unit is of several types (linear, polynomial, logistic, etc.) and it can be provided by a perceptron network too. Each type of unit has its own learning algorithm for coefficients estimation. Choice of the type of units that form a network is determined by the given criterion. This is so-called heterogeneous network structure;

the number of unit inputs increases together with the depth of the unit in the network. Transfer functions of units reflect growing number of inputs.

there exist interlayer connections in the network.

the network construction process does not search all possible layouts of units. It searches just the random subset of these layouts. The original GMDH produces one optimal model. This method produces the group of models that are locally optimal, each for its specific subset of unit layouts.

The Modified GMDH generates a group of models on a single training data set. The random processes influence the construction procedure. Weights and coefficients of units are randomly initialized. Transfer functions of many units types are defined pseudo-randomly when the unit is initialized. Inputs for units are selected pseudo-randomly as well. It results in the fact that the topology of models developed on the same training data set differs (fig.2, fig.3).

After reviewing the basic idea of the modified GMDH known as the GAME network, we can conclude that it like as in the algorithm Kondo also presents an original idea of active neurons (different activation function are sorted), so this idea might be used to improve the efficiency of models based on the generalization of structures of iterative and combinatorial type algorithms.

5. Hybrid Differential Evolution and Group Method of Data Handling for Inductive Modeling

The group method of data handling and differential evolution (DE) population-based algorithm are two well-known nonlinear methods of mathematical modeling. In paper [11] of Godfrey C. Onwubolu, a new design methodology which is a hybrid of GMDH and DE was proposed. The proposed method constructs a GMDH network model of a population of promising DE solutions. The new hybrid implementation was applied to modeling and prediction of practical datasets and its results were compared with the results obtained by GMDH-related algorithms.

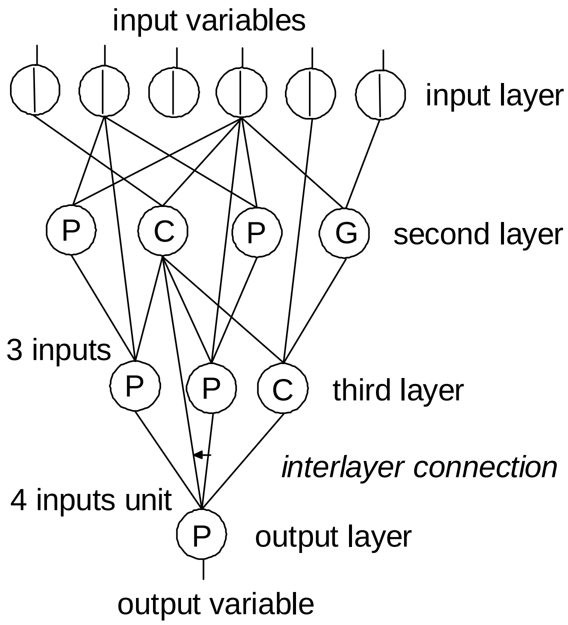

Fig. 2. GAME-network structure shema

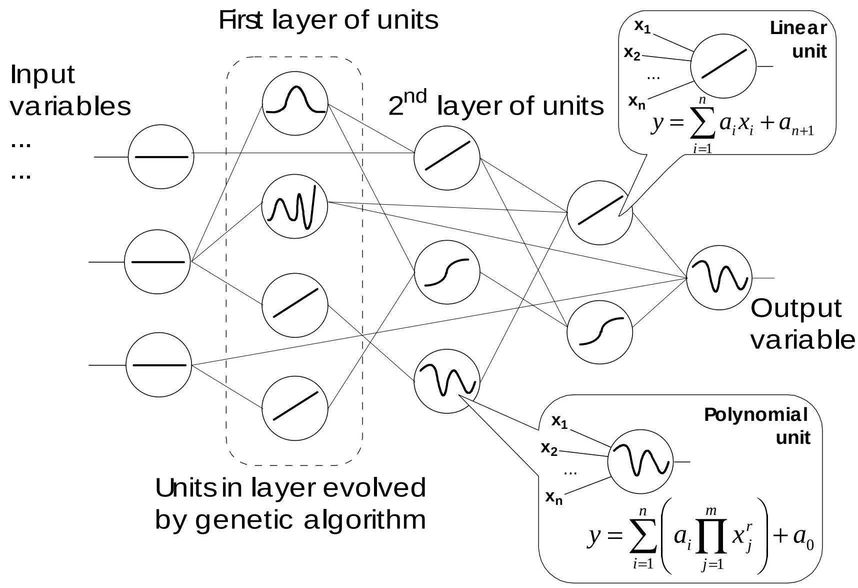

Fig. 3. GAME-network structure

The modeling methods have many common features, but, unlike the GMDH, DE does not follow a pre-determined path for input data generation. The same input data elements can be included or excluded at any stage in the evolutionary process by virtue of the stochastic nature of the selection process. A DE algorithm can thus be seen as implicitly having the capacity to learn and adapt in the search space and thus allow previously bad elements to be included if they become beneficial in the later stages of the search process. The standard GMDH algorithm is more deterministic and would thus discard any underperforming elements as soon as they are realized.

Using DE in the selection process of the GMDH algorithm, the model building process is free to explore a more complex universe of data permutations. This selection procedure has three main advantages over the standard selection method. Firstly, it allows unfit individuals from early layers to be incorporated at an advanced layer where they generate fitter solutions. Secondly, it also allows those unfit individuals to survive the selection process if their combinations with one or more of the other individuals produce new fit individuals. Thirdly, it allows more implicit non-linearity by allowing multi-layer variable interaction.

The new DE-GMDH algorithm is constructed in exactly the same manner as the standard GMDH algorithm except for the selection process. The selected fit individuals were entered in the GMDH algorithm as inputs at the next layer. The whole procedure is repeated until the criterion for terminating the GMDH run has been reached. Presented in [44] results show that the proposed algorithm appears to perform reasonably well and hence can be applied to real-life prediction and modeling problems.

Conclusion

This paper considers in detail the basic structural elements of data mining methods based on self-organizing models based on typical GMDH algorithm, analyzes its advantages and shortcomings, describes the historical ways to overcome these shortcomings. Presented an original idea of active neurons (different activation function are sorted), this idea might be used to improve the efficiency of models based on the generalization of structures of iterative and combinatorial type algorithms.

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UDC 004.89

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TIMESERIESFORECASTINGONTHEBASISOFTHECASE-BASEDREASONINGUSINGTHEMODELSOFARTIFICIALIMMUNESYSTEMS

Abstract. The article describes the immune algorithms of short-term forecasting of time series based on the clonal selection model and the immune network model using the case-based reasoning. The clonal selection model uses heterogeneous antibodies on the basis of the case-based reasoning and the simplest forecasting methods. Evaluation of the effectiveness of the models is carried out by the comparative analysis; the results of experimental studies that demonstrate the features of the proposed approaches are presented.

Keywords: forecasting, time series, case-based reasoning, artificial immune systems, antibody, antigen, affinity, cloning, mutation.

Introduction

The problem of short-term forecasting of time series plays an important role in the decision-making process in technical and economic systems. Forecasting future values of a time series allows solution of an actual problem of determining the future state based on the analysis of the already existing retrospective data.

Approaches based on the artificial intelligence methods, such as artificial neural networks and artificial immune systems (AIS) are currently actively developing [1-4]. There are various models based on the principles of immune system: clonal selection model, immune network model and others that can be used to solve the problems of short-term time series forecasting [2-4] and can be integrated with other approaches, which allows compensation for the shortcomings of some models by using the features of the others [4]. Promising is the use of the case-based reasoning (CBR), where, when considering a new problem of forecasting, a similar case is sought in history as an analogue [5].

The purpose of the study lies in the development of immune algorithms of short-term forecasting based on the models of clonal selection and of artificial immune network using the case-based reasoning.

Problem statement

This paper considers discrete time series, the values of which are obtained at times $t_1, t_2, t_3, \dots, t_N$. Let us denote time series $Z = z(t_1), z(t_2), z(t_3), \dots, z(t_N)$ of length N as $Z_1^N = z_1, z_2, z_3, \dots, z_N$. Let us call a set of consecutive values $Z_t^L = z_t, z_{t+1}, z_{t+2}, \dots, z_{t+L-1}$, within the time series Z_1^N, a sample of this series of length L, with a reference time t, $L \in \left[\overline{1, N-1}\right]$, $t \in \left[\overline{1, N-L}\right]$. The problem of forecasting a time series is the estimation of future values by its known section.

CBR-forecasting is based on the hypothesis proposed in [6]: if the similarity measure between the samples of the values of the forecasting series Z_t^L and Z_{t-k}^L has a value close to one, then the similarity measure between the samples of length P following them, Z_{t+L}^P and Z_{t-k+L}^P, is also close to one. I.e. by determining the sample, which is the most relevant to the latest known values of a time series, it is possible to estimate its future values.

However, case-based forecasting has a number of shortcomings, the main of which include the requirement for the number of the known values of a time series and the assumption that the past patterns will be the same in the future. To compensate for these shortcomings, one needs to use other forecasting methods, applying the CBR for the segmentation of the original time series. The problem of selecting an appropriate case from those existing in the database and its adaptation to the current conditions is one of the most important in the CBR-systems [5].

To solve this problem, this paper proposes to use the models of artificial immune network and of clonal selection.

Immune network model using the case-based reasoning

Case-based reasoning is a method of analyzing data to make conclusions about the situation on the search results of analogies stored in the database. This process includes steps such as the selection of a set of cases from those available in the database based on a given similarity relation, adaptation of the selected cases in relation to current conditions, comparison of the obtained and real values of the forecasting value, and saving in the database for future use of the taken decision and the current situation as a new case or a corresponding change in the previously selected case [5]. When solving the problem of forecasting using the CBR, a case is a combination of the problem (a sample of known values of a series) and the decision taken earlier (forecast).

To construct an AIS-based forecasting model, it is necessary to compare the biological objects and processes with their analogues from the domain. Antibodies are known values of a time series. Antigens are known values of a time series immediately preceding the forecasting one. Affinity of antibodies (primary criterion for the selection in the immune network algorithm) is a scalar value determining the measure of closeness between an antibody and an antigen. In this approach, the affinity is determined not for a separate antigen-antibody pair, but between the antigens and antibodies tuples of length L – multi-antibody $mAb = ab_1, ab_2, ab_3, \ldots ab_{L+f}$ andmulti-antigen $mAg = ag_1, ag_2, ag_3, \ldots ag_L$. Multi-antibody also includes f forecasting values – this part is not involved in the determination of affinity. The number of antibodies included in it corresponds to the forecasting horizon.

In terms of the CBR approach, multi-antibody plays the role of a case, describing the current situation (the sequence of known values of a series) and the decision taken earlier (the relevant forecast). Thus, to estimate future values of a series, one needs to find multi-antibodies with the greatest affinity – the most relevant for the current problem.

Affinity of a multi-antibody with length L is determined by the formula:

$$Aff = \frac{\sum_{i=1}^{L} (1 + d_i)^{-1}}{L} \in (0,1], \tag{1}$$

where $d_i = |ab_i - ag_i|$ – distancebetweenthepairsofthevaluesconstituting multi-antibody mAb and multi-antigen mAg.

The problem of selecting a suitable case from those existing in the database and its adaptation to the current conditions is one of the most important in the CBR-systems. These steps in the AIS-based forecasting model correspond to the selection of multi-antibodies with the highest affinity from those present in the population, and the subsequent AIS training. The feature of the immune network model is the relationship between individual antibodies – correction in the process of AIS training of antibodies belonging to one multi-antibody affects others, close to it.

Clonal selection model using the case-based reasoning

Clonal selection algorithm operates on fixed-length data lines and is often used for solving the problems of classification, identification and optimization [1]. Each data line of the algorithm called an antibody (in terms of the CBR – case) represents a set of parameters describing the set problem (a set of known values of a series) and the decision taken (proposed forecast option): $Ab_i = ab_1, ab_2, ab_3, \ldots, ab_L, \ldots, ab_{L+f}$, where i – index in the population, L – length of the sample of known values of a series, f – value of the forecasting horizon (length of a sample of forecasting values of a series).

Antigen is the set problem – sample of known values of a series immediately preceding the forecasting values: $Ag_j = ag_1, ag_2, ag_3, \ldots, ag_L$, where j – index in the population, L – length of the sample. I.e. an antigen is a section of a series, for which it is necessary to make a forecast.

Affinity between an antibody and an antigen is determined as

$$Aff = \eta * \frac{\sum_{k=1}^{L} \left(1 + |ab_k - ag_k|\right)^{-1}}{L} \in (0,1], \qquad (2)$$

where η – value of the selection coefficient for determining the priority of the various types of antibodies. Values of antibody $ab_{L+1}, \ldots, ab_{L+f}$, the affinity of which $Aff(Ab) \to 1$, are taken as the forecasting ones.

Formally, AIS model based on clonal selection can be represented as follows:

$$AIS\_ClonAlg = \left\langle Ab, n', n_c, Ab^C, Ab^M, Ag, D, \sigma_d, S, \sigma_s, \sigma_{age}, \eta \right\rangle, \qquad (3)$$

where Ab – population of the antibodies of size n; n' – number of the cells selected for cloning and mutation; n_c – number of the clones created by one antibody; Ab^C – population of clones; Ab^M – population of memory cells; Ag – population of the antigens of size m; D – matrix of affinities between antigens and antibodies; σ_d – threshold coefficient of cell stimulation; S – matrix of affinities between antibodies; σ_s – threshold compression coefficient; σ_{age} – threshold age of antibodies; η – set of selection coefficients.

Clonal selection model allows combining the use of the CBR and other forecasting methods, performing segmentation of a series and selection of the most appropriate forecasting method for each section of the original series during the obtainment of a forecast. Therefore, in addition to the antibodies implementing the case-based reasoning, other types of antibodies are created based on the same fragments of the time series, forming its own version of the forecast, using the simplest forecasting methods, such as simple average forecasting, exponential average forecasting, naive models [5].

Algorithm for short-term forecasting

Algorithm to obtain a forecast includes the following steps:

1. Creation of the initial population of antibodies. To create antibodies, a part of known values of a time series is used. Unused values serve as a training and test samples.

2. Formation of an antigen (or a multi-antigen for the immune network model) based on the latest known values of the series preceding the forecasting ones.

3. Determination of Ab-Ag (mAb-mAg) affinities and selection of antibodies (or multi-antibodies for the immune network model) having an affinity above the threshold value.

4. Forecast of the antibody (multi-antibody) having the highest affinity is taken as a result.

5. If there is a real value of the forecasting value, forecast error is determined.

6. Cloning antibodies with the highest affinity (selected in step 3), during which the mutation operator is performed. In the immune network model clones replace multi-antibodies that gave rise to them.

7. Determination of affinities between the antibodies (multi-antibodies), applying the suppression operator with a view to eliminate redundancy. In the clonal selection model the remaining antibodies from the previously selected ones become memory cells.

8. Application of the aging operator and correction of the population.

The immune network model (also for antibodies in the clonal selection model implementing the case-based reasoning) uses directional proportional mutation – the most suitable case for the set problem undergoes substantial correction. Only a part of the antibody that determines its forecast and is not involved in the determination of affinity is exposed to mutation. For antibodies computing their own version of the forecast, only the first part is exposed to undirected mutation (and therefore, the proposed version of the forecast changes), which partially solves the problem of the lack of cases in the database.

After receiving the real values of the forecast AIS based on the clonal selection model performs a correction of selection coefficient η. The coefficient is incremented for that type of antibody, which showed the smallest prediction error.

The population of memory cells formed in the process of AIS training based on the model of clonal selection represents a set of patterns that are the most typical for this time series.

Changing of the population of antibodies in the current generation gen occurring as a result of applying operators of cloning, mutation and selection can be generally represented as follows:

$$Ab^{gen+1} = Edit\left(Mutate\left(Clone\left(Ab^{gen}\right)\right)\right), \tag{4}$$

where

$$Clone : Ab^{gen} \to Ab_{C}^{gen}; \tag{5}$$

$$Mutate : Ab_{C}^{gen} \to Ab_{MC}^{gen}; \tag{6}$$

$$Edit : (Ab_{MC}^{gen}, Ab^{gen}) \to Ab^{gen+1}. \tag{7}$$

The graph in fig. 1 shows the effect of the multi-antibody length value L on the accuracy of the obtained forecast.

AIS training is repeated for each antigen from the training sample a given number of times. A stop to achieve a certain number of generations, or a stop to achieve a predetermined error value is used as a criterion for stopping the immune algorithm. Fig. 2 shows the dependence of the mean absolute error (MAE) on the affinity for the untrained (series 1) and trained (series 2) AIS based on the immune network model. Thus, the purpose of AIS training is to configure the system in accordance with new values of a time series.

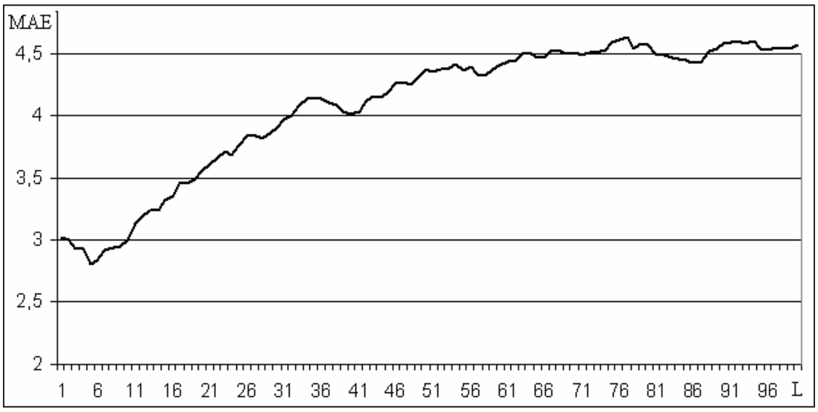

Fig.1 –Dependence of the mean forecast error on the multi-antibody length

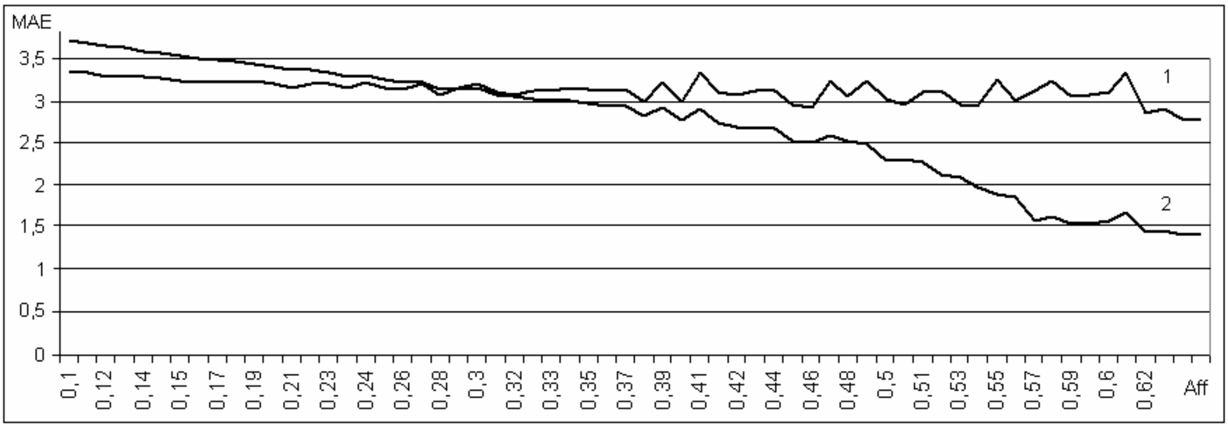

Fig.2 –Dependence of the error value on the affinity of multi-antibodies

Effectiveness of forecasting using the models considered is reduced when cases from the training sample created on the basis of similar patterns propose conflicting versions of the forecast. To solve this problem, an increase in the sample size is used, on the basis of which the first part of an antibody (multi-antibody) is built. Since the nature of the series can change over time, it is advisable to maintain sets of antibodies of various lengths in the population.

Results of the comparative analysis

Experimentalstudies included short-term forecasting for the series used in M3-Competition [7] and the series of average daily temperature readings. Forecastingresults by various methods are shown in table 1. To evaluate the prognosis,the value of the symmetrical mean absolute error (SMAPE) was used; the results of the use of the forecasting methods different from AINet ClonAlg areobtained from [7]. To estimate the Meteo time series prediction was used mean absolute error (MAE).

Comparing the results of the model based on the artificial immune network (AINet) and the model based on the clonal selection (ClonAlg), it may be noted that although the results are close for the series of temperatures (Meteo), the use of clonal selection allows better forecasting for the series with smaller background, i.e. this approach is less demanding to the number of values of the time series.

Table 1

Symmetrical mean absolute error (SMAPE, %) for different forecasting methods

Method	N704 (44)	N736 (44)	N1366 (63)	N2830 (104)	N2841 (104)	N2867 (79)	Meteo (21337)
Exp.Smooth	4,08	12,11	0,42	2,47	0,5	20,52	4,56
RobustTrend	4,76	8,88	0,41	2,18	0,52	18,83	–
HoltWinters	4,92	10,68	1,04	3,27	0,39	20,08	2,9
CombSHD	4,36	9,65	0,5	2,73	0,46	20,09	–
Box–Jenkins	3,66	7,35	0,57	2,45	0,5	26,13	2,99
ForecastPro	3,13	6,5	0,41	2,47	0,5	20,52	–
SmartFcs	5,18	8,62	0,29	2,47	0,5	23,85	–
AutoANN	3,42	8,73	0,27	1,56	0,53	26,11	–
AINet	5,36	9,71	0,46	2,37	0,68	18,93	2,45
ClonAlg	5,20	7,65	0,41	1,83	0,14	16,26	2,44

The result of forecasting a series of average daily temperature readings (Meteo) confirms the advantages of the AIS-based approaches using the CBR – sizes of the Meteo series allow creation of a population of antibodies that corresponds to the vast database of cases, and carrying out the training. However, with a small number of values of a time series, the absence of antibodies with high affinity in the database (there is no suitable case) is likely in the preparation of a forecast, and the value of a training sample will not allow full configuration (training) of the artificial immune system. As a result, in some series presented in the table the traditional methods have advantages over the considered approaches.

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Conclusions

This paper proposes a solution to the problem of short-term forecasting of time series by the case-based reasoning, using the models of artificial immune systems, such as the immune network model and the clonal selection model using heterogeneous antibodies.

The main features of the models considered are as follows:

- use of a population of antibodies as a database of cases;
- the possibility to configure the size of multi-antibodies in accordance with the nature of the series;
- antibodies in the model of clonal selection implement various forecasting methods; segmentation of a series is performed in the process of the AIS training to determine the most appropriate predictor for each section of the original series;
- formation of a plurality of patterns (population of memory cells) in the process of analyzing time series in the AIS training based on the model of clonal selection;
- the possibility to determine abnormal emissions in time series using the population of memory cells formed in the process of training;
- the possibility to extend the models to account for the influence of external factors presented in the form of other time series.

The results presented in the paper confirm the efficiency of the use of the considered approaches for short-term forecasting of time series, but in a lack of baseline information it is preferable to use the approach based on the clonal selection model, as this approach allows getting a better result with a small training sample.

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L. Kirichenko

THE METHOD OF DISTINCTION MONOFRACTAL AND MULTIFRACTAL PROCESS FROM TIME SERIES

Abstract. Based on the numerical analysis of the sample multifractal characteristics obtained by method of multifractal detrended fluctuation analysis the statistical criterion for accepting the hypothesis of monofractal properties of the time series is proposed. Results of investigations to identify mono- and multifractal properties of the time series of different nature are given.

Keywords: monofractal and multifractal time series, multifractal detrended fluctuation analysis, generalized Hurst exponent.

Problem statement

It is now recognized that many information, biological, physical and technological processes have a complex fractal structure. Fractal analysis is used for modeling, analysis and control of complex systems in various fields of science and technology. Fractal analysis is applied to predict seismic activity and tsunami and to determine the age of geological rocks in geology; to diagnose diseases and physiological states of the records of ECG and EEG in medicine, to study the mutations and changes at the genetic level in biology; to predict the crisis and risk using financial series in economy; to study the turbulence and thermodynamic processes in physics. This list is not exhaustive. [1,2].

Processes that exhibit fractal properties can be divided into two groups: self-similar (monofractal) and multifractal. Monofractal processes are homogeneous in the sense that they have single scaling exponent. Their scaling characteristics remain constant on any range of scales. Multifractal processes can be expanded into segments with the different local scaling properties. They are characterized by the spectrum of scaling exponents. [2,3].

All of the above led to the emergence of the models of fractal stochastic processes. Note the lack of universal models that could be used to describe the fractal processes of various nature. And vice versa one and the same process can be described in several models depending on research objective. In the general case the choice of model is based on the characteristics of the studied time series.

Determination if the time series has monofractal or multifractal property is one of the important steps of selecting and constructing mathematical models. In the case of monofractality the mathematical models of processes can be fractional Brownian motion, fractal point processes, fractal process ARIMA and others. For modeling multifractal processes can use fractal stable Levy motion, stochastic multiplicative cascades, fractal motion in multifractal time, etc [3].

In practice the distinction between monofractal and multifractal properties of the stochastic process is a difficult task. This is due to errors of estimation of fractal characteristics of real time series [4-7]. Currently, there is no universally accepted criterion of distinguishing mono- and multifractal processes by their sample fractal characteristics. The purpose of work is to present the method to distinguish between mono- and multifractal processes from time series, and the study on this basis fractal properties of time series of different nature.

Estimation of multifractal characteristics of from time series

Stochastic process with continuous time $X(t),\ t \geq 0$ is called self-similar with parameter $H,\ 0 < H < 1$ if for any value $a > 0$ finite-dimensional distributions of $X(at)$ identical to finite-dimensional distributions of $a^H X(t)$ i.e. $\mathrm{Low}\{X(at)\} = \mathrm{Low}\{a^H X(t)\}$. Parameter H called parameter Hurst, is a measure of self-similarity of a stochastic process. Moments of self-similar stochastic process can be expressed as $M\left[|X(t)|^q\right] = C(q) \cdot t^{qH}$, where the value $C(q) = M\left[|X(1)|^q\right]$.

Multifractal processes have more complex scaling behavior: $\mathrm{Law}\{X(a\,t)\} = \mathrm{Law}\{a^{H(a)} \cdot X(t)\}$, $a > 0$. For multifractal processes the following relation holds: $M\left[|X(t)|^q\right] = c(q) \cdot t^{qh(q)}$, where $c(q)$ is certain deterministic function, $h(q)$ is generalized Hurst exponent, which is nonlinear function in the general case. Value $h(q)$ at $q = 2$ matches the value of measure of self-similarity H. For monofractal processes the generalized Hurst exponent does not depend on the parameter q: $h(q) = H$. [3].

There are many methods of parameter estimation of self-similar and multifractal processes from time series.When estimating of the multifractal characteristics one of the most popular is the method of multifractal detrended fluctuation analysis (MFDFA) [5,6]. When using the method MFDFA the cumulative time series $y(t) = \sum_{i=1}^{t} x(t)$ of the initial investigated one $x(t)$ is constructed. Then it is divided into N segments of length s. For each segment of $y(t)$ fluctuation function $F^2(s) = \frac{1}{s}\sum_{t=1}^{s}(y(t) - Y_m(t))^2$ is calculated, where $Y_m(t)$ is local *m*-polynomial trend within the limits of this segment of length s. By changing the time scale s at a fixed value q the dependence $F_q(s) = \left\{\frac{1}{N}\sum_{i=1}^{N}[F^2(s)]^{\frac{q}{2}}\right\}^{\frac{1}{q}}$ is found. Next, the dependence of the fluctuation function $F_q(s)$ of the parameter q is determined. If the investigated series have fractal properties, then the fluctuation function $F_q(s)$ has the power dependence $F_q(s) \propto s^{h(q)}$.

Method to distinguish between mono- and multifractal processes

Thus, having received the values of generalized Hurst exponent $h(q)$, it is theoretically possible to conclude about monofractality of the process, if this function is constant. However, in practice this is a difficult task. Estimate $\hat{h}(q)$ obtained from the time series is a curve which tends to a constant value with increasing length of the series [4,5,7]. Figure 1 (left) presents the sample values $\hat{h}(q)$ of monofractal process for realizations of different lengths. On the other hand, comparison with the range of values Δh for the multifractal processes (Fig. 1, right), shows that the difference between mono- and multifractal realizations is quite significant.

The results of multifractal analysis of model time series allowed to develop and test the method proposed in [8], which allows to accept or reject the hypothesis about presence of monofractal properties of time series based on studies of sample values of the generalized Hurst exponent obtained by MFDFA.

Numerical analysis showed that a random variable $\Delta h = h(q1) - h(q2)$ at $q > 0$ has normal distribution $N(m_h, s_h)$ the parameters of which depend on the realization length and values q. The proposed criterion considers the magnitude $\Delta h = h(0.1) - h(5)$. By numerical simulation of mono- and multifractal processes sample values m_h and s_h for the time series of length N were obtained.

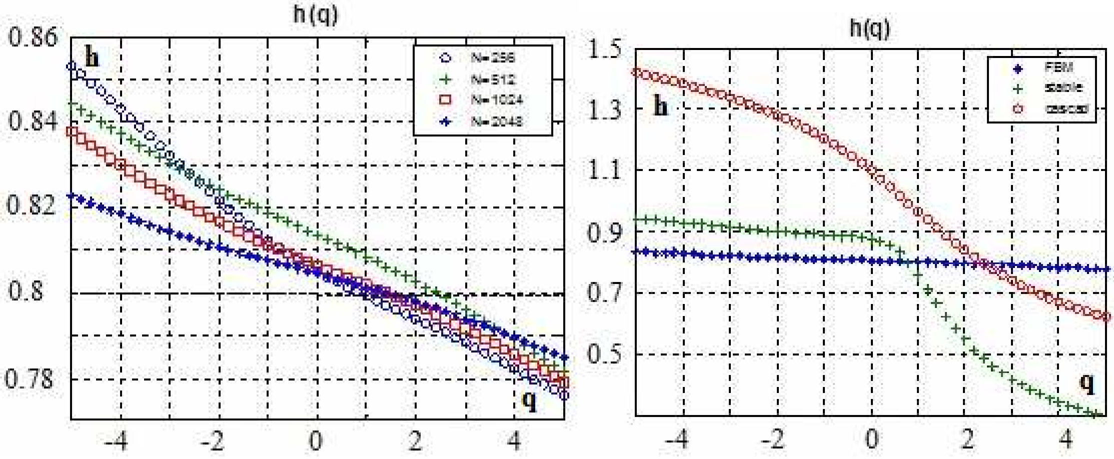

Figure 1 – Values $\hat{h}(q)$ for monofractal series with different lengths (left) and multifractal series (+, 0), and monofractal one (x) of length 1000 values (right)

The value of a random variable Δh can be used as a statistical criterion for acceptance or rejection of the hypothesis of monofractal properties of time series. In this case, the null hypothesis is the assumption of monofractality. After obtaining estimate of function $\hat{h}(q)$ by MFDFA observed value $\hat{\Delta h} = \hat{h}(0.1) - \hat{h}(5)$ is calculated. Hypothesis is accepted with a significance level α if the resulting value falls in the range of acceptable values $\hat{\Delta h} < m_h(N) + t_\alpha s_h(N)$, where N is length of time series, m_h and s_h are the corresponding values calculated for monofractal process, α is the significance level, t_α is quantile of the standard normal distribution.

Research results of time series

In this work, a number of studies to identify mono- and multifractal properties of time series of different nature were carried out. As studied time series the electroencephalograms, financial series and temperature series have been chosen. The left side of Fig. 2 shows time series of electroencephalograms of laboratory animals for different phases of sleep: wakefulness state (awake), rapid eye movement (REM) sleep and slow-wave sleep (SWS). Financial series are Dow Jones index and gold prices in 2004-2008. Also series of average daily temperatures in Kiev in 2000-2006 which possess a cyclic component were investigated.

For each series generalized Hurst exponent were obtained by MFDFA. The table shows the results of the analysis of sample values of the generalized Hurst exponent $\hat{h}(q)$. The sample values $\Delta h = h(0.1) - h(5)$ of the series shown in the fig. 2 are presented in the third column of the Table. Critical values Δh based on estimated data for the significance level $\alpha = 0.05$ and the corresponding length of the series are given in the fourth column. On the basis of the obtained values the hypothesis of monofractal properties of time series has been accepted or rejected.

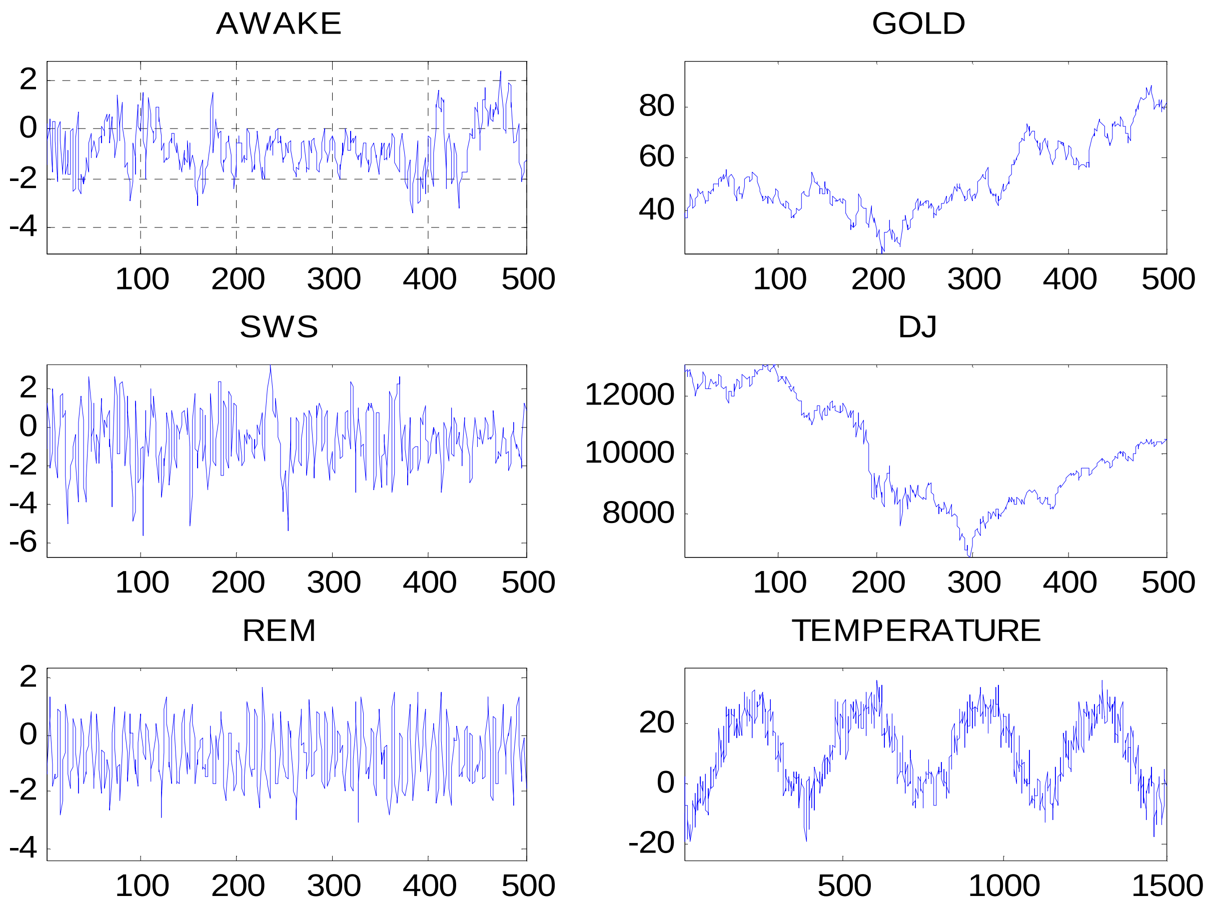

Figure 2 – Investigated time series: electroencephalograms, financial series and temperature series.

Conclusion

Based on the numerical analysis of the sample multifractal characteristics the statistical criterion to distinguish between mono- and multifractal processes from time series is proposed. Results of investigations to identify mono- and multifractal properties of the time series of different nature are given.

Table

Test of hypothesis of monofractality.

Time series	Length	Sample values $\widehat{\Delta h}$	Critical value Δh	Fractality
EEG (awake)	1000	0.1743	0.0859	multi
EEG (REM)		0.169		multi
EEG (SWS)		0.068		mono
Dow Jones index	500	0.2416	0.1248	multi

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Gold prices		0.0991		mono
Temperature	2000	0.0264	0.07312	mono

Studies indicate that the heterogeneity of the fractal structure of time series depends not only on the nature of the series, but also its local characteristics. Identifying the presence or absence of multifractal properties, we can find a more efficient mathematical model of a stochastic process that generates a similar time realizations. It should also be noted that usually monofractal mathematical models have less cumbersome mathematical apparatus and are simpler to implement than multifractal models.

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ARTIFICIAL COMPLEX NEURONS WITH HALF-PLANE-LIKE ACTIVATION FUNCTION

The paper deals with the problems of realization of Boolean functions on neural-like units with complex weight coefficients. The relation between classes of realizable function is considered for half-plane-like activation function. We also introduce the concept of sets separability, corresponding to our notion of neuron. The iterative online learning algorithm is proposed and sufficient conditions of its convergence are given.

Keywords: neuron, complex neuron, neural network, threshold unit, threshold function, activation function, learning, online learning.

Introduction

Artificial neural networks based on neural-like units have numerous applications in different areas, such as artificial intelligence, objects classification, pattern recognition, data compression, forecasting, approximation or extrapolation of functions of many variables and many others [1]. Different networks architectures and neuron kinds are described in [1, 2]. One of most important task in the theory of feed-forward neural networks with discrete activation functions is the one concerning the realization of a Boolean function on a single neuron. Its importance follows from the fact that for networks on the base of neurons with threshold-like activation function outputs of each network levels have two possible values (binary, bipolar, etc.). Minsky and Papert [3] proved that classical threshold units have enough weak capacity for recognition. Numerous improved models of neuron are proposed for overcome the mentioned limitations (see [1] for details).

In paper we deal with the one type of such extensions, namely complex neurons, which are introduced in [4]. There exists many way of complexification, e.g. [5].

Let $E_2 = \{-1, 1\}$ be the bipolar set and E_2^n is an n-thCartesian power of E_2. A Boolean function in bipolar basis is a function mapping from E_2^n to E_2.

A Boolean function $f(x_1, \ldots, x_n)$ on E_2^n is a Boolean threshold

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function if there exists a weight vector $(w_1, \ldots, w_n) \in R^n$ and a threshold $-w_{n+1}$ such that

$$\text{for all } (x_1,\ldots,x_n) \in E_2^n \sum_{j=1}^{n} w_j x_j < -w_{n+1} \Leftrightarrow f(x_1,\ldots,x_n) = -1.$$

With intent of simplify notation we extend input and weight vectors dimension by introducing one new additional (n+1)-th coordinate. Let $\mathbf{x} = (x_1,\ldots,x_n,1)$, $\mathbf{w} = (w_1,\ldots,w_n,w_{n+1}) \in R^{n+1}$, $(\mathbf{w},\mathbf{x}) = \sum_{j=1}^{n} w_j x_j + w_{n+1}$ — inner product of vectors **w** and **x** (sometimes called a weighted sum). Thus, for any threshold function *f*: $f(\mathbf{x}) = \operatorname{sgn}(\mathbf{w},\mathbf{x})$, where $f(\mathbf{x}) = f(x_1,\ldots,x_n)$ and sgn is sign function given by

$$\operatorname{sgn} a = \begin{cases} -1 & \text{if } a < 0, \\ 1 & \text{if } a \ge 0. \end{cases}$$

Complex neurons

Now we extend the notion of threshold function to the complex domain. Let us consider Boolean function over alphabet $\{\alpha,\beta\}$ where α and β are complex number. Let l be an arbitrary line dividing the complex plane C on two half-plane C_+ and C_-. We may regard following sgn function

$$\operatorname{sgn}_l z = \begin{cases} -1 & \text{if } z \in C_-, \\ 1 & \text{if } z \in C_+ \cup l. \end{cases}$$

A Boolean function $f : \{\alpha,\beta\}^n \to \{\alpha,\beta\}$ is a complex Boolean threshold function (CBTF) in the alphabet $\{\alpha,\beta\}$ if there exists a complex weight vector $\mathbf{w} \in C^{n+1}$ and line l such that $f(\mathbf{x}) = \operatorname{sgn}_l(\mathbf{w},\overline{\mathbf{z}})$, where $\overline{\mathbf{z}}$ is a complex conjugate vector for **z** (here we used the definition of inner product in complex vector spaces).

Note that we do not use the notion of the threshold in our definition, because it is convenient to include the threshold in the weight vector.

It is easy to see that using rotation and fitting of the free term w_{n+1} we can restrict the class of possible sign function to the following function

$$\operatorname{Resgn} z = \begin{cases} -1 & \text{if} \quad \operatorname{Re} z < 0, \\ 1 & \text{if} \quad \operatorname{Re} z > 0. \end{cases}$$

Note that "small" change of term w_{n+1} allows avoiding the possibility that the weighted sum $(\mathbf{w}, \overline{\mathbf{z}})$ value lies on the division line.

Let $T_C(\alpha, \beta)$ be a class of all CBTF in alphabet $\{\alpha, \beta\}$. The question arises about relations existing among the classes of CBTF in different alphabets. The answer is given by the following proposition.

Proposition 1. *There exists an bijective correspondence between the classes* $T_C(\alpha, \beta)$ *and* $T_C(\gamma, \delta)$ *for arbitrary alphabets* $\{\alpha, \beta\}$, $\{\gamma, \delta\}$.

Proof. Let $f(\mathbf{z}) \in T_C(\alpha, \beta)$. Then there exists $\mathbf{w} \in C^{n+1}$ such that for all $\mathbf{z} \in \{\alpha, \beta\}^n$ $f(\mathbf{z}) = \operatorname{Resgn}(\mathbf{w}, \overline{\mathbf{z}})$. The transformation $z' \to \dfrac{\beta - \alpha}{\delta - \gamma}(z' - \gamma) + \alpha$ is the one-one correspondence between sets $\{\gamma, \delta\}$ and $\{\alpha, \beta\}$. Then

$$(\mathbf{w}, \overline{\mathbf{z}}) = \sum_{j=1}^{n} w_j z_j + w_{n+1} = \frac{\beta - \alpha}{\delta - \gamma} \sum_{j=1}^{n} w_j z'_j + \left(\alpha - \frac{\beta - \alpha}{\delta - \gamma}\gamma\right) \sum_{j=1}^{n} w_j z'_j + w_{n+1} = (\mathbf{w}', \overline{\mathbf{z}}'),$$

where $w'_j = \dfrac{\beta - \alpha}{\delta - \gamma} w_j$, $(j = 1, 2, \ldots n)$, $w'_{n+1} = \left(\alpha - \dfrac{\beta - \alpha}{\delta - \gamma}\gamma\right) \sum\limits_{j=1}^{n} w_j + w_{n+1}$.

Let $g(\mathbf{z}')$ be a Boolean function in alphabet $\{\gamma, \delta\}$ realizable on the complex neuron with the weight vector $\mathbf{w}'$. It is easy to see that the correspondence $f \leftrightarrow g$ is bijective one between the functions from $T_C(\alpha, \beta)$ to $T_C(\gamma, \delta)$.

Note, in particular, that one cannot obtain the class of CBTF more powerful that $T_C(-1, 1)$ by altering the alphabet.

The next question is how the cardinality of the class of CBTF changes if we restrict the set of possible value for weight vector coefficients. Let $T_D^n(\alpha, \beta)$ be the class of all CBTF of *n* variables realizable on neurons with weight vectors from the set D^{n+1}, $T_D(\alpha,\beta)=\bigcup_{n=0}^{\infty} T_D^n(\alpha,\beta)$, where $D \subseteq C$.

Proposition 2.*If* $\operatorname{Re}\alpha \neq \operatorname{Re}\beta$, *then* $T_C(\alpha,\beta)=T_R(\alpha,\beta)$.

Proof. Let us proof that equality $T_C^n(\alpha,\beta)=T_R^n(\alpha,\beta)$ holds for all non-negative integer *n*. From proposition 1 it follows that $T_C^n(\alpha,\beta)\leftrightarrow T_C^n(\operatorname{Re}\alpha,\operatorname{Re}\beta)$. Let *f* be an arbitrary member of $T_C^n(\operatorname{Re}\alpha,\operatorname{Re}\beta)$, $\mathbf{z}\in\{\alpha,\beta\}^n\times\{1\}$, $z_j=x_j+iy_j$, $x_j,y_j\in R$ $(j=1,\dots,n)$, $w_j=u_j+iv_j$, $u_j,v_j\in R$, $(j=1,\dots,n+1)$. Then

$$f(\mathbf{z})=\operatorname{Re}\left(\sum_{j=1}^{n} w_j x_j + w_{n+1}\right)=\sum_{j=1}^{n} u_j x_j + u_{n+1} = \operatorname{Re}\left(\sum_{j=1}^{n} u_j z_j + u_{n+1}\right).$$

It follows from the last equality that the classes $T_C^n(\operatorname{Re}\alpha,\operatorname{Re}\beta)$ and $T_R^n(\alpha,\beta)$ have the same cardinality. Then the same holds for classes $T_C(\alpha,\beta)$and $T_R(\alpha,\beta)$. Since $T_C(\operatorname{Re}\alpha,\operatorname{Re}\beta)\subseteq T_C(\alpha,\beta)$, these classes are equal.

Note that for the alphabet E_2 the last proposition is proved in [4].

From the previous proposition also follows that usage of neurons with weights belonging to the real line enable us to generate all CBTF. We will prove that similar fact is true for neurons with weights lying on any line in complex space.

Proposition 3.*If* $\gamma\in C$, $\gamma R=\{\gamma\mathbf{x}\mid \mathbf{x}\in R\}$ *and complex numbers* α,β,γ *satisfy conditions* $|\arg\gamma|<\frac{\pi}{2}$, $\operatorname{Re}(\alpha-\beta)\gamma\neq 0$, *then classes* $T_C(\alpha,\beta)$ and $T_{\gamma R}(\alpha,\beta)$*coincide.*

Proof. Let us consider an arbitrary CBTF $f(\mathbf{z})\in T_C(\alpha,\beta)$. Then there exists $\mathbf{w}\in C^{n+1}$ such that for each $\mathbf{z}\in\{\alpha,\beta\}^n$ equality$\operatorname{Resgn}(\mathbf{w},\overline{\mathbf{z}})=f(\mathbf{z})$ is true, from which it follows that

$$(\mathbf{w},\overline{\mathbf{z}})=\sum_{j=1}^{n} w_j z_j + w_{n+1} = \sum_{j=1}^{n} w_j\gamma^{-1}\gamma z_j + w_{n+1} = (\mathbf{w}',\overline{\mathbf{z}}'),$$

where $w'_j = w_j\gamma^{-1}$, $z'_j = \gamma z_j$ $(j = 1,\dots,n)$, $w'_{n+1} = w_{n+1}$. So, for all CBTF $f(\mathbf{z})$ inalphabet $\{\alpha,\beta\}$ there exists uniqueCBTF $g(\mathbf{z}')$ inalphabet $\{\gamma\alpha,\gamma\beta\}$ such thatfor each $\mathbf{z}\in\{\alpha,\beta\}^n$ equality $f(\mathbf{z}) = g(\mathbf{z}')$ holds. Using proposition 2 to function $g(\mathbf{z}')$ we obtain

$$\mathrm{Re}(\mathbf{w},\overline{\mathbf{z}}) = \mathrm{Re}(\mathbf{w}',\overline{\mathbf{z}}') = \mathrm{Re}\left(\sum_{j=1}^{n} u_j z'_j + u_{n+1}\right) = \mathrm{Re}\left(\sum_{j=1}^{n} u_j\gamma\cdot z_j + u_{n+1}\right) = \mathrm{Re}(\tilde{\mathbf{w}},\overline{\mathbf{z}}),$$

where $u_j\in R$, $\tilde{w}_j = u_j\gamma$, $(j = 1,\dots,n)$, $\tilde{w}_{n+1} = \dfrac{u_{n+1}\gamma}{\mathrm{Re}\,\gamma}$. Thus, the Boolean function $f(\mathbf{z})$ is realizable on complex neuron with weight vector $\tilde{\mathbf{w}}\in\gamma R^{n+1}$.

Learning algorithm

We have seen that $T_C(\alpha,\beta) = T_{\gamma R}(\alpha,\beta)$, and question how find some weight vector $\mathbf{w}\in T_{\gamma R}(\alpha,\beta)$, corresponding to given CBTF f naturally arises. That is, we need a learning algorithm for the class of CBTF.

Let A^+, A^- be two finite disjunctive subsets of vectors from the set $C^n\times\{\gamma\}$, $(\gamma\neq 0)$ (i.e. $A^+\cap A^- = \varnothing$) and $A = A^+\cup A^-$. We call sets A^+ and A^- γ-separable, if there exists vector $\mathbf{w}\in\gamma R^{n+1}$ such that for all $\mathbf{z}\in A$ following conditions hold

$$(\mathbf{w},\overline{\mathbf{z}}) > 0 \quad \text{if } z\in A^+,$$
$$(\mathbf{w},\overline{\mathbf{z}}) < 0 \quad \text{if } z\in A^-.$$

Next, we will suppose that there exists an angle ϕ and real number c such that

$$\forall\mathbf{z}\in A \quad \left|\mathrm{Re}\left(e^{i\phi}z_j\right)\right| \geq c > 0 \quad (j = 1,\dots n). \tag{1}$$

We will assume **(1)**, without any loss of generality, because A is a finite set.

Let the training sample of vectors $\{\mathbf{z}^k\}$ satisfies following two conditions:

1) $\mathbf{z}^k\in A$, $k\in N$;

2) each element of the set*A*repeats in learning sample infinitely many times.

Without any loss of generalitywe will assume that $\gamma = e^{i\phi}$, where $-\frac{\pi}{2} < \phi < \frac{\pi}{2}$. Let the initial weight vector be $\mathbf{w}^0 = (0,\ldots,0)$.Let us build the sequence of vectors $\{\mathbf{w}^k\}$ as follow:

$$\mathbf{w}^k = \mathbf{w}^{k-1} + t_k h_\phi\left(\mathbf{z}^k\right) e^{i\phi}, \tag{2}$$

where $h_\phi(\mathbf{z}) = \left(\operatorname{Re}\left(\overline{\mathbf{z}}_1 e^{-i\phi}\right), \ldots, \operatorname{Re}\left(\overline{\mathbf{z}}_n e^{-i\phi}\right), 1\right)$, and a coefficient t_k in defined by

$$t_k = \begin{cases} 1 & \text{if } \operatorname{Re}\left(\mathbf{w}^{k-1}, \overline{\mathbf{z}^k}\right) \le 0 \text{ and } \mathbf{z} \in A_+, \\ -1 & \text{if } \operatorname{Re}\left(\mathbf{w}^{k-1}, \overline{\mathbf{z}^k}\right) \ge 0 \text{ and } \mathbf{z} \in A_-, \\ 0 & \text{otherwise.} \end{cases} \tag{3}$$

The algorithm of weights updating according to the rule (2)-(3) we call "the online learning algorithm" for the complex neural unit. The next proposition gives the sufficient condition for our learning algorithm to be convergent.

Proposition 4.*If finite sets* A^+ *and* A^- *are* γ*-separable, then there exists finite natural m such that the sequence* (2) *of weight vector, obtaining according to the rules* (2)-(3) *of online learning algorithmyield after m updates the weight vector* $\mathbf{w}^m$*, which separates sets* A^+ *and* A^-.

Proof. We do our proof by contradiction. Suppose that the opposite is true. We can assume that at each step of the learning algorithm the coefficients $t_k \ne 0$ (in opposite case we can simply throw awaysuch $\mathbf{z}^k$, for which $t_k = 0$, because weights are persistent on respective steps of the algorithm). Then $\mathbf{w}^{m+1} = t_1 h_\phi\left(\mathbf{z}^1\right) e^{i\phi} + \ldots + + t_m h_\phi\left(\mathbf{z}^m\right) e^{i\phi}$. Now find the inner product of both sides of the last equality by $\mathbf{w} \in R^{n+1}(\gamma)$, which separates sets A^+ and A^-. Without loss of generality we can assume there exists$d > 0$ such that $\forall \mathbf{z} \in A$ the following inequalityholds

$\left|\left(\mathbf{w}, h_\phi(\mathbf{z})\right)\right| \geq d > 0$ (we always can satisfy it by changing in corresponding way the free term w_{n+1}). It follows from Cauchy-Schwartz inequality that

$$\|\mathbf{w}\| \cdot \left\|\mathbf{w}^{m+1}\right\| \geq \left|\left(\mathbf{w}, \mathbf{w}^{m+1}\right)\right| \geq \sum_{k=1}^{m} \left|\left(\mathbf{w}, h_\phi\left(\mathbf{z}^k\right)\right)\right| \geq md,$$

and, hence,

$$\left\|\mathbf{w}^{m+1}\right\|^2 \geq \frac{m^2 d^2}{\|\mathbf{w}\|^2}. \qquad (4)$$

In other way, if we square the both sides of (2), then we have that

$$\left\|\mathbf{w}^{k+1}\right\|^2 = \left\|\mathbf{w}^k\right\|^2 + 2t_{k+1} \operatorname{Re}\left(\mathbf{w}^k, h_\phi\left(\mathbf{z}^{k+1}\right) e^{i\phi}\right) + \left\|h_\phi\left(\mathbf{z}^{k+1}\right)\right\|^2.$$

Accordingly to the learning algorithm all vectors $\mathbf{w}^k$ satisfythe conditions $\mathbf{w}^k = e^{i\phi}\mathbf{u}^k$, where $\mathbf{u}^k \in \mathrm{R}^{n+1}$. Therefore,

$$\operatorname{Re}\left(\mathbf{w}^k, h_\phi\left(\mathbf{z}^{k+1}\right) e^{i\phi}\right) = \operatorname{Re} \sum_{j=1}^{n} u_j^k e^{i\phi} \operatorname{Re}\left(\overline{\mathbf{z}_j^{k+1}} e^{-i\phi}\right) \cdot \overline{e^{i\phi}} + \operatorname{Re}\left(u_{n+1}^k e^{i\phi} \overline{e^{i\phi}}\right) =$$

$$= \operatorname{Re} \sum_{j=1}^{n} u_j^k \left(x_j^{k+1} \cos\phi - y_j^{k+1} \sin\phi\right) + u_{n+1}^k = \operatorname{Re}\left(\sum_{j=1}^{n} \operatorname{Re}\left(u_j^k e^{i\phi}\left(x_j^{k+1} + i y_j^{k+1}\right)\right) + u_{n+1}^k e^{i\phi} \overline{e^{i\phi}}\right) =$$

$$= \operatorname{Re}\left(\sum_{j=1}^{n} w_j^k z_j^{k+1} + w_{n+1}^k \overline{e^{i\phi}}\right) = \operatorname{Re}\left(\mathbf{w}^k, \overline{\mathbf{z}^{k+1}}\right).$$

From (3) it followsthat $t_k \operatorname{Re}\left(\mathbf{w}^k, \overline{\mathbf{z}^{k+1}}\right) \leq 0$. Then, according to last equalities and condition (1) $\left\|\mathbf{w}^{k+1}\right\|^2 - \left\|\mathbf{w}^k\right\|^2 \leq \left\|h_\phi\left(\mathbf{z}^{k+1}\right)\right\|^2 \leq nc^2 + 1, \ (k = 0, 1, \ldots, m)$.

Let us sum the last equality by $k$from 0 to$m$. Then

$$\left\|\mathbf{w}^{m+1}\right\|^2 \leq \sum_{k=0}^{m} \left\|h_\phi\left(\mathbf{z}^{k+1}\right)\right\|^2 \leq (m+1)\left(nc^2 + 1\right). \qquad (5)$$

Inequalities (4) and (5) contradict for sufficiently large m. Hence, the learning process (2)-(3) cannot last infinitely long.

Conclusion

Artificial complex neurons with the half-plane surface of activation function are enough simple and powerful computational units. Main our results concerning complex neurons with Resgn activation function are following:

1. The choice of the alphabet of Boolean functions representation has no importance for representative power of class of respective realizable Boolean functions.
2. The restriction of possible weights to ones on an almost every line in complex plane does not shrink the class of respective complex Boolean threshold functions.
3. Neurons with restricted weights can be learned by using perceptron-like learning technique.

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A.E. Kucherenko

USING SEMIDEFINITE OPTIMIZATION TO FIND EFFECTIVE TOPOLOGY OF TRUSS-LIKE ELASTIC STRUCTURES

Abstract. The paper considers a convex formulation of the truss topology optimization problem and solving it via semidefinite programming regarding to the minimalcompliance of the truss, volume and buckling constraints.

Keywords: topology, semidefinite optimization, buckling, stiffness matrix, stress constraints.

Introduction

The effectiveness of rod systems such as trusses, which are widely used in building, largely depends on the correct constructive scheme or, in general, topology. Often it is very difficult to solve this problem, so usually it is necessary to consider several options. It is not the fact that among them there will be an option that provides the usage of the minimal amount of the material. Therefore, in these cases the optimization algorithms that allow to solve such problems in different formulations become actual.

In the field of theory of structures the optimization problems, including the optimization of truss-like systems, have been regarded many times. For example, in [1] the author proposes to use a genetic algorithm to find an optimal topology and minimize the mass of the system. But, as he notes himself, the performance of the algorithm drops dramatically even with a slight increase in the number of structural elements. In the paper [2] an approach to optimize the design of single-span single-storey frames, based on the search for such a topology, which would allow to minimize the potential energy of the frame under a load, is presented. Unfortunately, the author does not provide a complete methodology for finding of such topology. Thus, despite the existence of interesting developments in this field, many of them are purely mathematical problems which find rarely application in the engineering practice.

Problem formulation

In the computational mechanics a topology optimization can be considered as a mathematical programming problem [3]. In [4] this problem has been solved as a problem of minimization of displacements of structure nodes or - according to scalar quantities - minimization of a potential energy of an elastic deformation. Using a slightly modified mathematical formulations from [4], the author of this article has provided an algorithm that takes into account all of the basic requirements (strength, buckling, deformability) which are applicable to truss-like structures, and validated the obtained results in the **ANSYS** simulation software. The algorithm represents a beam system as a graph, where the set of edges E represents the beams and the set of vertices Y represents the connections of the beams. Since the structure of the system has to be detected, initially it appears as a complete graph, and the problem eventually reduces to the finding of a such minimally required set of edges and their sections which provides the minimal total mass of the structure for given external loads and constrains.

Governing equations and optimization variables

Considering the prototype of a construction as a complete graph, which has $n=|Y|$ vertices and $m=|E|$ edges, let's define such variables:

$f \in R_+^m, E \in R_+^m, L \in R_+^m, v \in R_{\geq 0}^m$ - axial forces, Young's modulus, lengths and volumes of beams;

$A \in R^{3n \times m}$ - the matrix of the system, where a_i^T is its column;

$K \in R^{3n \times 3n}$ - the element stiffness matrix of the system;

$F \in R^{3n}$ - external loads, which are applied to the nodes of the construction;

$u \in R^{3n}$ - nodes displacements.

If the system is in equilibrium then the law of conservation of forces in a matrix form can be written as:

$$Af + F = 0. \quad (1)$$

Axial forces, which appear in the beams according to the theory of Euler-Bernoulli, are described as:

$$f_i = \frac{-E_i v_i}{L_i^2} a_i^T u. \quad (2)$$

The nodal displacements are described by the matrix system:

$$K \cdot u = F, \tag{3}$$

where the stiffness matrix can be written as [6]:

$$K = \sum_{i=1}^{m} \frac{E_i v_i}{L_i^2} a_i a_i^T. \tag{4}$$

The work of external loads (and the energy of elastic deformation of the construction) we can represent as:

$$W = \frac{1}{2} F^T u. \tag{5}$$

Thus, to solve the optimization problem it is necessary to minimize two quantities: W and $\sum_{i=1}^{m} v_i$.

Semidefinite optimization problem

The problem of the topology optimization of a truss-like system can be written as follows:

$$\begin{aligned} &\text{minimize}_{u,v} W \\ &\text{s.t.} Ku = F \\ &\sum_{i=1}^{m} v_i \le V \\ &v \in R_{\ge 0}^{m} \end{aligned} \quad . \tag{6}$$

But this formulation of the minimization problem is not convex, so we need to transform it according to the equations (1)-(5). We will choose the form of a semidefinite programming because available software for solving semidefinite programs is efficient and reliable. It can be shown that for a positive semidefinite matrix

$$\begin{pmatrix} \Omega & F^T \\ F & K \end{pmatrix} \ge 0 \tag{7}$$

there is a vector u, which allows to write an equivalent system:

$$\begin{aligned} &Ku = F \\ &K \ge 0 \\ &\Omega \ge W \end{aligned} \quad . \tag{8}$$

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Moreover, the numerical experiments show, that the ratio $v_1 : v_2 : \ldots : v_m$ remains constant regardless of the quantity V, so we can limit the sum $\sum_{i=1}^{m} v_i$ to 1. This fact can significantly speed up the overall solution of the problem. In view of the above we can redefine the problem (6) as follows:

$$\begin{aligned}
&\text{minimize}_{\Omega,v}\Omega \\
&\text{s.t.}\sum_{i=1}^{m} v_i \le 1 \\
&v_i \ge 0 \forall i = 1\ldots m \\
&\begin{pmatrix} \Omega & F^T \\ F & \sum_{i=1}^{m} \frac{E_i v_i}{L_i^2} a_i a_i^T \end{pmatrix} \ge 0
\end{aligned} \qquad (9)$$

In this form the problem becomes convex. The solution of this problem determines the optimal topology design and the relationship between the volumes of the beams. The next step consists in the selection of the minimal total volume of material V (and the cross-sectional areas, respectively), which would be carried out under the conditions of the strength (10) and the overall stability of the system (11):

$$\frac{f_i L_i}{V v_i} \le \gamma R \forall i = 1\ldots m, \qquad (10)$$

where γ is a resistance factor, R is a nominal resistance.

The overall stability of the system is defined as:

$$\det K_\tau > 0, \qquad (11)$$

where K_τ is a tangent stiffness matrix of the system.

The last step is to verify the model, using the **ANSYS** simulation software.

Arch truss topology optimization

Let's consider an arch truss with a complete graph which has been depicted in the figure 1. Node 1 is a freely supported end, node 7 is a roller bearing. A force $|F|$=-10^5N has been applied to the node 4. Coordinates of vertices (in meters) have been shown in Table 1.

Young's modulus is $2 \cdot 10^{11}$ Pa, shear modulus is $7.81 \cdot 10^{10}$ Pa, nominal resistance is $2.1 \cdot 10^{8}$ Pa, resistance factor is 0.9. The tube section with inner and outer diameters ratio d/D=0.95 has been used. The modelling has been carried out in the MATLAB environment with package CVX [8].

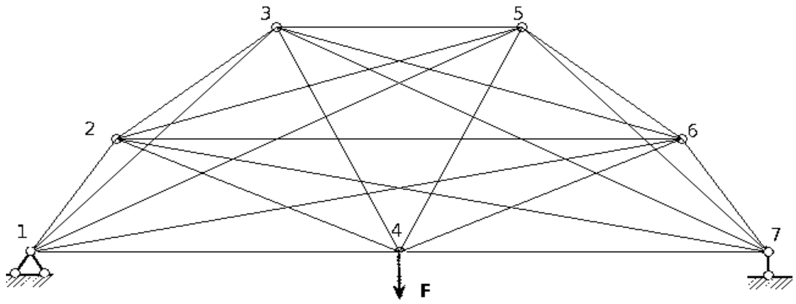

Figure 1 - A complete prototype graph of the truss

Table 1

Coordinates of vertices

	1	2	3	4	5	6	7
X axis	0	0.7	2	3	4	5.3	6
Y axis	0	1	2	0	2	1	0

In the figure 2 the optimized truss topology is depicted. In the table 2 the outer diameters of the tubes are presented. The verification of the model in the **ANSYS** simulation software has shown that the truss would loose its stability under the load of $|F| > 97774$ N (the calculations have been done according to the load of 100000 N). Thus, the solution of the semidefinite optimization problem in MATLAB is consistent with the results of the model validation in ANSYS.

Table 2

The diameters of the tubes

Beam	1-2	1-4	2-3	2-4	3-4	3-5	4-5	4-6	4-7	5-6	6-7
D, м	0.078	0.059	0.083	0.046	0.068	0.087	0.068	0.046	0.059	0.083	0.078

Conclusions

A problem of finding of an optimal topology of truss-like elastic structures using semidefinite programming has been presented. In contrast to the approaches [1, 2, 4, 6, 7] this solution of the problem takes into account such criteria as the strength and buckling. Verification of the model has been performed in ANSYS.

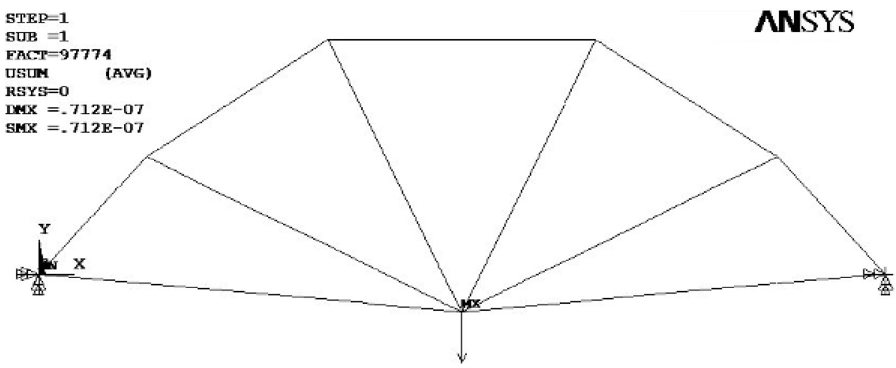

Figure 2 - Buckling of the truss

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MODELS, METHODS AND INFORMATION TECHNOLOGIES OF PROTECTION OF INFORMATION SYSTEMS OF TRANSPORT BASED ON INTELLECTUAL IDENTIFICATION OF THREATS

In article results of researches on development of methods and models of intellectual recognition of threats to information systems of transport. The article to contain results of the researches, allowing to raise level of protection of the automated and intellectual information systems of the transportation enterprises (AISTE) in the conditions of an intensification of transportations. The article to contain mathematical models and results of an estimation information systems having Internet connection through various communication channels. The article also considers the issues of research and protection of the AISTE under the condition of several conflict data request threads.

Keywords: information security, information security, intelligent recognition of threats, logic functions, fuzzy sets, heterogeneous data streams, the transport industry.

Introduction

The influence of information automation systems pervades many aspects of everyday life in most parts of the world. In the shape of factory and process control systems, they enable high productivity in industrial production, transport systems they provide the backbone of technical civilization. One of the foremost transport businesses security concerns is the protection of critical information, both within their internal financial infrastructures and from external elements. Now more and more open and standardized Internet technologies (e-business, e-logistics, e-cargo etc.) are used for that purpose.

The focus on cyber security is increasing rapidly due to many high profile and highly disruptive/damaging security breaches threatening financial and physical damage across critical national and corporate infrastructures. It also appears the nature of the threat is changing[1].

The automated systems on transport vary in technologies applied, from basic management systems such as car navigation; traffic signal control systems; container management systems; variable message signs; automatic number plate recognition or speed cameras to monitor applications, such as security CCTV systems; and to more advanced applications that integrate live data and feedback from a number of other sources, such as parking guidance and information systems; weather information; and the like.

A Transportation Management System (TMS) is a software system designed to manage transportation operations. TMS are one of the systems managing the supply chain. They belong to a sub-group called Supply chain execution (SCE). TMS, whether it is part of an Enterprise Level ERP System and has become a critical part of any (SCE).

The block diagram of a typical control system for transport, figure 1.

Rapidly changing external and internal business environment, necessity to adapt oneself very quickly and take adequate management decisions in time make the effective use of corporate information to be a pre-requisite for business success.

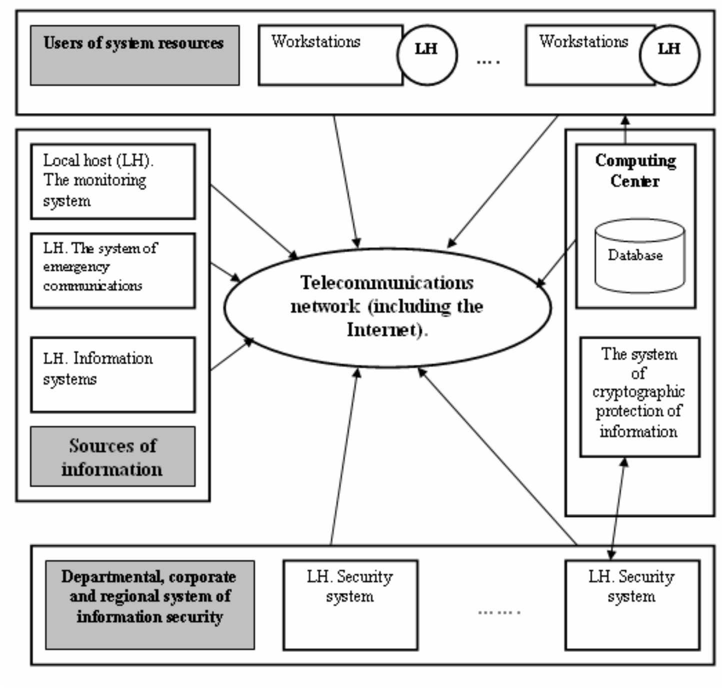

Fig. 1. The block diagram of control system for transport

Various functions of automated information management systems for transportation: Management of road, railway, air and maritime transport; Planning and optimizing of terrestrial transport rounds;

[1] AhmadD., DubrovskiyA., FlinnX., *Defense from the hackers of corporate networks,* Moscow 2005, p. 170.

Transportation mode and carrier selection;Real time vehicles tracking; Service quality control; Vehicle Load and Route optimization; Transport costs and scheme simulation; Shipment batching of orders; Cost control, KPI (Key performance indicators) reporting and statistics.

Since economic activities in Ukraine and CIS countries have boosted in the recent years and, therefore, nomenclature and volume of traffic has considerably grown, load on all types of transport (railway, motor, air, sea and pipeline transport) has been increasing. Along with increasing capacities of the existing and construction of new transportation capacities, there are great reserves in enhancing efficiency of the existing capacities (reduction of idle time due to more accurate planning, etc.) and organization of automated information exchange among consignors, carriers and other participants in the transportation process. Various forms of wireless communications technologies have been proposed for intelligent transportation systems in Europe, USA and Asia. Short-range communications (less than 500 yards) can be accomplished using IEEE 802.11 protocols. Theoretically, the range of these protocols can be extended using Mobile ad-hoc networks. Longer-range communications have been proposed using infrastructure networks such as IEEE 802.16, GSM, or 3G. Long-range communications using these methods are well established, but, unlike the short-range protocols, these methods require extensive and very expensive infrastructure deployment. There is lack of consensus as to what business model should support this infrastructure.

Today there is a wide range of software products of the leading vendors at the market (Interbase, Oracle, IBM, SAP, Sun Microsystems, Informatica), aimed at ensuring the maximum quality of resolving these tasks. Service-oriented architecture (SOA) and technologies of web-services based on open standards are very popular.

The modern approach to ensure the reliability of information processes (IP) and its protection from unauthorized access (UA) is supported at the international level by standard ISO/IEC 15408. According to this approach, a reliable IP successfully counteracts to the specified threats of security at the given external conditions of its operation. This leads to continuous improvement as ways and means of information protection (MIP) as well as ways and means of implementation of threats to information security (IS), resulting that appearance of new MIP leads to its bypassing by means of attack[2,3].

Information security management has become a critical and challenging business function because of reasons such as rising cost of security breaches, increasing scale, scope and sophistication of information security attacks, complexity of information technology (IT) environments, shortage of qualified security professionals, diverse security solutions from vendors, and compliance and regulatory obligations.

As part of the state and interstate programs of information to create information systems, information-management and automated information systems transport industry (ISTI), as well as state integrated information system (SIIS).

Active expansion of information and communication environment in transport, accompanied by the emergence of new threats to information security (IS), as evidenced by the statistics of incidents (see Figure 2)[4].

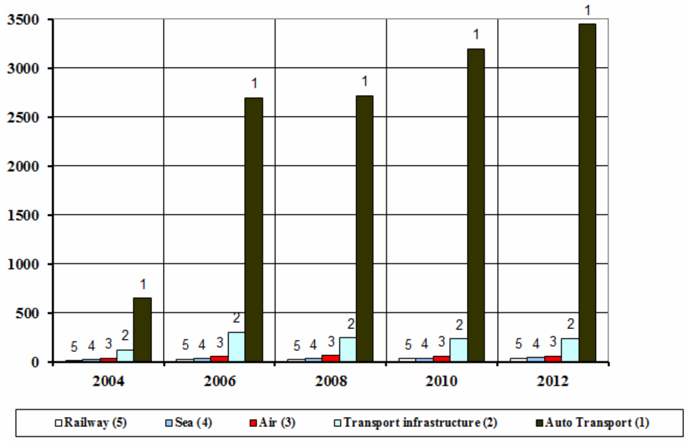

Fig. 2.The number of incidents of information security in transport

This, in its turn leads to the need for a new interpretation of the term "reliability of IP" that should be understand as lack of security vulnerabilities, which can be a consequence of the implementation of the various unintentional and intentional threats.

This eliminates a number of inconsistencies in the definition of conflict MIP and attack.

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[2] AvizienisA., LaprieJ.-C., RandellB., LandwehrC., *Basic concepts and taxonomy of dependable and secure computing, IEEE Trans.Dependable and Secure Computing*, USA 2004.
[3] TrivediK., KimD., RoyA., *Dependability and Security Models*, USA 2001, p. 290.
[4]*Transportation & Logistics 2030. Securing the supply,* Germany 2014. pp. 254-286.

In so doing, the reliability of IP should be characterized by its conformity to some reference security model (invincible) circulation (processing and transmission) of information. In this regard, there is a practical problem that such things are only partially implemented in practice and is not directly reflected in the relevant standards for architectural solutions of automated systems, such as transport[5] satisfying the common reference models.

Studies on the further development of models and methods of information security based on the intelligent recognition of threats and information security in transport is one of the main problems of information protection of critical infrastructures state.

The reason lies in the fundamental theoretical difficulties of modeling technologies ensuring the reliability and protection of IP in automated data processing systems of critical applications (ADPS CA) occurring when you try to connect a promising approach to ensure the safety and protection of IP from UA with the flexibility of the protective mechanisms.

The purpose of the article - description of the method and models of recognition of information security threats, which, unlike the existing permit to take a final decision on the existence of a threat to existing and new classes of attacks against information systems.

1. Previous researches

The results of researches, allowing raising the level of protection of the automated and intellectual information systems of motor transport (AIS) enterprises under conditions of transportations intensification are presented in the work.

The Top 10 information security threats for 2014:

1. Malware (Rising Threat).
2. Malicious Insiders (Rising Threat).
3. Exploited Vulnerabilities (Steady Threat).
4. Careless Employees (Steady Threat).
5. Mobile Devices (Rising Threat).
6. Social Networking (Rising Threat).
7. Social Engineering (Steady Threat).
8. Zero-Day Exploits (Rising Threat).

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[5] LahnoV., PetrovA.*Ensuring security of automated information systems, transportation companies with the intensification of traffic*, Ukraine 2011, p. 170.

9. Cloud Computing Security Threats (Rising Threat).

10. Cyberespionage (Rising Threat).

The 2014 CVE survey found 90% of respondents detected computer security breaches within the last year and 73% reported financial losses due to these computer breaches. Questions about the adequacy of the Ukrainian science, engineering, and technology workforce are also rising to a chorus. Reported shortages of skilled workers in the IT sector are only one example.

To evaluate security of such a system, a security analyst needs to take into account the effects of interactions of local vulnerabilities and find global vulnerabilities introduced by interactions. This requires an appropriate modeling of the system. Important information such as the connectivity of elements in the system and security related attributes of each element need to be modeled so that analysis can be performed. Analysis of security vulnerabilities, the most likely attack path, probability of attack at various elements in the system, an overall security metric etc. is useful in improving the overall security and robustness of the system. Various aspects, which need to be considered while deciding on an appropriate model for representation and analysis, are: ease of modeling, scalability of computation, and utility of the performed analysis. The analysis of the protection of information systems and automated control systems for transport companies has yielded the following results (period 2012 -2014), fig. 3, 4[6].

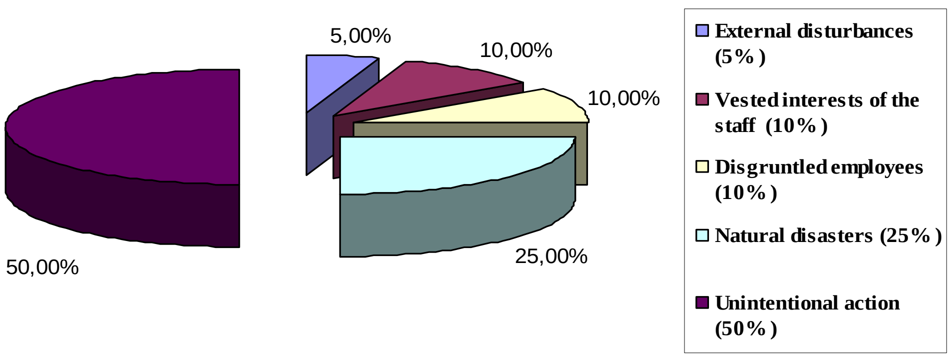

Fig. 3. The distribution of sources breach AIS

The decision of questions of complex maintenance of security and stability of functioning of the AIS in the conditions of unauthorized access (UNA), including, influences of computer attacks, demands the

[6]*Worldwide Security and Vulnerability Management 2004-2014*, Manchester 2014, p. 178.

system analysis and synthesis of possible variants of construction of means of counteraction UNA means. At complex formation it is necessary to co-ordinate and inter connect functions and parameters of the EXPERT, protection frames of the information from UNA, anti-virus means, gateway screens, the communication equipment, the general and special software and perspective means of counteraction to computer attacks.

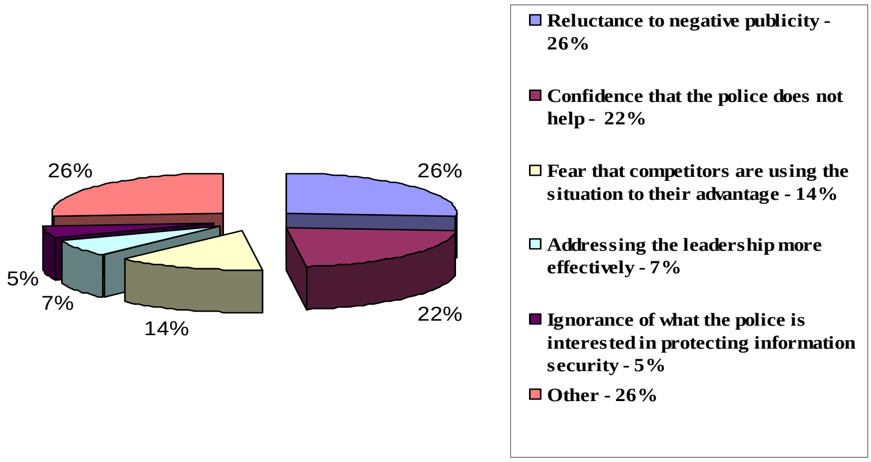

Fig. 4. The reasons for silence with information security incidents

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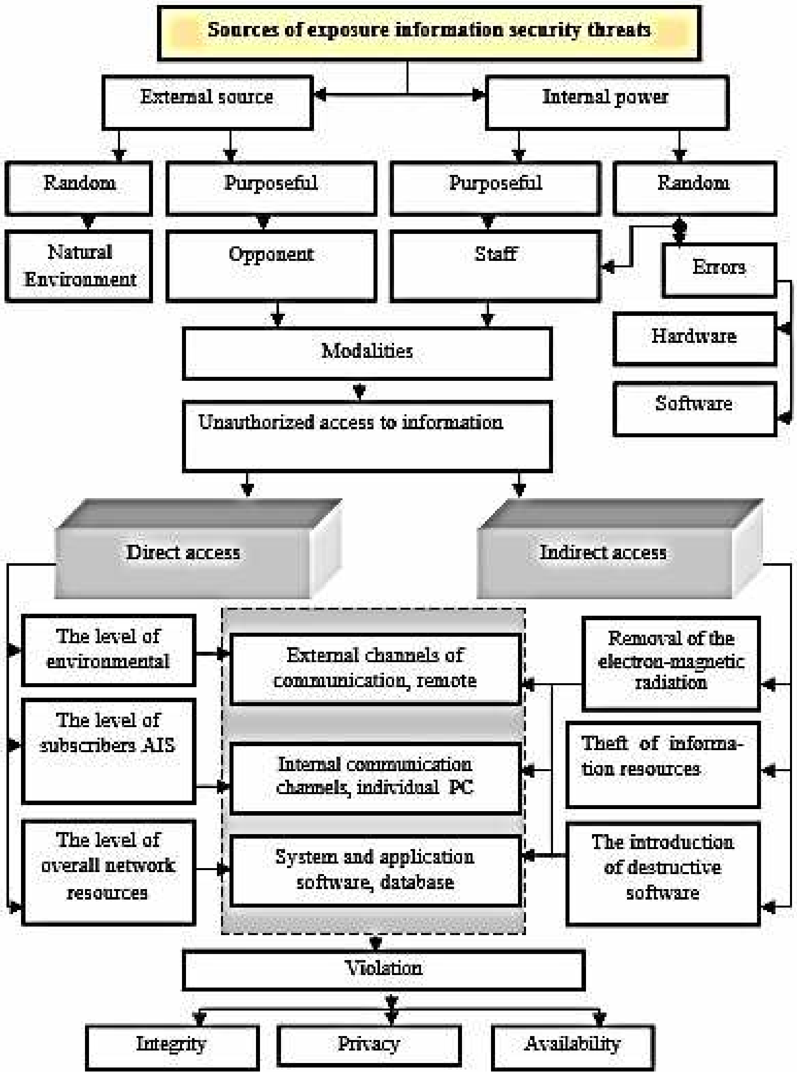

Fig. 5. Sources of exposure information security threats

As a result of systematic analysis of relevant information security threats, figure 5. The classification has been done with certain basic features and gives an idea about the various options of a destructive impact on information resources.

Security professionals are aware that cyber criminals have increasingly sophisticated weapons at their disposal for maneuvering through online commerce systems and stealing information. Traditional firewalls, IPS/IDS, and web application firewalls do little to help online businesses understand the behavior of website visitors. Instead, they narrowly focus on the network and server exploits only. The challenge of detecting anomalous activity in real-time requires gathering various "big data" sources and correlating them to understand user behavior. However, current methods of detection fall short of this goal –

individually, they examine only pieces of the behavior puzzle, not the entire picture[7,8].

To determine the likelihood of a future adverse event, threats to AIS must be analyzed in conjunction with the potential vulnerabilities and the controls in place for the AIS. Impact refers to the magnitude of harm that could be caused by a threat's exercise of a vulnerability. The level of impact is governed by the potential cyberattacks impacts and in turn produces a relative value for the assets and resources affected (e.g., the criticality and sensitivity of the information system components and data).

Threat assessment system consists of the following steps:

1. System Characterization (AIS);
2. Threat Identification;
3. Identification vulnerability;
4. Control Analysis;
5. Likelihood Determination;
6. Impact Analysis;
7. Risk Determination;
8. Control Recommendations;
9. Results Documentation.

A threat is the potential for a particular threat-source to successfully exercise a specific vulnerability. A vulnerability is a weakness that can be accidentally triggered or intentionally exploited. A threat-source does not present a risk when there is no vulnerability that can be exercised. In determining the likelihood of a threat, one must consider threat-sources, potential vulnerabilities AIS, and existing controls.

The goal of second step is to identify the potential threat-sources and compile a threat statement listing potential threat-sources that are applicable to the information system being evaluated. A threat-source is defined as any circumstance or event with the potential to cause harm to an information system. The common threat sources can be natural, human, or environmental.

In assessing threat-sources, it is important to consider all potential threat-sources that could cause harm to an automated information

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[7] HarelD., *Visual Formalism for Complex Systems*, USA 1987, pp. 231-274.

[8] LauF., RubinS., SmithM., TrajkovicL., *Distributed denial of service attack*s, USA 2000, p. 304.

system and its processing environment. Result - a threat statement containing a list of threat-sources that could exploit system vulnerabilities.

The analysis of the threat to an automated information system must include an analysis of the vulnerabilities associated with the system environment. The goal of this step is to develop a list of system vulnerabilities (flaws or weaknesses) that could be exploited by the potential threat-sources. Vulnerability: A flaw or weakness in system security procedures, design, implementation, or internal controls that could be exercised (accidentally triggered or intentionally exploited) and result in a security breach or a violation of the system's security policy.

2. Models, methods and information technologies of protection of corporate systems of transport based on intellectual identification of threats

The main task of discrete recognition and vulnerability search procedures (DRVSP) building is search of informative sub descriptions (or description fragments) of objects[9].

We consider informative objects to be the objects that reflect certain regularities in description of objects used for training, that is presence or, vice versa, absence of these fragments in the object, which is being considered, allows attributing it to one of classes. The fragments that are met in descriptions of one-class objects and cannot be met in descriptions of other classes' objects are considered to informative in DRVSP. The regarded fragments as a rule have a substantial description in terms of designing information safety systems (ISS).

An elementary classifier is understood as a fragment in a description of a training sample. A certain multitude of elementary classifiers with preset properties are built for each $\{KL_1,...,KL_l\}$class. Another problem is presence of objects, which are on borderline between classes $\{KL_1,...,KL_l\}$ and $\{B_{p_{a1}},...,B_{p_{al}}\}$among the study samples of objects. Each of such objects is not "typical" for its class, as it resembles to descriptions of objects belonging to other classes. Presence of untypical objects extends the length of fragments used to distinguish objects

[9] LahnoV., PetrovA., *Modelling of discrete recognition and information vulnerability search procedures*, TEKA, Poland 2010, pp. 137-144.

belonging to different classes. Long fragments are less frequent in new object, thus extending the number of unrecognized objects.

The necessity of building effective realizations for discrete recognition and vulnerability search procedures is directly connected to problems of metric (quantitative) characters of informative fragments' multitudes. The most important and technically complex are the problems of obtaining asymptotical estimates for typical number values of (impasse) coveringand the length of integer matrix (impasse) covering and also the problems of obtaining analogical estimates for permissible and maximum conjunctions of a logical function, which are used for synthesis of circuit hardware-based ISS solutions.

There is, as a rule, no reliable information about the structure of *PA* multitude available while solving tasks connected with projecting an effective AIS information safety system, that's why having built a discrete recognition and vulnerability search procedures algorithm we cannot guarantee its high performance on new objects different from $\{sp_{a1},\ldots,sp_{am}\}$. Nevertheless, if the training samples are quite typical for the considered multitude of objects, than the algorithm that makes infrequent mistakes in studies will show acceptable results with unknown (not included in training samples) objects also. In this connection, correctness of discerning algorithm is the problem that should be paid great attention. The algorithm is considered to be correct if it discerns all the training samples correctly.

The main objective is to search DRVSP building fragments describing objects, see. Table 1.

The simplest example of a correct algorithm is the following: the considered object $sp_{an}$is compared to descriptions of every training sample$\{sp_{a1},\ldots,sp_{am}\}$. In case if the sp_{an}object's description coincides with a description of a sp_{an}training sample, the sp_{an}object is attributed to the same class as the sp_{ai} object. In other case, the algorithm declines to recognize the object. There is no difficulty noticing that though the foregoing algorithm is correct, it is not able to discern any object which description does not coincide with description of any training sample[10].

[10] LahnoV., PetrovA., *Experimental studies of productivity change in corporate information systems for companies in terms of computer attacks. Informationsecurity*, Ukraine 2011, pp. 181-189.

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Let us introduce the following symbols. Let NP_{p_a} stand for a set of r_{p_a} , $r_{p_a} \le MI$ different integer-valued characters of $\{p_{aj_1},\ldots, p_{aj_r}\}$ kind.

Thus, the schematic circuit of estimation algorithm building for information safety systems is the following. The whole range of different $NP_{p_a} = \{p_{aj_1},\ldots, p_{a_{MI}}\}$, $r_{p_a} \le MI$ type sub multitudes is picked out inside the $\{p_{a_1},\ldots,p_{a_{jMI}}\}$ character system. Later the picked sub multitudes are named reference multitudes of the algorithm, and their whole range is designated by ΩMI .

Further, let us set the following parameters:

- po_{sp_a} is a parameter characterizing significance of a sp_{ai}, *i= 1, 2,..., PA* target (object);
- $po_{NP_{pa}}$ is a parameter characterizing significance of an object belonging to a reference multitude $NP_{p_a} \in \Omega MI$.

Table 1

The knowledge base for the intelligent recognition of threats to information systems

Attributes (Signs Class threats)	Signs Class threats	The importance of sign	The univer-sum	Terms for the linguistic evaluation $\phi_u,\ldots,\phi_v$
The set of classes of information security threats $KL = \{KL_1,\ldots,KL_n\}$, The set targets for attack $PA = \{PA_1,\ldots,PA_z\}$, The set of information security $N_j^{p_a} = \{n_1^{p_{a1}},\ldots,n_j^{p_{au}}\}$, The mathematical sets of possible attackers $U = \{u_1,\ldots,u_g\}$, The sets of incidents $NIS = \{nis_1,\ldots,nis_f\}$,	$p_{ax} = \{p_{ax1},\ldots, p_{ax_{MI}}\}$.	based on NIS $-1 \le IZ_{p_{axj}} \le 1$	$[0, N_a]$ or $[0,1]$, c. u.	Critical and uncritical *or* Identified, partially identified threats, undiag-nosed

The sets of variants attack on the system $AT = \{AT_1,\dots, AT_q\}$ and others.				
The state systems **(AIS)** $S_{IK} = \{S_{IK_1},\dots, S_{IK_m}\}$				
Methods and means of protection of information systems $D_{ззi} = \{D_{ззi_1},\dots, D_{ззi_r}\}$				
The rules for result output *IF(* $KL_1 \vee \dots \vee KL_n \vee S_{IK_J} \vee \dots \vee S_{IK_m}$ *)* *THEN* $D_{ззi_r}$ and $\mu^{d_j}(S_{IK_i}) = \bigvee_{p=1}^{h_j}\left[\mu^{y_1}(y_1) \wedge \dots \wedge \mu^{\phi_v}(\phi_v)\right]$, $p = \overline{1, h_j}$, $j = \overline{1, MI}$, де $\mu^{y_1}(y_1),\dots, \mu^{\phi}(\phi_u), \mu^{\phi}(\phi_v)$ – membership function y_1, $\phi_u,\dots,\phi_v$ of the fuzzy variables to terms; y_1 – the state of information security {below critical, critical, above the critical, high}; $\vee$ – logical **OR**, $\wedge$ - Logical **AND** as operations max and min, respectively.				

Further comes the estimation procedure. The considered object sp_{an} is compared to every training sample sp_{ai} of every reference multitude.

$A\Gamma(sp_a, KL)$ estimation of sp_a object belonging to *KL* class is calculated for each vulnerability class of AIS KL, $KL \in \{KL_1,\dots,KL_l\}$ in the following way:

$$\Gamma(sp_a, KL) = \frac{1}{|LW_{KL}|}\sum_{sp_{ai}\in KL}\sum_{NP_{p_a}\in\Omega MI} po_{sp_a}\cdot po_{NP_{pa}}\cdot BN(sp_a, sp_{ai}, NP_{p_a}), (1)$$

Where $|LW_{KL}| = |KL \cap \{sp_{a1},\dots,sp_{aMI.}\}|$.

The sp_{an} object is attributed to the class that has the highest estimate. In case if there are several classes with the highest estimate, discerning fails. Obviously, the ready-built algorithm is not always correct. Correctness of this algorithm requires compliance with a linear inequalities system of the following type:

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$$\begin{aligned}
&\Gamma(sp_{a1}, KL_1) > \Gamma(sp_{a1}, KL_2),\ \Gamma(sp_{aMI_1}, KL_1) > \\
&> \Gamma(sp_{aMI_1}, KL_2),\ \Gamma(sp_{aMI_{1+1}}, KL_2) > \Gamma(sp_{aMI_{1+1}}, KL_1). \\
&\cdot \quad \cdot \quad \cdot \\
&\Gamma(sp_{aMI}, KL_2) > \Gamma(sp_{aMI}, KL_1).
\end{aligned} \tag{2}$$

The solution of the system comes up to choice of $po_{sp_{ai}}$ i = 1, 2,...,*PA*,and $po_{NP_{pa}}$, $NP_{p_a} \in \Omega MI$ parameters. In case if the system is not combined, its maximum combined subsystem should be found and the solution of this subsystem defines the parameter points for $po_{sp_{ai}}$ and $po_{NP_{pa}}$.

Let's regard the situation, when the objects of the considered PA multitude are described by the characters, each possessing values of the $\{0, 1, \ldots, k_{p_a} - 1\}$ multitude.

Let's associate the (σ_{DOP}, NP_{pa}) elementary classifier, where $\sigma_{DOP} = (\sigma_{DOP_1}, \ldots, \sigma_{DOP_r})$, NP_{pa} is a set of characters numbered $j_1, \ldots j_{r_{pa}}$, with an elementary conjunction $\Re = p_{axj_1}^{\sigma_{DOP1}} \ldots p_{axj_{r_{pa}}}^{\sigma_{DOP r_{pa}}}$.

If $sp_a = (\alpha p_{a1}, \ldots, \alpha p_{aMI})$ is an object of the *PA* multitude, then obviously $BN(\sigma_{DOP}, sp_a, NP_{pa}) = 1$ only in case when $(\alpha p_{a1}, \ldots, \alpha p_{aMI}) \in NI_{\Re}$, where $NI_{\Re}$ is a truth interval for the elementary conjunction $\Re$.

Let's show that building a multitude of $(KL_l) = (B_{p_{al}})$ class elementary classifiers for the models previously considered in the article adds up to finding permissible and maximum conjunctions of the characteristic $(KL_l) = (B_{p_{al}})$ class function, which is a double-valued logical function possessing different values for training samples of $KL_l \& \overline{KL_l}$.

The procedure of threat recognition for a certain target, that is the $sp_a = (\alpha p_{a1}, \ldots, \alpha p_{aMI})$ object, is carried out based on the calculation built with the help of elementary conjunctions. Using the algorithm of conjunction calculation by class coverings seems to be the most economical in this case. A characteristic function of KL_1 class of information threats is a certain logical function $F_{\overline{KL}}$, possessing value 0 for descriptions of $sp_{an} = (\alpha p_{an1}, \ldots, \alpha p_{anMI})$ belonging to KL_l and possessing value 1 for other character sets belonging to E_{KL}^{MI}. Here E_{KL}^{MI} is a multitude of all r_{p_a} long sets. A permissible conjunction for $F_{\overline{KL}}$ is associated with the KL_1 class covering, and the maximum conjunction for $F_{\overline{KL}}$ is associated with its terminal covering. A permissible (maximum) conjunction $\Re$ is used to determine if the $sp_{an} = (\alpha p_{an1},\ldots,\alpha p_{anMI})$ object belongs to $(KL_1) = (B_{p_{a1}})$ class, in case if $(\alpha p_{a1},\ldots,\alpha p_{aMI}) \notin NI_{\Re}$.

Thus, building a multitude of elementary classifiers for the simulated class of information treats adds up to the following[11]:

1) specifying a characteristic function;

2) building a disjunctive normal form, which realizes this function. The biggest difficulty is building disjunctive normal forms from maximum conjunctions (shortened disjunctive normal forms) of a characteristic function;

3) calculating a permissible (maximum) conjunction $\Re$, which determines of the object belongs to a certain class of threats.

For each class, the number of threats to information security signs ranged from 3 to 9. Informational content of a sign can change in the range from -1 to +1. To evaluate the effectiveness of recognition procedures used cross-validation method. Examples of the results of performance testing method DRVSP shown in Fig. 6-9.

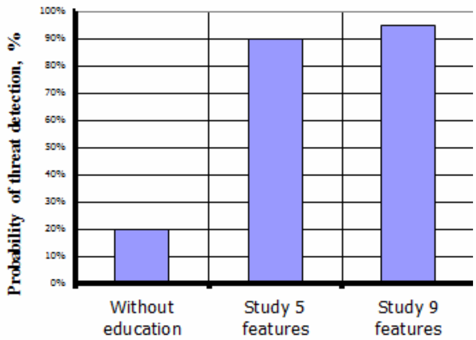

Fig. 6. The probability of recognizing the threat of “Unauthorized access to the video server”

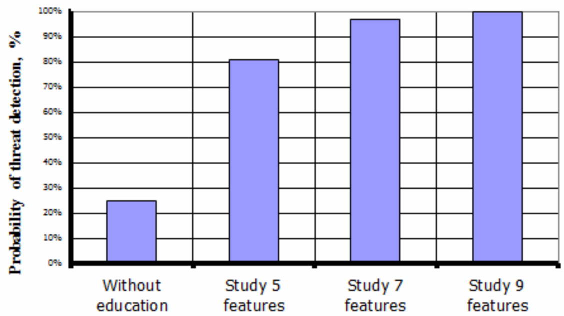

Fig. 7. The probability of recognizing the threat of “Unauthorized access to the user's password”

[11] LahnoV., PetrovA.,*Marketing and logistics problems in the management of organization. Task The Research of the conflict Request Threads in the Data Protection Systems*,Bielsko-Biala 2011, pp. 230-251.

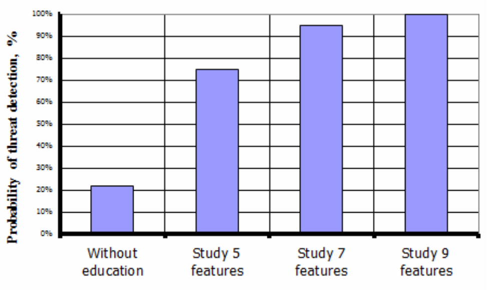

Fig. 8. The probability of recognizing the threat of "Unauthorized access to software and databases"

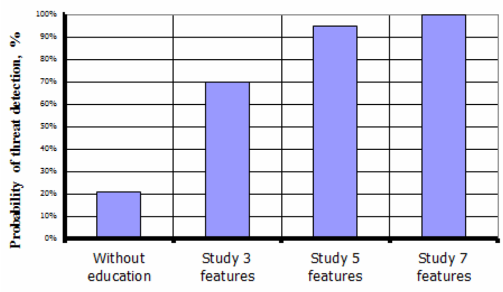

Fig. 9. The probability of recognizing the threat of "Unauthorized access to the navigation system"

In the following part of article the question of application of models of intellectual recognition of threats, for the task of the description of operation modes of information systems with blocking of the non-uniform flows of requests is considered. These non-uniform flows of requests meet in case of difficult invasions into information systems, for example, in modules of systems the client-bank, e-business, e-logistics, e-cargo, e-ticket, GSM-R, VSAT systems, etc.

During tests of the developed expert system (Fig. 10), the task of detection of DoS/DDoS of attacks is selected.

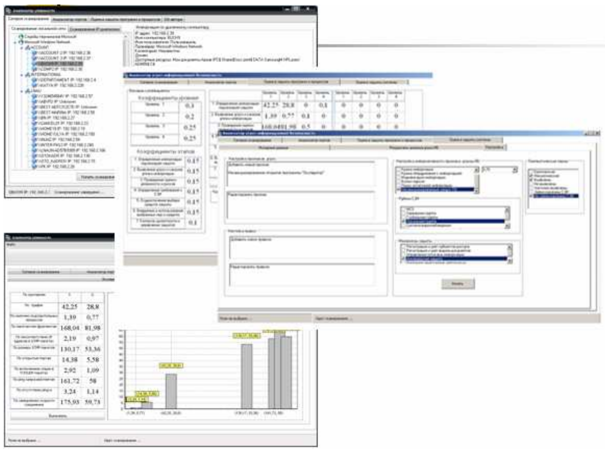

Fig. 10. General view of the "Analyzer threats"

The knowledge base from nine rules was used. The knowledge base is capable to define seven types of attacks of DoS/DdoS. In addition, known signs of attacks and additional signs for the description of a status of system (tab. 1) were used. Example list of factors that affect the productivity of information systems under the threat of DDoS attacks, presented in the form of linguistic variables, for which the selected set and universal terms. According constructed fuzzy knowledge base, representing a set of fuzzy rules "IF-THEN" that define the relationship between input and output variables. For fuzzy knowledge bases composed logical equation[12].

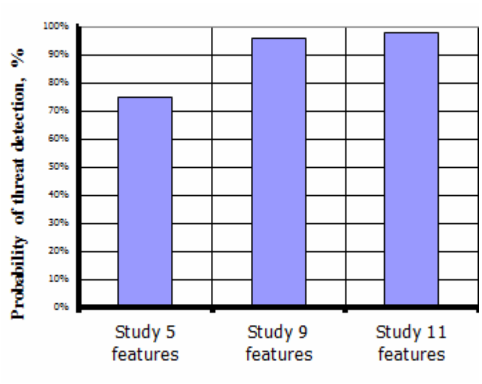

Fig. 11. Probability of detecting DDoS attacks

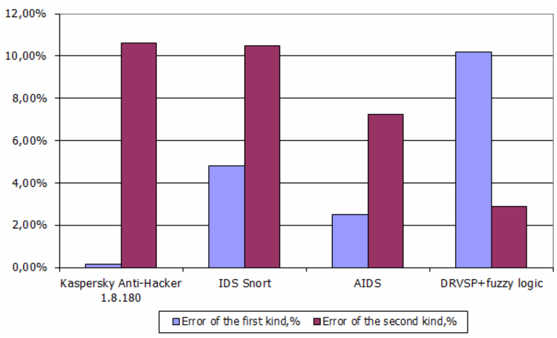

Fig. 12. The value of error detection of DDoS attacks of the first kind and the second kind

According to the results of the experiment, the DRVSP DoS/DDoS - attacks, following results were obtained for the errors of the first kind (false positives) - 10.2% for the error of the second kind (the number of detected attacks) - 2.9%, Fig. 12.

The discrete recognition search procedures allow creating "intelligent" system in which the detectors can effectively detect not only known but also unknown cyber-attacks. The structure, functioning and learning algorithms of discrete recognition search procedures detectors are presented. The results of studies that prove the effectiveness of the proposed approach are also presented.

3. Results

In the aftermath of the DDoS attacks, security experts identified network intrusion detection as one of several technologies that can lead to improved network security. While intrusion detection processes alone cannot prevent or defend against security attacks, they can serve as a valuable source of information for security administrators about the types of activity attackers may be using against them. Network intrusion detection (NID) is the process of identifying network activity that can lead to the compromise of a security policy.

With the fuzzy input sets defined, the security administrator can then construct the rules of the fuzzy system. Fuzzy rules are written

[12] LahnoV., PetrovA.,*Management and production engineering. Modeling information security system of transport enterprises,* Bielsko-Biala 2012, pp. 221-248.

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using common sense experiences by the security administrator. The rules designer seeks to define rules that cover as much of the input space as possible Using tools such as the Matlab Fuzzy Toolbox, the designer can check the input rule space to ensure that the fuzzy rules cover the input space and that all output responses are defined, figure 13.

4. Conclusions of the work

Operation is devoted to research and development of theoretical methods, models and software products for support of information security on transport.

Main results of researches:

1) The method of intellectual recognition of threats based on the logic functions and indistinct sets has been developed. The method allows increasing the efficiency of recognition of threats for information security to 85-98% (depending on a threat class). In addition, it is possible, to use a method for creation of new systems of information security on transport.

2) The offered models have been realized in the form of expert system, which can increase efficiency of recognition of computer invasions DDoS to 97-98%.

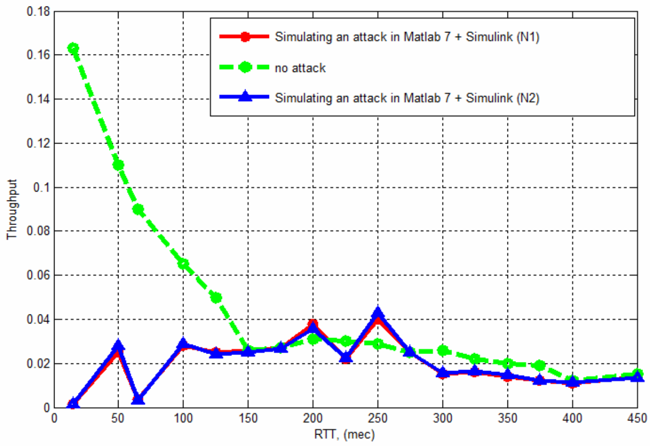

Fig. 13.Dos Inter-burst Period

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APPLYING OF DISCRETE KALMAN FILTER TO PROBLEM OF MEASURING OF LIQUID PROPELLANT LEVEL UNDER CONDITIONS OF SWING

The article is devoted to designing of a discrete Kalman filter for solving problem of measurement of propellant level in launch vehicle tanks during load operation under conditions of launch platform swing as well as to some results of study of effectiveness of designed filter.

Keywords: launch vehicle, level gauge, Kalman filter

Dosing operation for tanks of sea based launch vehicles (LV) such as LV of space launch systems “Sea Launch” goes on under conditions that are significantly different to conditions in which ground based rockets are loaded. A feature of sea based system is that a launch pad where rocket is installed is non static. Launch pad being part of launch platform (LP) moves together with LP swinging under influence of sea waves. Rocket makes oscillating motions deviating from vertical with angles about one degree. An error that could significantly decrease loading accuracy and respectively reduce launch vehicle performance [1] occurs during liquid propellant level measurement process provided by dosing system (Level Monitoring System – LMS) sensors that are usually located at some distance from a longitudinal tank axis. Using of hydraulic dampers to decrease influence of rocket swing (that from point of view of level measuring is seen as a respective periodic deviation of liquid surface from a nominal position that is a perpendicular to longitudinal tank axis plain) on dozing accuracy is ineffective because frequency of that oscillations is ten times lower than frequency of free liquid oscillations inside tank to suppress which hydraulic dampers are dedicated. There is another way to achieve appropriate measurement accuracy and this one is an applying of algorithmic methods for filtering sensor signal. One of the most effective methods of filtering is a discrete Kalman filter.

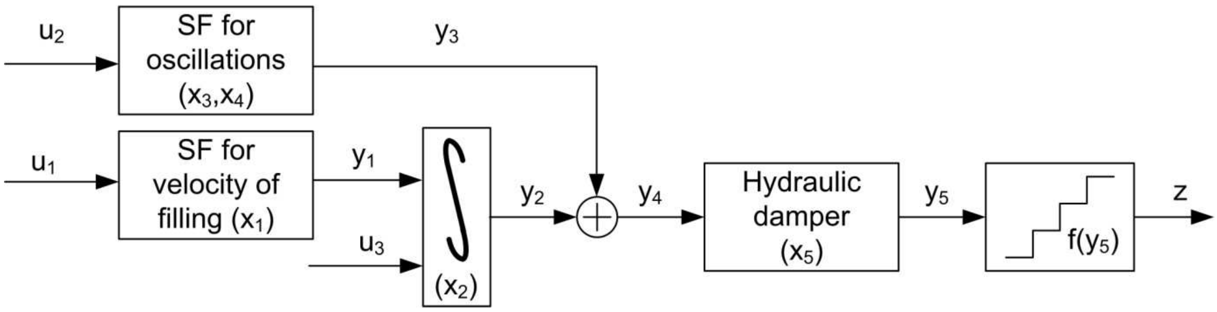
This article is devoted to designing of a discrete Kalman filter for solving the problem of measurement of propellant level in LV tanks during load operation under conditions of LP swing as well as to some results of study of effectiveness of designed filter.

A paper [2] presented a model for simulation of liquid propellant level measuring process going on under conditions of swing and this model could become a base of discrete Kalman filter for digital treatment of signal from continuous (along tank height) level sensor. In space state representation the model is described by two matrix equations. First one describes a system movement in space states, another one represents an output:

$$\mathbf{x}_k = \mathbf{A}\mathbf{x}_{k-1} + \mathbf{B}\mathbf{u}_{k-1} \quad (1)$$

$$\mathbf{z}_k = \mathbf{C}\mathbf{x}_k + \mathbf{D}\mathbf{u}_k \quad (2)$$

Space states vector is $\mathbf{x}_k = [x_{1k} \quad x_{2k} \quad x_{3k} \quad x_{4k} \quad x_{5k}]^T$. Input vector is $\mathbf{u}_k = [u_{1k} \quad u_{2k} \quad u_{3k} \quad u_{4k} \quad u_{5k}]^T$. Output variable that is result of measuring is a scalar z_k. A model structure that includes shaping filters (SF) for simulation of liquid level oscillations and velocity of tank filling with required statistic characteristics is presented in picture 1.



Picture 1 Model structure

Hereinafter: y_1 – linear velocity of tank filling, y_2 – level of propellant in the tank, y_3 – liquid surface oscillations, y_4 – propellant level at the LMS sensor location point, y_5 – propellant level inside hydraulic damper shell, z – value of propellant level measured by LMS sensor. All values y_i, z are measured along longitudinal tank axis from one common point of reference.

Matrix in equations (1) and (2) are like this:

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$$\mathbf{A} = \begin{bmatrix} \dfrac{T_a - \dfrac{\Delta t}{2}}{T_a + \dfrac{\Delta t}{2}} & 0 & 0 & 0 & 0 \\ \dfrac{T_a \Delta t}{(T_a + \dfrac{\Delta t}{2})^2} & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & -a_2 & -a_1 & 0 \\ \dfrac{T_a \Delta t^2}{2(T_a + \dfrac{\Delta t}{2})^2} & \Delta t & b_2 & b_1 & \dfrac{T_y - \dfrac{\Delta t}{2}}{T_y + \dfrac{\Delta t}{2}} \end{bmatrix} \quad \mathbf{B} = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 \\ \dfrac{\Delta t}{2(T_a + \dfrac{\Delta t}{2})} & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \\ \dfrac{\Delta t^2}{4(T_a + \dfrac{\Delta t}{2})} & 0 & \dfrac{\Delta t}{2} & 0 & 0 \end{bmatrix}$$

$$\mathbf{C} = \begin{bmatrix} \dfrac{T_a \Delta t^3}{4(T_a + \dfrac{\Delta t}{2})^2 (T_y + \dfrac{\Delta t}{2})} & \dfrac{\Delta t^2}{2(T_y + \dfrac{\Delta t}{2})} & \dfrac{b_2 \Delta t}{2(T_y + \dfrac{\Delta t}{2})} & \dfrac{b_1 \Delta t}{2(T_y + \dfrac{\Delta t}{2})} & \dfrac{T_y \Delta t}{(T_y + \dfrac{\Delta t}{2})^2} \end{bmatrix}$$

$$\mathbf{D} = \begin{bmatrix} \dfrac{\Delta t^3}{8(T_a + \dfrac{\Delta t}{2})(T_y + \dfrac{\Delta t}{2})} & 0 & \dfrac{\Delta t^2}{2(T_y + \dfrac{\Delta t}{2})} & 0 & 0 \end{bmatrix} \tag{3}$$

To explore system state via variables that reflect real physical values it is convenient to use the expression below:

$$\mathbf{y}_k = \mathbf{G}\mathbf{x}_k, \text{ where} \tag{4}$$

$$\mathbf{G} = \begin{bmatrix} \dfrac{T_a \Delta t}{(T_a + \dfrac{\Delta t}{2})^2} & 0 & 0 & 0 & 0 \\ \dfrac{T_a \Delta t^2}{2(T_a + \dfrac{\Delta t}{2})^2} & \Delta t & 0 & 0 & 0 \\ 0 & 0 & b_2 & b_1 & 0 \\ \dfrac{T_a \Delta t^2}{2(T_a + \dfrac{\Delta t}{2})^2} & \Delta t & b_2 & b_1 & 0 \\ \dfrac{T_a \Delta t^3}{4(T_a + \dfrac{\Delta t}{2})^2 (T_y + \dfrac{\Delta t}{2})} & \dfrac{\Delta t^2}{2(T_y + \dfrac{\Delta t}{2})} & \dfrac{b_2 \Delta t}{2(T_y + \dfrac{\Delta t}{2})} & \dfrac{b_1 \Delta t}{2(T_y + \dfrac{\Delta t}{2})} & \dfrac{T_y \Delta t}{(T_y + \dfrac{\Delta t}{2})^2} \end{bmatrix} \tag{5}$$

There are following constant values: – time constant of attenuation in a correlation function of linear velocity of tank filling, T_y – time constant in a first order system that represents a hydraulic damper model, Δt – sampling period. Some coefficients were introduced:

$$a_1 = \frac{2 - \frac{8b}{\Delta t^2}}{1 + \frac{2a}{\Delta t} + \frac{4b}{\Delta t^2}}, \quad a_2 = \frac{1 - \frac{2a}{\Delta t} + \frac{4b}{\Delta t^2}}{1 + \frac{2a}{\Delta t} + \frac{4b}{\Delta t^2}}, \quad b_1 = \frac{2}{1 + \frac{2a}{\Delta t} + \frac{4b}{\Delta t^2}}, \quad b_2 = \frac{2}{1 + \frac{2a}{\Delta t} + \frac{4b}{\Delta t^2}}, \tag{6}$$

where $a = \dfrac{2\mu}{\mu^2 + \beta^2}$ $\qquad b = \dfrac{1}{\mu^2 + \beta^2}$

Symbols applied: μ – coefficient of irregularity in description of signal model like “an irregular swing” type that generated by SP of oscillations, β – predominant frequency in “an irregular swing” type signal. Inputs u_1 and u_2 are white Gauss noise with variance:

$$D_1 = \frac{2T_a D_c}{\Delta t} \quad \text{and} \quad D_2 = \frac{2aD_\alpha}{\Delta t} R, \text{ where} \tag{7}$$

D_c – a variance of tank filling velocity, D_α – variance of LV inclination angle α in direction to sensor, R – distance between tank longitudinal axis and sensor.

Input u_3 is used to enter some determinate signal during simulation.

LMS level sensors could be continuous or discrete type [3]. Formula (2) covers only case of continuous measurement and then $z = y_5$. For simulation of discrete measurement a quantization with a permanent step should be applied to output:

$$z = \left[\frac{y_{5k} - h_0}{\delta} + \frac{1}{2}\right] + h_0, \text{ where} \tag{8}$$

h_0 – height of zero level of a LMS sensor measured along longitudinal tank axis from a common point of reference, δ – quantization step (along tank height).

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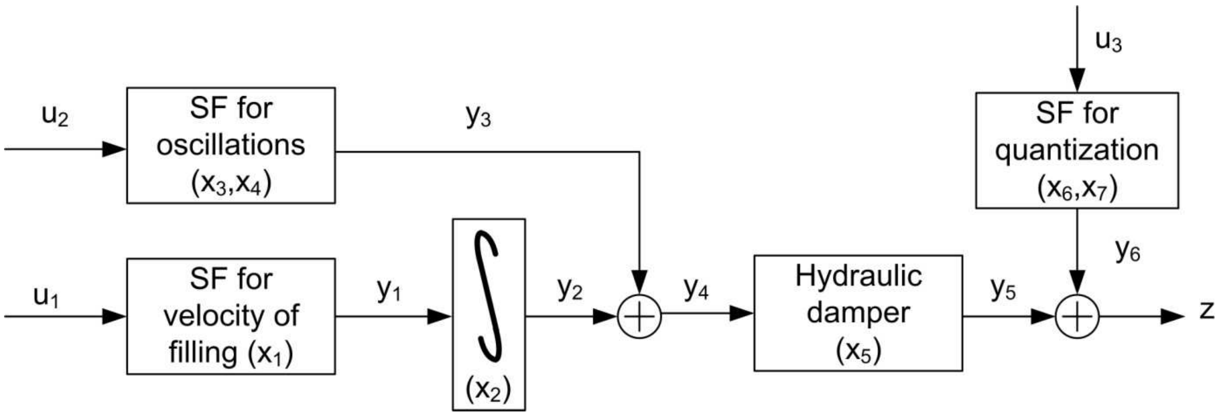
Expression (8) together with (1)÷ (5) is a simulation model capable of generating of signal sequence that adequately reflects a process of tank filling and measuring of liquid propellant level by discrete sensor under conditions of LP swing. But this model is not suitable for discrete Kalman filter due to significant nonlinearity of relation (8). Building of linear discrete Kalman filter for processing of signal from discrete level sensor could be made as a follow.

1. We will use the mathematical model (1) ÷ (3) to describe the observed process.

2. We will suppose the sensor static characteristic as a linear $z = y_5$.

3. We will consider the deviation of real static characteristic (8) from assumed linear characteristic as a random value or "a quantization noise". To simulate the quantization noise we will introduce one more SP to the model (pic. 2).



Picture 2 Model of process with SF for quantization

In this case the quantization noise is not white. This conclusion is a consequence of the fact that float discrete level sensors with inductive link between float and sensitive circuit are used in LMS as discrete level gauges. A quantization step of these sensors is 5-6% of measurement range [4] and no less than 10 mm. Level of liquid passes one discrete quantization level of sensor for 20–60 seconds but sampling period for such type of measurements is no more than one second. When quantization step is big and velocity of variation of input signal is low then rounding of sequence of impulses occurs to the same side, to the same value. Quantization error at certain point of time becomes to be depended on its previous value and therefore can't be considered as a white noise.

Guided by the approach described in [5] we assume correlation function of discrete random process that represents the quantization error of the described type in this form:

$$K(m) = \frac{\delta^2}{12}\frac{K_V(m)}{\sigma^2}\left[1 - 6\left|\frac{m\Delta t}{T_c} - l\right| + 6\left|\frac{m\Delta t}{T_c} - l\right|^2\right], \text{ where} \tag{9}$$

$m-$ number of sampling periods of time between two impulses, $K_V(m)$ –correlation function of linear velocity of tank filling, σ –standard deviation of linear velocity of tank filling, l –integer part of quotient $\frac{m\Delta t}{T_c}$, T_c –average time period of passing one discrete quantization level by liquid surface $T_c = \frac{\delta}{V_c}$, where V_c- average linear velocity of tank filling during load operation.

We suppose that correlation function that describes signal of linear velocity of tank filling could be presented in the form:

$$K_V(m)=\sigma^2 e^{-\xi|m\Delta t|} \text{ , where} \tag{10}$$

$\xi = \frac{1}{T_a}$ –attenuation constant.

Discrete spectral density of signal described by correlation function (9) after consideration of (10) is presented in terms of pseudo frequency λ by the formula:

$$S(\lambda) = \frac{\delta^2}{2\pi^2\Delta t}\sum_{i=1}^{\infty}\frac{1}{i^2}\frac{c_i\left(1 + b_i\lambda^2\right)(1 + \frac{\Delta t^2}{4}\lambda^{\ 2})}{\left|1 + c_i j\lambda + d_i(j\lambda)^2\right|^2} \text{ , where} \tag{11}$$

$$c_i = \frac{2\xi}{\xi^2 + (\frac{2\pi}{T_c}i)^2}, \qquad d_i = \frac{1}{\xi^2 + (\frac{2\pi}{T_c}i)^2}$$

If it is limited only by first harmonic then formula (11) describing the discrete spectral density will be represented in this form:

$$S(\lambda)=N\frac{(1+b\lambda^2)(1+\frac{\Delta t^2}{4}\lambda^{\,2})}{\left|1+aj\lambda+b(j\lambda)^2\right|^2},\quad c=\frac{2\xi}{\xi^2+\gamma^{\,2}},\quad d=\frac{1}{\xi^2+\gamma^{\,2}},\ \text{where} \tag{12}$$

$\gamma=\frac{2\pi}{T_c}$ –specific own frequency, i.e. average angular frequency of passing across quantization levels, N – level of spectral density that is defined by the way of integration (12) over the interval with infinity endpoints and then equating of obtained value to variance of quantization noise $D=\frac{\delta^2}{12}$. In accordance with [5]:

$$N=\frac{\delta^2}{12}\frac{c}{\Delta t} \tag{13}$$

On the base of formula (12) afrequency response of required shaping filter shall be:

$$H(j\lambda)=\frac{(1+\sqrt{d}j\lambda)(1+\frac{\Delta t}{2}j\lambda)}{1+cj\lambda+d(j\lambda)^2}\ , \tag{14}$$

and variance of white noise that should be entered via its input to provide required level of spectral density (13) of signal shaped on filter output shall be:

$$D_{бш}=\frac{\delta^2}{12}\frac{c}{\Delta t} \tag{15}$$

To pass from frequency response to discrete transfer function we performed substitution $\lambda j\to\frac{2}{\Delta t}\frac{1-z^{-1}}{1+z^{-1}}$ and have got:

$$H(z)=\frac{\dfrac{2+\dfrac{4\sqrt{d}}{\Delta t}}{1+\dfrac{2c}{\Delta t}+\dfrac{4d}{\Delta t^2}}+\dfrac{2-\dfrac{4\sqrt{d}}{\Delta t}}{1+\dfrac{2c}{\Delta t}+\dfrac{4d}{\Delta t^2}}z^{-1}}{1+\dfrac{2-\dfrac{8d}{\Delta t^2}}{1+\dfrac{2c}{\Delta t}+\dfrac{4d}{\Delta t^2}}z^{-1}+\dfrac{1-\dfrac{2c}{\Delta t}+\dfrac{4d}{\Delta t^2}}{1+\dfrac{2c}{\Delta t}+\dfrac{4d}{\Delta t^2}}z^{-2}} \tag{16}$$

After entering of obvious designations and reductions we have got discrete transfer function of SF for quantization noise:

$$H(z) = \frac{d_0 + d_1 z^{-1}}{1 + c_1 z^{-1} + c_2 z^{-2}} \tag{17}$$

Considering definitions presented by pic. 2 it is in space state representation:

$$\begin{cases} x_{6k} = x_{7k-1} \\ x_{7k} = -c_2 x_{6k-1} - c_1 x_{7k-1} + u_{3k-1} \end{cases} \tag{18}$$

$$y_{6k} = -d_0 c_2 x_{6k} + (d_1 - d_0 c_1) x_{7k} + d_0 u_{3k} \tag{19}$$

We will modify the model of continuous measuring that was presented above (1) – (3) in such way that the model could be used at Kalman filter even in case of discrete measurements. After changes that are caused by appearance of additional equations (17) and (18) matrix **A**,**B**,**C** and **D** will take form presented bellow. Matrix equations (1) and (2) will remain in the same form.

$$\mathbf{A} = \begin{bmatrix} \dfrac{T_a - \dfrac{\Delta t}{2}}{T_a + \dfrac{\Delta t}{2}} & 0 & 0 & 0 & 0 & 0 & 0 \\ \dfrac{T_a \Delta t}{(T_a + \dfrac{\Delta t}{2})^2} & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & -a_2 & -a_1 & 0 & 0 & 0 \\ \dfrac{T_a \Delta t^2}{2(T_a + \dfrac{\Delta t}{2})^2} & \Delta t & b_2 & b_1 & \dfrac{T_y - \dfrac{\Delta t}{2}}{T_y + \dfrac{\Delta t}{2}} & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 & -c_2 & -c_1 \end{bmatrix} \tag{20}$$

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$$\mathbf{B} = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ \dfrac{\Delta t}{2(T_a + \dfrac{\Delta t}{2})} & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ \dfrac{\Delta t^2}{4(T_a + \dfrac{\Delta t}{2})} & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 \end{bmatrix} \tag{21}$$

$$\mathbf{C} = \begin{bmatrix} \dfrac{T_a \Delta t^3}{4(T_a + \dfrac{\Delta t}{2})^2 (T_y + \dfrac{\Delta t}{2})} & \dfrac{\Delta t^2}{2(T_y + \dfrac{\Delta t}{2})} & \dfrac{b_2 \Delta t}{2(T_y + \dfrac{\Delta t}{2})} & \dfrac{b_1 \Delta t}{2(T_y + \dfrac{\Delta t}{2})} & \rightarrow \\ & \rightarrow & \dfrac{T_y \Delta t}{(T_y + \dfrac{\Delta t}{2})^2} & -d_0 c_2 & d_1 - d_0 c_1 \end{bmatrix}$$

$$\mathbf{D} = \begin{bmatrix} \dfrac{\Delta t^3}{8(T_a + \dfrac{\Delta t}{2})(T_y + \dfrac{\Delta t}{2})} & 0 & d_0 & 0 & 0 & 0 & 0 \end{bmatrix} \tag{22}$$

A recurrent algorithm of the discrete Kalman filter [6] consists of two phases: predict and update.

Predict

$$\hat{\mathbf{x}}_k^- = \mathbf{F}\hat{\mathbf{x}}_{k-1} \tag{23}$$

$$\mathbf{P}_k^- = \mathbf{F}\mathbf{P}_{k-1}\mathbf{F}^T + \mathbf{B}\mathbf{Q}\mathbf{B}^T \tag{24}$$

Update

$$\mathbf{K}_k = \mathbf{P}_k^- \mathbf{H}^T (\mathbf{H}\mathbf{P}_k^- \mathbf{H}^T + \mathbf{R})^{-1} \tag{25}$$

$$\hat{\mathbf{x}}_k = \hat{\mathbf{x}}_k^- + \mathbf{K}_k (\mathbf{z}_k - \mathbf{H}\hat{\mathbf{x}}_k^-) \tag{26}$$

$$\mathbf{P}_k = (\mathbf{I} - \mathbf{K}_k \mathbf{H})\ \mathbf{P}_k^-, \text{ where} \tag{27}$$

It is applied following commonly used definitions that relate to current state of measuring and estimation process, i.e. to step k:

$\hat{\mathbf{x}}_k$ –7x1 vector of state estimate, $\mathbf{P}_k$ – covariance 7x7 matrix of estimation errors, $\mathbf{Q}$ – covariance 7x7 matrix of input white noises, $\mathbf{K}_k$ –7x1 vector of Kalman gain, $\mathbf{R}$ – covariance matrix of observation noise (in this case – scalar R), $\mathbf{z}_k$ – observation vector (in this case – scalar z_k), $\mathbf{I}$ – identity 7×7 matrix. Matrix $\mathbf{F}$ and $\mathbf{H}$ are defined in this way: $\mathbf{F} = \mathbf{A}, \quad \mathbf{H} = \mathbf{C}$.

To monitor system state via variables that reflect real physical values it is reasonable to use transformation $\hat{\mathbf{y}}_k = \mathbf{G}\hat{\mathbf{x}}_k$, where matrix $\mathbf{G}$ has the form (5).

Values z_k are indications received from output of discrete LMS level sensor at time k. During filter debugging and testing these values should be obtained from the output (8) of the model (1) – (3) (pic. 1).

Signals u_1, u_2 and u_3 are independent therefore in accordance with (7) and (15) matrix $\mathbf{Q}$ has the form:

$$\mathbf{Q} = \begin{vmatrix} \frac{2T_a D_c}{\Delta t} & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & \frac{2aD_\alpha}{\Delta t}R & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & \frac{\delta^2}{12}\frac{c}{\Delta t} & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{vmatrix} \tag{28}$$

R –is a scalar that, in substance, is a variance of the random variable $\mathbf{Du}_k$ and on the base of expressions (7), (15), (22) it is calculated like this:

$$R = \left(\frac{\Delta t^3}{8(T_a + \frac{\Delta t}{2})(T_y + \frac{\Delta t}{2})}\right)^2 \frac{2T_a D_c}{\Delta t} + d_0{}^2 \frac{\delta^2}{12}\frac{c}{\Delta t} \tag{29}$$

To provide filtering of signal from continuous level sensor by the designed Kalman filter, matrix $\mathbf{A}$, $\mathbf{B}$, $\mathbf{C}$ and $\mathbf{D}$ shall be defined by

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expression (3), and elements of matrix $\mathbf{Q}$ as well as scalar R shall be defined by formulas (28) and (29) considering that variance of signal u_3 is zero.

Series of simulations using model (pic. 1) to imitate signal from discrete LMS level sensor have been performed with the aim to confirm a capability and efficiency of the designed discrete Kalman filter in its application to the task of measuring of propellant level in LV tanks during load operation going on under conditions of launch platform swing. A second stage fuel tank of LV "Zenith" of "Sea Launch" system was selected as an example for simulation. Input data for calculations are indicative and were formed by the analogy with known samples. Geometric characteristics of tank, quantity of fuel inside tank and LP inclination angles during load operation were defined using document [7]. Supposed quantization step is 12 mm and assumed sampling period is one second. Modeling was performed in MATLAB environment and for that a specific set of scripts and functions was designed and tested there. Designed software is a program implementation of methodology of simulation and filtering presented in this paper. It provides simulations for process of tank filling with liquid propellant in different modes and under different conditions as well as algorithmic treatment of simulated LMS input signal by the means of discrete Kalman filter with imitation of forming of signals for load operation control. The software set permits to perform variations of all mentioned above parameters of measuring process and filtering as well as of ambient parameters. Thus it is created a possibility to estimate influence of those or other factors including constructive ones on principal characteristics of dosing system.

The performed works have confirmed a full capability of designed filter and have demonstrated that applying of discrete Kalman filter for processing of level sensor signal redsuces a value of random component of loading error related to LP swing and discreteness of sensor from ± 130 liters to ± 50 liters.

Findings

As a result of performed theoretical studies, the key content of which is presented in this article:

1. A discrete Kalman filter for solving problem of measurement of a propellant level inside LV tanks during their loading under conditions of launch platform swing have been developed.

2. It is developed a software set that provides simulations of filling process inside LV tank in different modes and under different loading conditions as well as it provides processing of level sensor signal obtained during simulations, by the means of discrete Kalman filter.

3. Simulation and estimation of efficiency of the designed discrete Kalman filter in its application to measurements processing at Level Monitoring System have been performed. Calculations made for selected example demonstrate that applying of Kalman filter could reduce a value of a loading error component related to LP swing and discreteness of sensor two and a half times.

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S.V. Olszewski, O.M. Tanygina, V.F. Demchenko, E.R. Zayats

MODELLING OF KINETICS PLASMA-CHEMICAL DISPOSAL OF PERSISTENT ORGANIC POLLUTANTS IN WATER SOLUTIONS BY HIGH-VOLTAGE PULSED DISCHARGE

Summary. The problem of disposal of persistent organic pollutants arose in 1972 and did not lose relevance to the present day. Modern technologies for waste disposal for example the high-temperature incineration or pyrolysis can't produce satisfactory results, because any from these methods transforms target toxic compounds to some other harmful compounds. For example, incineration of organochlorine compounds and polychlorinated biphenyls intensively produces dioxins. This work represents materials of experimental and theoretical research that can be the basis for creating plasma-chemical technologies for the full destruction of persistent organochlorine toxicants in water solutions.

Keywords: spark, long streamer, persistent organochlorine toxicants.

Introduction

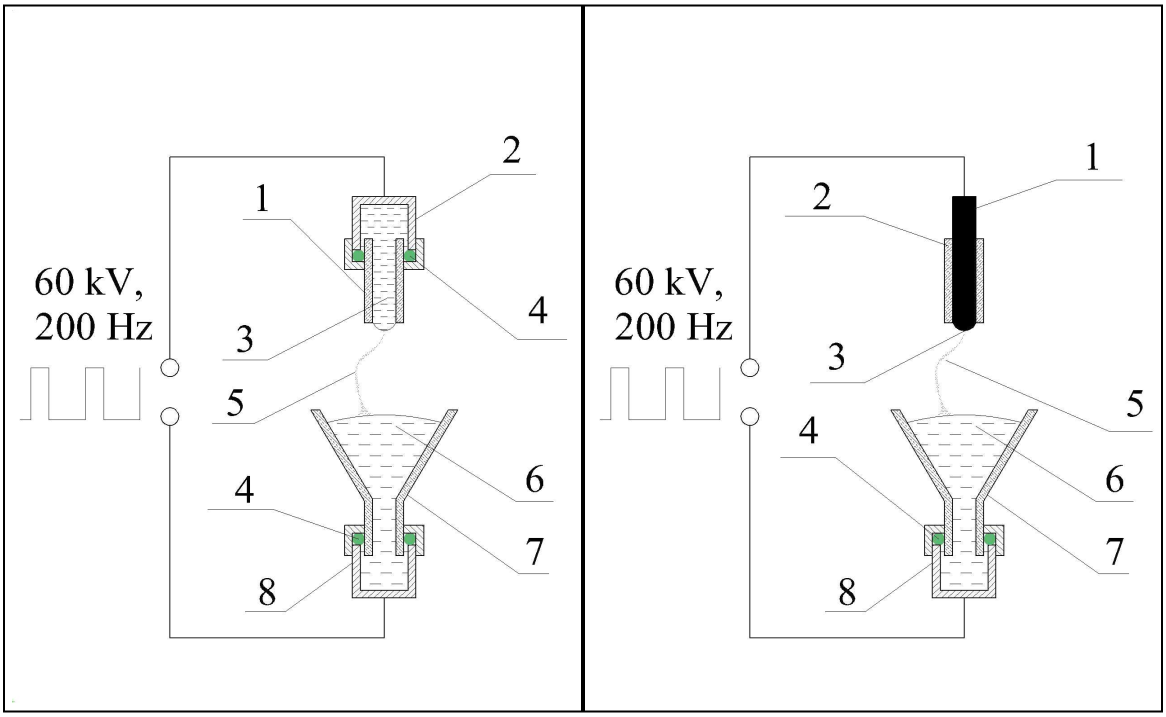
Analysis of the proposed internationally efforts to ensure environmental safety, gives reason to believe the low level of industrial technology utilization persistent organic pollutants (POPs) on the list established by the Protocol on Persistent Organic Pollutants Stockholm and other conventions 1979-2001 years [1-4]. At the same time this very list updated with new items. The difficulty creating such technologies associated with extraordinary chemical resistance under normal conditions these substances and not only [5]. Typically, destructive ways of recycling materials associated with the use of high temperature combustion, pyrolysis, electric burning, and so on. However, in a reactor, where the following processes, there is always a transition zone between the area where intensive decomposition precedes target compounds and the environment under normal conditions. So these reactors contain essentially the area in which a high probability of the reverse process can occur, leading to the synthesis of toxic substances. For example, the destruction of organochlorine POPs in pyrolysis furnaces is intense produsing of dioxins due to fundamental thermodynamic properties of pyrolytic decomposition of PCBs [6]. That is, there is no general disposal but only converting one kind of pops into another. It is even harder to achieve the required result during the destruction of toxic pollutants that exist in the form of water solutions. The problem is that the presence of water molecules, hydroxyl and hydrogen in the reaction zone by quite a wide range of temperature conditions causes a cascade of fast processes of synthesis of toxic substances - such as phosgene [7].

One of the most effective and safest directions of plasma-chemical treatment of POPs can be using of high-chemically active particles, that are generated in electrical discharges, as the main factor of degradation of toxic molecules. From the results of experiments it is known that plasma discharge treatment of water solutions of stable macromolecular compounds can lead to total destruction of their [8]. However, the question of the composition of the end products of this process remains open.

The proposed work is devoted to experimental and theoretical investigation of the possibilities of using plasma-liquid systems atmospheric pressure for removal of certain kinds of POPs in water solutions by their complete decomposition and clarify of possible mechanisms of degradation of toxic molecules under the influence of physical and chemical factors generated in plasma.

Experiment technique

Discharge system to implement a pulsed discharge in a long streamer mode [9] is shown schematically in Figure 1. To compare the effects of electrode material for chemical processes in the working solution a system was created in two versions: with liquid - a) and metal - b) base electrode. Liquid base electrode consisted of a cylindrical quartz insulator - 1.a), hermetically sealing silicone injected through - 4 in nickel camera to supply current – 2.a). Working solution - 6 was placed in a glass vessel conical shape, which served as the working liquid electrode – 7. This glass vessel is tightly connected with the nickel camera to supply current – 8 similar to the camera – 2. Defensive liquid filled electrode with distilled water – 3.a). The metal base electrode – 1.b) were placed in a teflon insulator – 2 so as to form its recording surface liquid meniscus shape repeated electrode. To test the spark discharge between the reference and working electrodes were served a series of high-voltage pulse of 75 kV repetition rate of 200 Hz.The plasma channel – 5 formed between the surface of the working fluid – 6 and the meniscus surface of distillate– 3or working surface of the metal electrode. Breakdown voltage level at the beginning of exposure was ~ 60 kV. In the process of changing the chemical composition of the working fluid under the plasma influence this voltage decreased in some cases up to 30 kV. The average pulse energy was ~ 200 mJ. Pulse duration equal to 150 microseconds.



a) b)

Figure 1 – High-voltage pulse-periodic discharge system with liquid - a) and metal - b) bas electrode.

Electrical characteristics of the investigated discharges were recorded direct measurement with capacitive sensors and high-voltage current transformers using high-speed digital oscilloscope «Regol DS1102M». Plasma parameters were recorded emission spectroscopy methods whith using CCD-spectrometer «OceanOptics S2000». Registration composition of working solutions was performed by liquid-gas chromatography and gas chromatography-mass spectrometry. Qualitative and quantitative chromatographic analysis was performed using a gas chromatograph "KrystalLyuks 4000m" produced by MetaHrom and chromatography-mass spectrometer «Clarus 600" manufactured by PerkinElmer.

The destruction of POPs in water solutions by high-voltage pulsed discharge

Experiments for the disposal of some of the most persistent and widespread POPs have been held for water solutions of p,p'-DDT, DDE and aldrine. The concentration of substances in the solution was ~ 1 mg/l. We used the following modes of solutions processing: positive and negative potential on the solution for the case of liquid reference electrode - Fig. 1 a), and positive and negative potential on the solution in the case of metallic reference electrode - Fig. 1 b). Solution was processed with pulsed-periodic discharge frequency of 200 Hz for 60 min.

The chemical composition of organic compounds in solution before and after processing was recorded by liquid-gas chromatography and gas chromatography-mass spectrometry. The results of chemical analysis of processed solution p,p'-DDT, are shown Table 1. The complete destruction of the substance tested for all modes. In similar experiments, it was found that the DDE and aldrine for 60 min. destroyed completely too.

Table 1

The products of destruction p,p'-DDT ($C_{14}H_9Cl_5$) under the influence of plasma high-pulse-periodic dischargee. Presence of the substance marked in gray.

Compound	Initial solution	Liquid electrode		Metal electrode	
		On solution +	On solution −	On solution +	On solution −
$C_{10}H_{18}O_2$					
$C_{22}H_{44}$					
$C_{19}H_{34}O_2$					
$C_{22}H_{42}O_4$					
$C_{19}H_{38}O_2$					
$C_{16}H_{34}O$					
$C_{27}H_{56}$					
$C_{14}H_9Cl_5$					
$C_{22}H_{42}O_4$					

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To enable the kinetic model of the mechanism of plasma-chemical destruction of macromolecular compounds the experimental studies of spark electrophysical characteristics at plasma-liquid system were held. Studies have shown that the shape of the pulse voltage to discharge that breaks between two water surfaces or between the metal and the water surface, somehow evolves during exposure solution by plasma (Fig.2.).

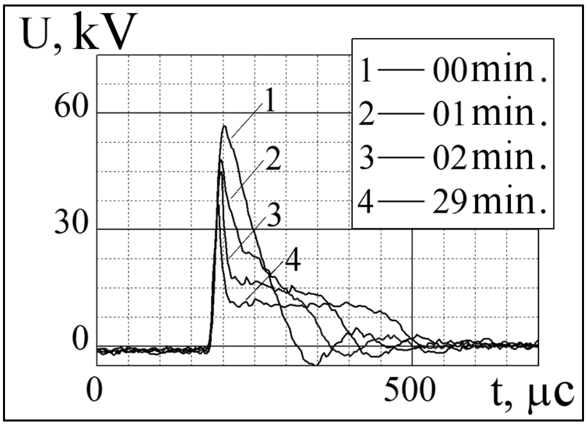

Figure 2 – Evolution of the shape of the pulse voltage during plasma exposure solution. Curve – 1 corresponds to the solution state at the beginning of processing 2 – Exposure for 1 min., 3 – 2 min., 4 – 29 min.

Form voltage pulse consists of relatively sharp peak amplitude from 30 to 60 kV and duration of ~ 10 – 50 μs, and trapezoidal pulse amplitude of 10 – 20 kV and duration of ~ 50 – 100 μs. The high-voltage sharp peak corresponds to capacitive discharge combustion mode, trapezoid – inductive. The evolution of the discharge pulse was increasing steepness Ξ_C falling edge of «capacitive» peak and decreasing inclination angle Θ_L «plateau» of inductive mode.

The experiment showed that the evolution of the pulse form is mostly in the first 120 seconds of exposure of working solution by plasma. Comparison of evolution curves for pulse form to the working fluid and metal electrodes (Figure 3) provide grounds to consider that this evolution is related to the changing of the conductivity solution due chemical modification of working liquid under the influence of plasma.

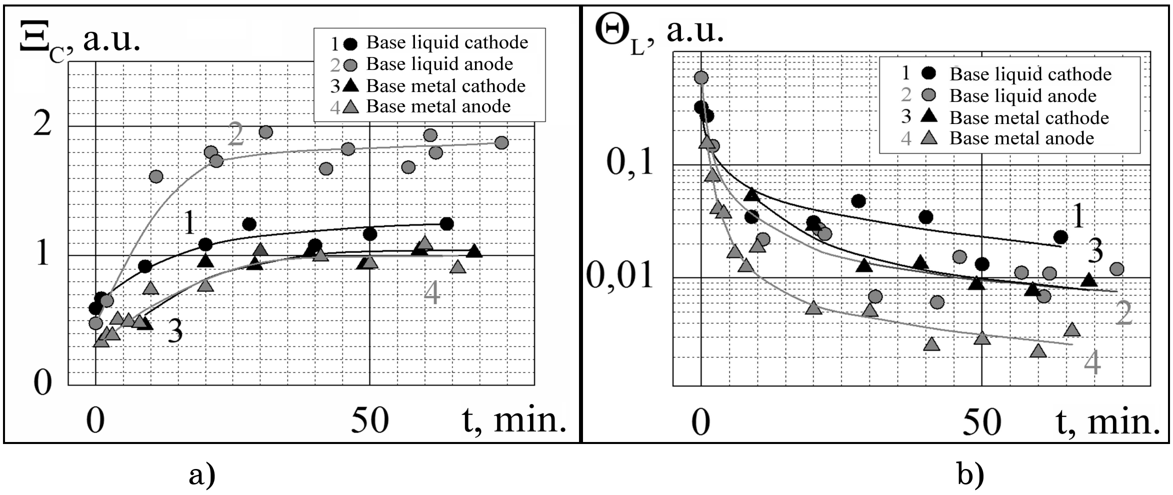

Figure 3 – The time dependence of the falling edge steepness Ξ_C of the high peak discharge pulse – a) and inclination angle Θ_L «plateau» inductive discharge mode – b) for various configurations discharge system. Round markers correspond to the liquid base electrode, triangular – to the metal electrode. Black color corresponds to the case of a positive potential on the solution, gray – negative.

Results of modeling the kinetics of plasma-chemical degradation of p,p'-DDT

Kinetic model of spark discharge between the liquid surfaces was built as the development of long streamers classical model [10] in conditions of liquid electrodes. The ultimate aim of the simulation was to calculate the number of particles in the liquid phase that are born during one high-voltage impulse, to calculate the solutions' relative conductivity time dependans, and comparison of simulation results with experimentally obtained curves. According to [10], the classic basic physical model of long streamers includes continuity equation for electrons, positive and negative ions of different sort and electron-excited molecules based on photoionization sources:

$$\left(n_e\vec{v}_e\right) = \left(k_iN + k_i^*n^*\right)n_e - \left(k'_a + k''_aN\right)N_{e\text{-}}n_e + \\ + \left(k_dN + k_d^*n^*\right)n_- - \beta_{ei}\,n_+n_e + S_\phi \quad (1);$$

$$\frac{\partial n_+}{\partial t} + \nabla\cdot\left(n_+\vec{v}_+\right) = \left(k_iN + k_i^*n^*\right)n_e - \beta_{ei}\,n_+n_e - \beta_{ii}\,n_-n_+ + S_\phi \quad (2);$$

$$\frac{\partial n_-}{\partial t} + \nabla\cdot\left(n_-\vec{v}_-\right) = \left(k'_a + k''_aN\right)N_{e-}n_e - \left(k_dN + k_d^*n^*\right)n_- - \beta_{ii}\,n_-n_e \quad (3);$$

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$$\frac{\partial n^*}{\partial t} = k^* N n_e - k_i^* n^* n_e - k_q N n^* \qquad (4);$$

$$\vec{v}_k = \vec{v}_{др.k} - D_k \nabla \left(\ln \left(n_k \right) \right) \qquad (5).$$

Where $N, n^*, n_e, n_+, n_- \left(\text{abbreviated:} n_k \right)$ - are the concentration of neutrals, excited molecules, electrons, positive and negative ions - respectively. $\vec{v}_k, \vec{v}_{др.k}$ - are velocity and drift velocity of k^{th} component of the plasma. D_k - is the diffusion coefficient of k^{th} component of the plasma. S_ϕ - is the photoionization source. β_{ei}, β_{ii} - are the coefficients of electron-ion and ion-ion recombination.

Poisson equation for electric field:

$$\Delta\varphi = e \frac{n_e + n_+ - n_-}{\varepsilon_0}, \quad E = -\nabla\varphi \qquad (6).$$

Energy balance equation for the gas temperature:

$$c_V N \frac{\partial T}{\partial t} = \lambda_{rt} jE + Q_{vT} + Q_{eT} \qquad (7),$$

and relaxation equation:

$$\frac{\partial E_v}{\partial t} = \lambda_v jE - Q_{vT}, \quad Q_{vT} = \frac{E_v - E_v(T)}{\tau_v(T)} \qquad (8).$$

Where j - is a current density, E - is a longitudinal field in the channel, c_V -is a heat capacity of one molecule, λ_x - is a part of energy that was spent on excitation of x^{th} internal degree of freedom. Q_{vT}, Q_{eT} - are the contributions of heat from the vibrational and electronic states of molecules de-exitation, $E_v(T)$ - is the equilibrium vibration energy, $\lambda_{vT}(T)$ - is a time of vT - relaxation.

Extending the classical model in case of liquid electrodes was to neglect the surface effects, in particular - the photoemission from the surface. The source of photoionization was only volume isotropic processes. The disappearance of particles on the liquid surface was considered as a gradual loss of particles' kinetic energy acquired in plasma during the inelastic collisions between molecules in the solution. In case of a liquid phase the excitation of all internal degrees of freedom and striking dissociation of molecules were considered. The constants of elementary processes were taken mostly from the database NIST. Those constants that were absent in the database, were calculated from the quantum-mechanical principles using the notorious package Gaussian 09W. For plasma-forming gas the mixture of air with water molecules was chosen, excluding from consideration the processes with atomic metal ions. In the region of gas phase, the component mixture was considered as inhomogeneous along the axial axis of the system. The axial profiles of the water molecules' concentration and air components were calculated using the analytical theory that was developed in [11] and based on the conditions of heat - mass - transfer through the liquid-gas boundary with diffuse evaporation.

Simulation results presented in Fig. 4 show that the behavior of conductivity in time qualitatively agrees with the experimental dependences on Ξ_C and Θ_L. This fact is illustrated by calculateddependenceof high-voltage peaks' falling edge ξ in exponential approximation overlayed with experimental data Ξ_C. However, the quantitative agreement of the experimental data with the model was not observed. The calculated time-to-saturation was three times lower than the experimental, while the level of induced conductivity was approximately 2-times lower than the experimentally obtained for all test solutions. The best quantitative agreement of the experimental results and the calculations took place for the case of distilled water. Calculated characteristic time within the error limits coincided with the experiment, and calculated saturation level was lower than the experiments in about 1.3 times. Disagreements of calculation and experiment can be explained by the fact that in the model was not taken into account that the shock dissociation products of complex organic molecules are also non-stable, and the gradual disintegration of complex fragments is taking place [12]. The latter leads to a significant increase of the solutions' conductivity as a result of current carriers generation in a volume comparing to the calculated number of acts of shock dissociation.

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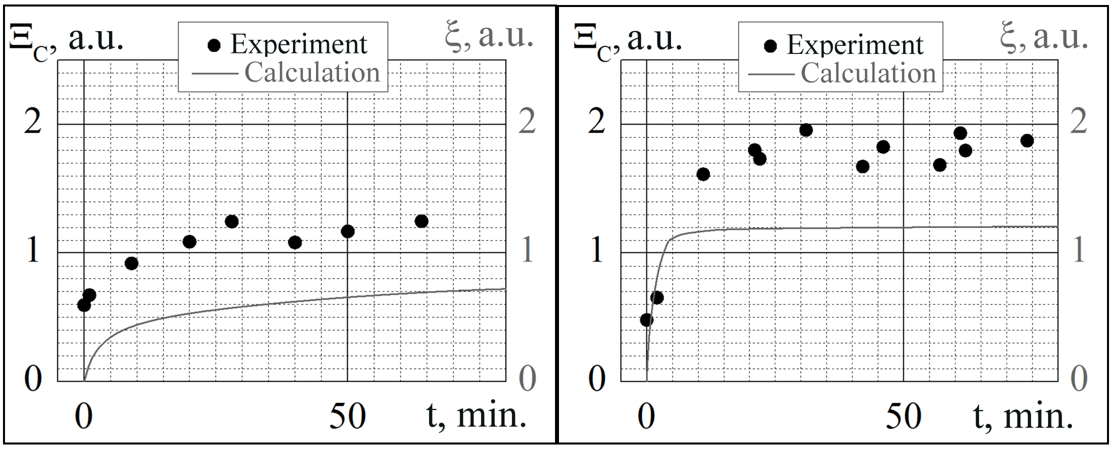

a) b)

Figure 4 – The calculated time dependence of the falling edge steepness ξ of the high peak discharge pulse for spark discharge between liquid electrodes compering with experiment ΞC. – a) illustrates the case of a positive potential on the working solution b) – negative potential. The solid gray curve – is a calculation, black markers – experiment.

Conclusions

- By means of gas chromatography, it was shown that treatment of the p,p'-DDT, DDE, and aldrinu water solutionswith the plasma of high-voltage pulse-periodic discharge leads to their complete decomposition.
- The proposed model of the spark discharge between the liquid surfacesshow that the evolution of electrophysical discharges' parameters is determined by the change of electro conductivity of a liquid phase with increasing of organic molecules' degradation products' concentration in the solution.

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INFORMATION TECHNOLOGY OF SUPPORT OF DECISIONMAKING IN ERGATIC SYSTEM

The improved information technology to support decision-making in complex dependable human-machine systems has been offered. Proposed the fuzzy adaptive model to the formation of alternatives taking into account the human factor and influence of environmental parameters, as well as a generalized algorithm for choice the optimal solutions using proportionate selection.

Keywords: *information technology, decision making, fuzzy relational model, membership function, expert evaluations.*

INTRODUCTION

In informational technologies decision support (DS) in the complex of dependable human-machine (ergatic) systems (ES) in such industries as power, transportation, chemical manufacturing, etc., a major problem is the account of psycho-physiological and cognitive factors of the decision maker (DM) under the influence of environment factors.

The urgency of research of this problem stems from the fact that the proportion of accidents in these ES caused by human factor still remains high, in particular, according to [1], it can reach 60%.

Decision-making in ergatic systems are determined by the functional state of the decision maker and the influence of external factors. These factors include factors working environment: noise, vibration, light, temperature, etc .; factors operating activities: unevenness flow of information, its inaccuracy and contradictoriness, changes in the state of the control object, etc. Internal factors caused by a functional state, such as fatigue, tension, motivation, etc. depend on both the initial state decision-makers to work shift, and on its individual characteristics and the influence of external factors as well.

Thus, the decision maker can be considered as a complex the nonlinear nonstationary dynamical system with internal feedback.

The accounting of indicated factors in the creation of information technologies will allow forecasting the risk of incorrect decision-making by DM, and improve the overall reliability of whole ergatic systems functioning.

THE PURPOSE OF WORK

The aim of the work is to create an information technology that could take into account the influence of external and internal factors taking into account their uncertainty and non-numeric character in the DM activity with abilities to adaptation under operating conditions change and of decision-makers condition.

LINKAGES WITH EXISTING SCIENTIFIC DIRECTIONS

This work is aimed to improving of information technologies for support of decision-making in complex dependable human-machine systems, taking into account the human factor as well as environmental factors. Questions of theory and methods of decision-making are considered by D. A. Pospelov, T. Saaty, N. Nilsson, S. A. Orlovsky, O. I. Laricheva, V. N. Tomaszewski, P. I. Bidyuk et al. Accounting issues properties like of human ones in ergatic systems devoted to the works of B. F. Lomov, V. V. Pavlov, G. Salvendi, T. B. Sheridan et al.

ANALYSIS OF THE PROBLEM

Currently, human factors in dynamic ES is carried out mainly through the rational design of the workplace, human-machine interface in ES and working conditions of DM.

The standards, such like GOST 12.0.001, 12.0.003 et al., governing the requirements for the workplace and environmental factors have been developed.

The problems of improving the reliability of human activities as part of ES [1-3] have been developed as well.

The control systems and identification of the functional state of DM with notifiable psycho-physiological characteristics determined by indirect measurement methods during operation of DM have been developed too [4-6].

Nevertheless, remains unresolved problem of construction the formation of alternatives model, allowing the linkages between the factors discussed above, the functional state and the relevance of DM. This task is the key when creating new information technologies in integrated human-machine systems.

STATEMENT OF THE PROBLEM

Developing an information technology should have the following properties:

- display of the influence of various factors on the formation of alternatives taking into account the relevance of DM solutions;
- allowance for the nonlinear linkages between factors;
- ability to adaptation under change of DM conditions or environmental conditions;
- presentation of the factors with non-numerical nature;
- possibility of constructing a model on the basis of the available of experimental data and availability of expert knowledge in the subject area.

THE RESULTS OF RESEARCH

Information technology in ES is shown in Fig. 1.

To represent values of external, psycho-physiological and cognitive factors appropriate to use the fuzzy linguistic variables $X_1, X_2, \ldots, X_n$, which are fuzzy sets $X_i = \{x_1, \mu_1; x_2, \mu_2; \ldots; x_c, \mu_c\}$ [7]. Application of the theory of fuzzy sets due to the fact that many of the factors discussed above are non-numerical nature (for example, the degree of fatigue and motivation of DM), and can not be measured with a given accuracy, i.e. in their values present the uncertainty.

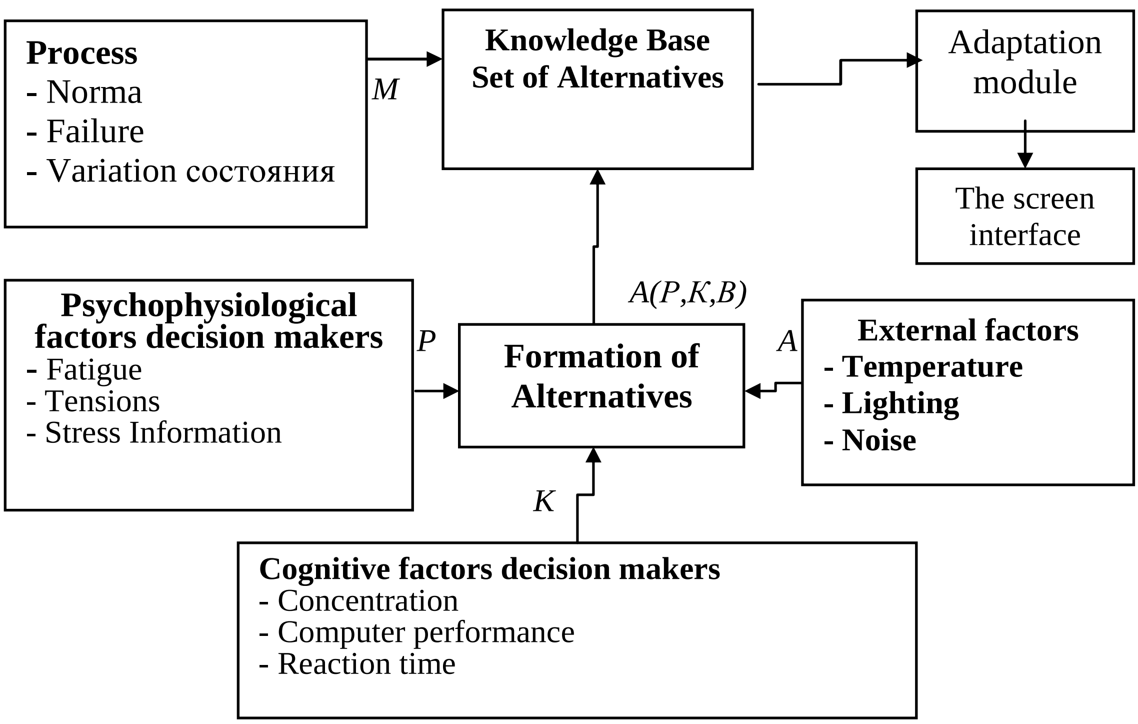


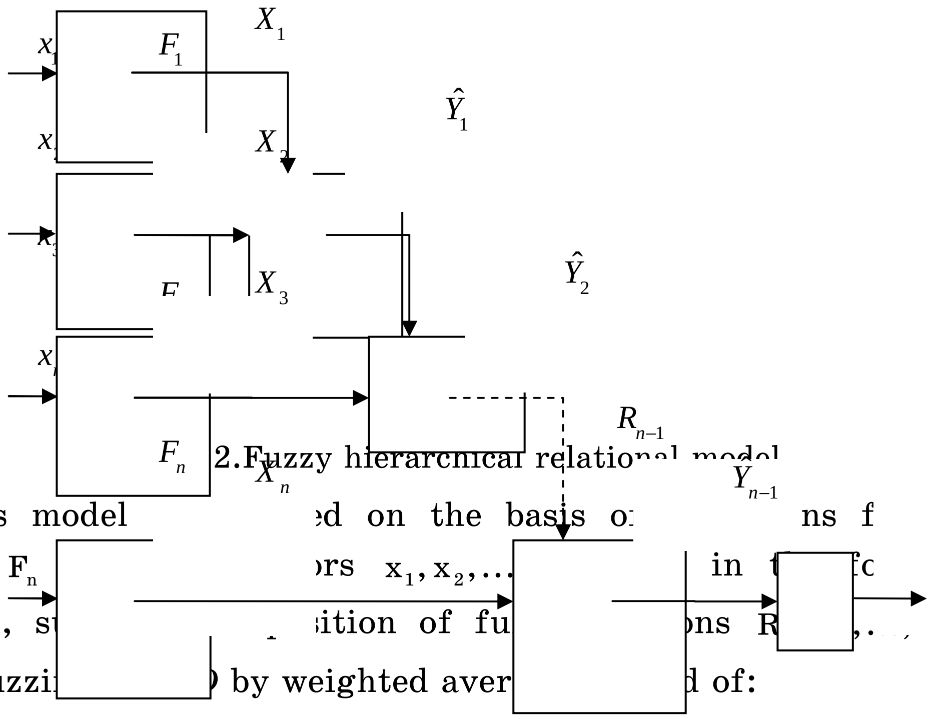
Fig. 1. Information technology of decision making processes in system ergatic

As the membership functions μ_{ij} appropriate to use the functions of the form [7, 9]:

$$\mu_{ij}\left(x_i\right)=\exp\left(-\frac{\left(x_i-\theta_{ij}\right)^2}{\sigma_{ij}^2}\right), \tag{1}$$

where θ_{ij},σ_{ij} - are the parameters of the membership functions.

Communication between the factors $X_1, X_2, \ldots, X_n$ and the output value y representing the ability of DM to make the relevant decisions is formalized using fuzzy relational model of hierarchical structure (Figure 2).



2.Fuzzy hierarchical relatio... model

This model ...ed on the basis o... ns f... ion $F_1, F_2, \ldots, F_n$ ...ors $x_1, x_2, \ldots$ in ... real numbers, s... sition of fu... ns R... 10] and defuzzi... by weighted aver... of:

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$$\begin{cases} \hat{Y}_1 = \left(\Psi_1^T R_1\right)^T; \Psi_1^T = \left(X_2 \otimes X_1\right)^T; \\ \hat{Y}_2 = \left(\Psi_2^T R_2\right)^T; \Psi_2^T = \left(X_3 \otimes \hat{Y}_1\right)^T; \\ \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots; \\ \hat{Y}_{n-2} = \left(\Psi_{n-2}^T R_{n-2}\right)^T; \Psi_{n-2}^T = \left(X_{n-1} \otimes \hat{Y}_{n-3}\right)^T; \\ \hat{Y}_{n-1} = \left(\Psi_{n-1}^T R_{n-1}\right)^T; \Psi_{n-1}^T = \left(X_n \otimes \hat{Y}_{n-2}\right)^T, \end{cases} \qquad (2)$$

here $\otimes$ - denotes the Kronecker product. The output value in fuzzy form determined by the formula [9,10]:

$$\hat{y} = \frac{\sum_{h=1}^{c} \hat{Y}_{(n-1)h} \theta_h}{\sum_{h=1}^{c} \hat{Y}_{(n-1)h}},$$

where h - the number term output NLP $\hat{Y}_{n-1}$, c - the number of terms, θ_h - the center of the membership function of the term with the number h, $\hat{Y}_{(n-1)h}$ - the value of the membership function of the term with the number h. This defuzzification method has less computational complexity as compared with the center of gravity method.

Definition of the matrices in the expression (2) is made on the basis of experimental data and expert estimates. This information is stored in the knowledge base. It is necessary to minimize the total Euclidean distance between fuzzy model and output result Δ [10]:

$$\Delta = \sum_{j=1}^{N} \sqrt{\frac{1}{c} \sum_{i=1}^{c} \left(\hat{Y}_{(n-1)ji} - \hat{Y}^R_{(n-1)ji} \right)^2} \to \text{MIN},$$

where$N$ - number of samples in the knowledge base, j - the number of sampling units, $\hat{Y}^{R}_{(n-1)ji}$ - the value of the membership function contained in the knowledge base.

To solve this problem it is expedient to use genetic algorithms [9].

Selection of optimal decisions made by means of the initial population of selection. It is advisable to use the method of proportional selection [9, 11] because it is characterized by a high rate of convergence. The implementation of this method is performed by the following algorithm.

Step 1. For each chromosome in the population of the objective function is calculated value of $\Delta_i, i = 1,\ldots,N_p$.

Step 2. The total value of the objective function $\Delta_s = \sum_{i=1}^{N_p} \Delta_i$ determined.

Step 3: A random number of $\Delta_R \in [0;\Delta_s]$ generated.

Step 4. Summation of values Δ_i as long as the sum does not exceed value of Δ_R. For the formation of the next generation of selected chromosome, the objective function which was last added to the sum.

Step 5.Repetition of steps 3 and 4 for the next generation of the population.

To form the solution that differs from members of the current population is performed crossover (crossbreeding): [9.11]

Step 1: Set the threshold of a crossover $P_c \in [0,4;0,9]$; this value characterizes the intensity of participation in the chromosomes crossed.

Step 2. For each pair of the chromosomes selected at step of selection a random number $\Delta_{cj} \in [0;1], j = 1,\ldots,N_p/2$ is generated.

Step 3. If the condition $\Delta_{cj} \le P_c$ is satisfied, then go to step 4, otherwise go to step 6.

Step 4. Generate a random number $\Delta_L \in [1;L-1]$, where L - length binary string encoding the chromosome. This number determines the coordinates of the point of discontinuity of the chromosome to perform crossover.

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Step 5: The chromosomes P_1, P_2 of the pair participating in the crossover are replaced descendants:

$$P_{N1} = (P_1)_1, (P_1)_2, \ldots, (P_1)_{\Delta_L}, (P_2)_{\Delta_L+1}, (P_2)_{\Delta_L+2}, \ldots, (P_2)_{R_L},$$
$$P_{N2} = (P_2)_1, (P_2)_2, \ldots, (P_2)_{\Delta_L}, (P_1)_{\Delta_L+1}, (P_1)_{\Delta_L+2}, \ldots, (P_1)_{R_L},$$

where $(P_1)_2$ denotes the 2nd bit of a chromosome P_1.

Steps 2-5 are repeated as long as the there are no more pairs of chromosomes in the population.

In order to attract additional information in the population mutation produced by the following algorithm [7, 9].

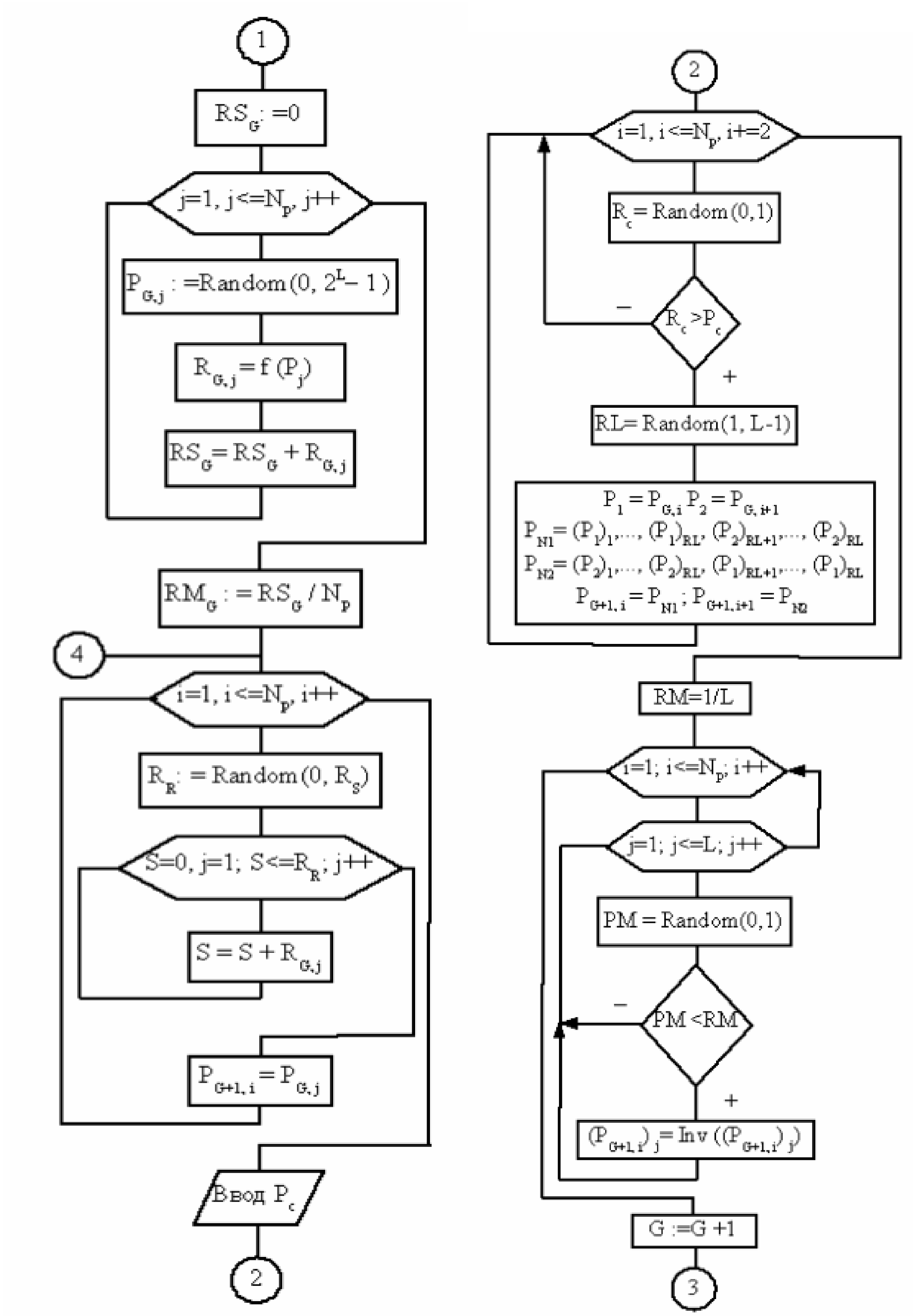
Step 1. The threshold of mutation determined as $P_M = 1/L$.

Step 2. From population selected the chromosome.

Step 3. In the selected chromosome selected bit.

Step 4. A random number $\Delta_M \in [0;1]$ generated.

Step 5.If $\Delta_M < P_M$ then selected bit is inverted.



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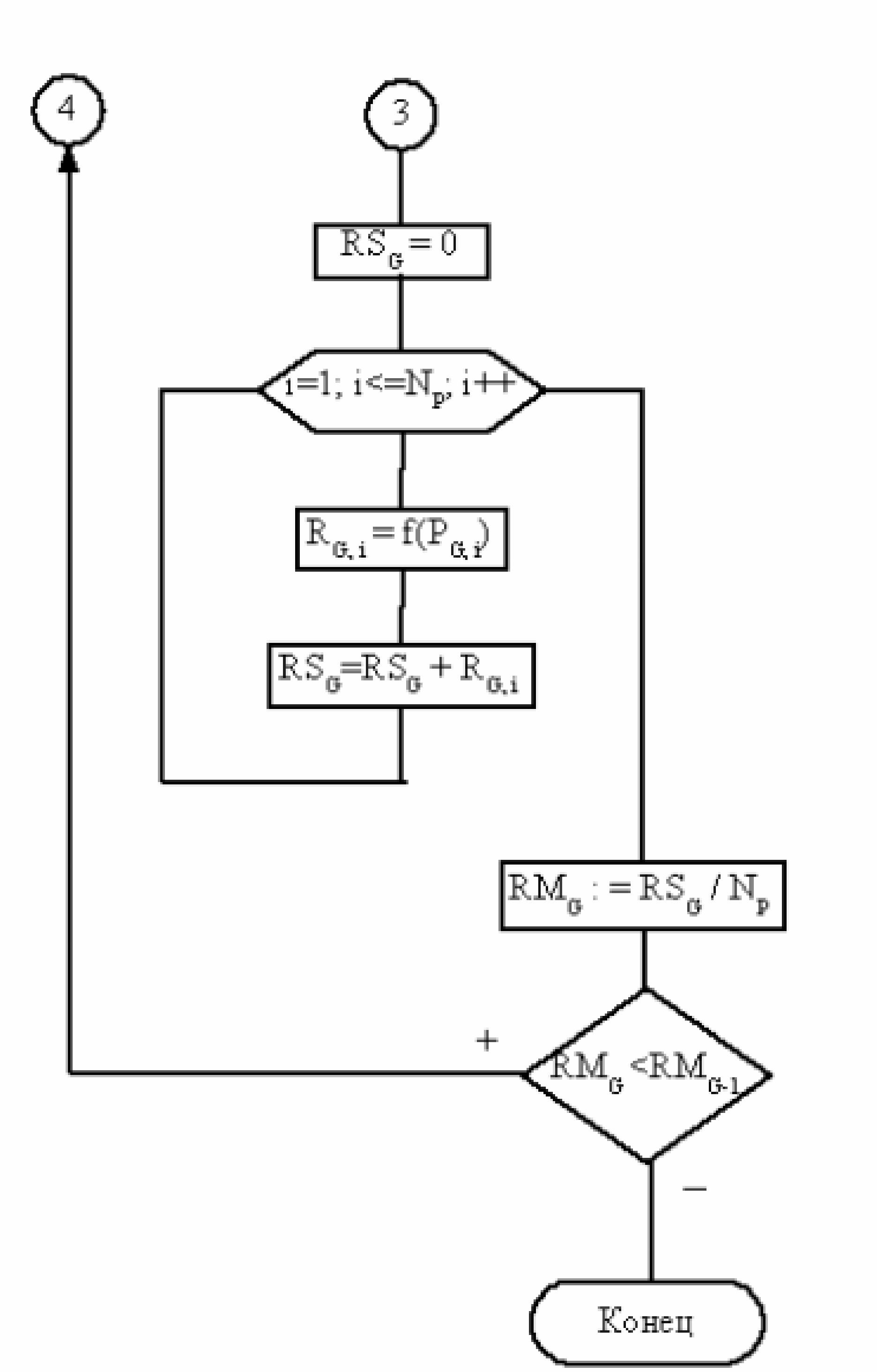

Fig. 3.A generalized algorithm of optimal solutions selection using proportionate selection method.

CONCLUSIONS

Step 6: Repetition of steps 3-5 until all bits of the current chromosomewould be processed.

Step 7. Repetition of steps 2-6 until processed all population chromosomes.

After performing these steps, a transition occurs to a new generation of the population.

These algorithms are presented in Fig. 3.

The problems of information technologies improvement to support decision-making in complex dependable human-machine system considered. The fuzzy adaptive model of the formation of alternatives taking into account the human factor and the influence of environmental parameters, as well as a generalized algorithm for selection of optimal solutions using proportionate selection has been proposed.

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M.A. Voronenko, G.S. Abramov

THE SEARCH MODEL FOR RATIONAL SOLUTION OF RESOURCE DISTRIBUTION

Introduction

The worldwide attention is attracted today to the problem of the quality of drinking water, as the use of poor-quality drinking water can cause illness with severe and even fatal consequences for humans. In Ukraine, only during the years of its independence there were registered numerous cases of disease cholera, typhoid, hepatitis A, dysentery, salmonellosis etc., associated with water and in particular drinking water. Drinking tap water, in the case of bacterial contamination may cause the emergence and spread of intestinal infections, and can also be a potential source of harmful chemicals getting into human body with general toxic, sensitizing, carcinogenic effect and can cause genetic consequences.

Epidemiological studies have confirmed the association of the chemical composition of drinking water to the population incidence of cardiovascular disease, cholelithiasis and urolithiasis, dental caries, etc. The consequences of chemical pollution, particularly heavy metals, pesticides and radionuclides, especially through contaminated soil and water, were evidenced by the increase of morbidity and mortality of population [1].

The long-term use of underground sources of water supply in the Kherson region led to their pollution by more mineralized waters of downstream aquifers, in according 45% of artesian wells give water that does not meet the sanitary requirements for mineralization, the dry residue, hardness, nitrates, sulfates, chlorides (Figure 1).

In spring and summer most of the population of Belozersky, Beryslavsky, Vysokopolsky, V.Aleksandrovsky, Genichesky, Kahovsky and Chaplynsky areas stay without water [2].

With aggravated medical and biological history, and adverse social conditions, the effect of the negative impact of anthropogenic factors is manifested stronger [3].

Thus, the poor quality of drinking water can cause different problem epidemiological situations in the region, for the elimination of which is necessary to attract more material and human resources.

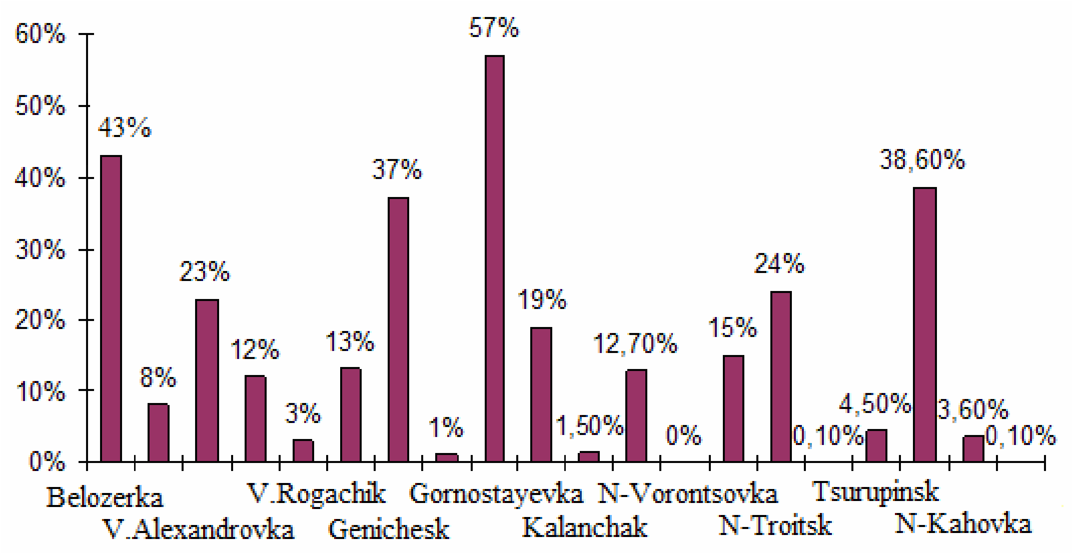

Figure 1 – The percentage of non-compliance to the total number of samples

The purpose

To develop operational and reasonable decisions on resource management and rescue activities it is necessary to use adequate models of training and assessment options for the distribution of resources in the dangerous infectious area admitting an effective computer implementation and being comfortable to understand. The known approaches in solving the problems of resource distribution are based on the mathematical optimization of functions defined on the set of combinations of discrete variables [4].

The iterative methods for finding optimal solutions to these problems are characterized by the rapid growth of computational complexity when the number of variables grows and does not allow proposing the optimization algorithm in the foreseeable analytical form.

The improvement of the efficiency and validity of decisions in terms of occurrence of the problem situation is possible with the help of formal logic models for the distribution of resources, allowing a relatively simple computer implementation [5]. In this article, we propose a search model for a rational resource distribution solutions using logic function selection, which is built on interactively based expert knowledge.

The main material

Suppose that in a certain region (Kherson region) *r* mini-regions fell into the epidemiologically dangerous area (regional area) in each of which, for ease of review in this area misses *s* micro-regions (cities, towns, villages), i.e. $\lambda = 1, s$ for all $\mu = 1, r$. For each λ micro-region experts establish situational characteristics that determine the causal relationships between the predicted situation and necessary rescue interventions. Situational characteristics can be set in advance by the alternative scenarios of stereotypical situations.

Rescue measures are provided by the following set of components $\alpha = 1, n$:

- the number of doctors,
- the number of medications,
- the number of medical equipment.

To perform the work of the same kind of resources (capabilities) can be of different types: doctors of the highest qualification, nurses, population. Each type $\beta = 1, m$ of these resources is characterized by a certain capacity, depending on the skill level of doctors and equipment means. Resource productivity is measured by the volume of work performed per unit time.

In relation to existing management practices and rescue activities, we introduce the following parameters:

a_{λ}- required amount of care α species in the λ microregion;

h_{β}- performance of Biomedical Resources β-type μ th miniregion for medical care α species;

T_{μ} - time allowed for medical care α species in the μminiregion.

Using these indicators, we construct a matrix of time-consuming resources μminiregion to perform works αspecies in each microregion λ (see. Table.).

For the rational distribution of resources based on this matrix is necessary to define the logic function selection. As a logical basis using multi-valued operations of disjunction, conjunction and inversion, which together with its arguments take values from the set of real numbers.

With the help of these operations we establish such logical dependencies between parameters table time costs that will ensure rational distribution of resources by the criterion of minimizing the time of care.

For each resource (table row) is necessary to ensure selection of the micro-region (column), where the amount of medical care for a period is not exceeding the allowable and will be the highest compared to other micro-regions. In turn, all of the resources necessary to define a β resource, which is selected for it by the maximum amount of health care in the λmicroregion can do it in a minimum of time compared with other resources. In this case, we assume that transport costs disproportionately small compared to the cost to perform the bulk of the work on the rescue activities.

Selected as a result of these logical operations βrow and λcolumn are deleted from the table 1. The subsequent steps are performed similarly for the remaining resources and microregions until all rows and all columns erased.

Table 1

A matrix of time-consuming resources

	a_1	a_λ	a_s
h_1	τ_{11} ...	τ_{21} ...	τ_{s1}
h_β	τ_{12} ...	τ_{22} ...	τ_{s2}
h_m	τ_{1m} ...	τ_{2m} ...	τ_{sm}

Thus, as a result of no more than m-1 transits is made the rational distribution of internal resources of miniregions for first aid.

This also holds for the second etc. medical care after appropriate adjustments of required and possible scope of work. If internal resources in μ miniregions ($\mu = \overline{1, r}$) are not sufficient to perform all work within the allowed time, free resources involved neighboring ν miniregions ($\nu = \overline{1, q}$), outside the region. In this case, a table of time spent at the level of the region including all its affiliated miniregions in aggregated form. The columns of this table represent the amount of work required in the μ miniregions that are not provided inside resources, and lines - the possible scope of work with available resources ν miniregions and executed the distribution of free resources on unsecured miniregions.

The results of this distribution allow to correct local time consuming table.

With a lack of regional resources, the above process can be raised to higher levels of management.

So, at the first sign of an epidemic situation - namely, the number of patients and the number of carriers is approaching epidemic proportions in some situational zone region, epidemic department Regional Sanitary-epidemic station provides data to the City Commission for emergencies, which will decide on the interaction services. Telephone messages are sent to take action in all public institutions contact: kindergartens, schools, institutions, etc. - All are ought to wear masks, to establish quarantine, etc. If the scale of the epidemic reaches a viral disease, with the help of the media the vaccination is announced (vaccination, nasal drops, etc.) in the clinics or in the workplace.

In the presence of the epidemic situation the rescue activities in this situational area are carried out as follows. From all the cases of disease are highlighted critical, requiring emergency hospitalization and emergency medical care, the provision of which depends on the patient's life. From the current number of doctors is allocated the brigade, which is directed at the elimination of these critical cases. In turn, the remaining medical workers are working in accordance with the basic algorithm. Then after assisting in all critical cases the brigade joins the main group of doctors, and with them continues to work on the basic algorithm.

Conclusion

The considered search model of the rational solutions allows us to formulate an algorithm of resource management at the elimination of problematic situations, the main stages of which are as follows:

1. Assess the situation, determine the initial data for the calculation.

2. Determine the required total a_{λ} health care αtype in the μ miniregions.

3. Determine the possible total $h_{\lambda\mu}$health care αtype of internal medical and biological resources of μminiregion for allowed time.

4. Determine the mismatch between the desired and the possible amount of care αtype in μminiregions.

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5. If the discrepancy is greater than zero, then seek assistance from neighboring regions on the value of the error, otherwise go to step 6.

6. Identify possible volume of $h_{\lambda\mu}$ health care of αtype available biomedical resources in μminiregion for allowed time.

7. Determine the duration $\tau_{\lambda\beta\mu}$ care of αtype of internal medical and biological resources of βtype in μ miniregion for the allowed time.

8. Distribute internal biomedical resources of μminiregion between λ micro-regions.

9. Analogically distribute free medical and biological resources of ν miniregions between μ miniregions.

10. Distribute internal biomedical resources of μ miniregion between external and free λ micro-regions.

11. Determine the current situation after the intervention; determine the quantitative values of the characteristics. If necessary, repeat the procedure in accordance with the algorithm.

The algorithm is verified on the model problem management of sanitary and epidemic situation in the region.

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UDC 621-83 681.51

V.B. Zvorykin, A.I. Mikhalyov, G.Y. Stanchyts

MODELING OF TRANSIENT PROCESSES IN SYSTEMS WITH DELAY

The work dedicates to investigate the transient response of the system dosage of bulk materials in the presence of the transport delay. The demands for the control system are formulated. The optimization of controllers based on the receipt of the transient response at maximum speed with no overshoot. Peculiarities setting controls are shown when developing large and small tasks.

Most models of control objects in the implicitly or explicitly have a delay between the appearance of the input action and reaction control parameters.

The transfer function of such objects is as follows:

$$W_o(s) = e^{-\tau s}\ . \tag{1}$$

where τ - delay time.

Consider modeling and calculation controllers in systems that have hysteresis, for example, tape dispenser.

All dispensers are equipped with automatic control systems performance. Performance is controlled by changing the material from the feed hopper and in the case of the tape dispenser, simultaneous correction tape speed. Performance monitoring is carried out via power sensors. System of regulation is closed. The controller has PID - control law.

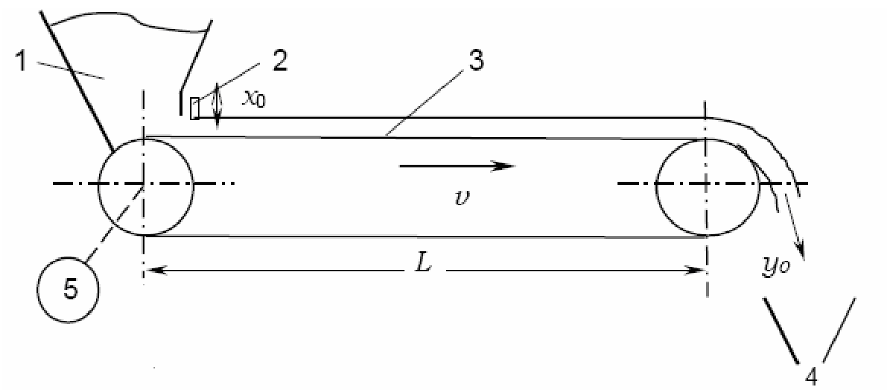

Figure 1 - Diagram tape dispenser for bulk materials

The dispenser (fig. 1) transmit bulk material from the hopper 1 into the mixer 4. The length of the conveyor is L m.

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The speed of the belt 3 driven by the electric drive 5 is v m/s. Obviously, if a time $t = 0$ change the extent of opening of the regulating flap 2, the flow of material from the tape to the mixer 4 will not move immediately, but only after some time:

$$\tau = \frac{L}{v}. \tag{2}$$

Time τ is transport delay and represent reaction yield of the object in time relative to the input action.

The mass of bulk material $m_б$, that is supplied per unit time from the hopper onto the conveyor varies depending on the position of the regulating flap. The flap is opened and closed by an actuator which includes an AC motor with a frequency-controlled inverter and the reducer.

The task of control the dispenser is formulated as follows: for a given speed of the belt v ensure the fastest possible time of receipt into the mixer 4 bulk material weight $m_{сз}$ by changing the extent of opening of the regulating flap 2.

Mathematical models of the engine, gearbox, flap, conveyor.

The transfer function of the engine:

$$W_д(s) = \frac{\omega_д}{U_з} = K_д, \tag{3}$$

where $\omega_д = \omega_{д_{max}}$ - speed flap actuator engine; $U_з$ - voltage setting.

The transfer function relating the engine speed with the angle of rotation of the gearbox shaft:

$$W_з(s) = \frac{\varphi_р}{\omega_д} = \frac{K_з}{s}, \tag{4}$$

where $K_з = \dfrac{\varphi_{р_{max}}}{\omega_{д_{max}} t_о}$; $\varphi_р$ - opening angle of the flap; $\varphi_{р_{max}}$ - maximum opening angle of the flap; $t_о$ - the opening time of the flap.

The transfer function relating the flow of material from the hopper via a conveyor belt into the mixer:

$$W_m(s) = \frac{m_с}{m_б} = \frac{K_m}{s} e^{-\tau s}, \tag{5}$$

where $K_m = \frac{m_{б_{max}}}{\varphi_{p_{max}}}$; m_c - the mass of bulk material act into the mixer; $m_{б_{max}}$ - the mass of bulk material act from hopper when flap is full opened $\varphi = \varphi_{p_{max}}$.

Perform a control system of the mixer filling two-level (fig. 2).

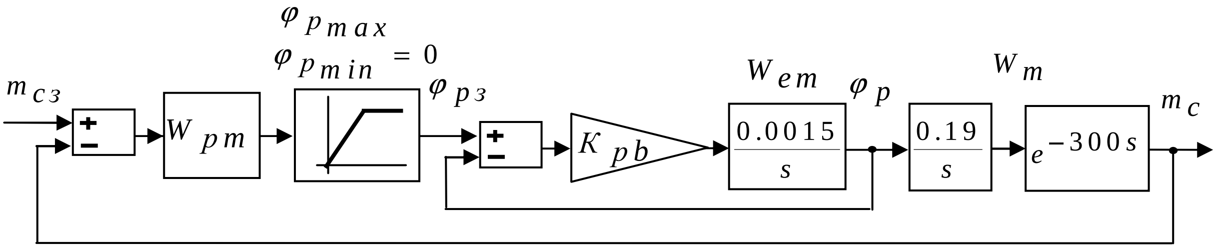

Figure 2 - Block diagram of the mixer filling system

The inner loop controls the position of the damper, outdoor loop - tape dispenser. In the block diagram is introduced non-linear element type restrictions. His presence caused by the fact that the opening angle of the flap cannot exceed $\varphi_{p_{max}}$ (the minimum value of the opening angle of the flap $\varphi_{p_{min}} = 0$).

In the control loop of the position flap applicable regulator in the form of proportional gain K_{pb}, because the flap is presented integrating link $W_{ет}(s)$ and in a closed system of regulation the static error is zero.

Statement of the problem optimization loop control of the position flap. For a given object structure management $W_{ет}(s)$ find the value of the coefficient K_{pb} which will provide the following quality indicators:

- no overshoot,
- regulation time do not greater than 15 seconds,
- transition time not more than 20 seconds.

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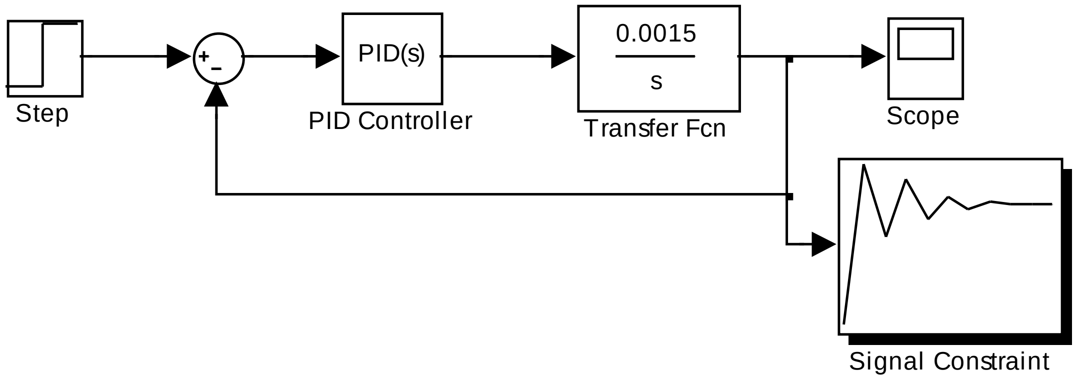

Figure 3 - Control loop model of the position flap with Optimizer

Fig. 3 shows the Simulink-model of the position flap corresponding to the block diagram shown in Fig. 2.

This model is a closed structure, which consists of the following components:

- the object of the regulation with the transfer function $W_{em}(s) = \dfrac{0.0015}{s}$ (block Transfer Fcn);
- PID - controller (PID Controller from Library Simulink Extract);
- feedback circuit and node comparisons;
- the input source in the form of a single jump (block Step);
- oscilloscope (block Scope);
- block Signal Constrain, intended for tuning PID - controller.

Search for the optimal process using block Signal Constrain illustrated the initial, intermediate and final curve (fig. 4). In the MATLAB command window displays information about the course of optimization.

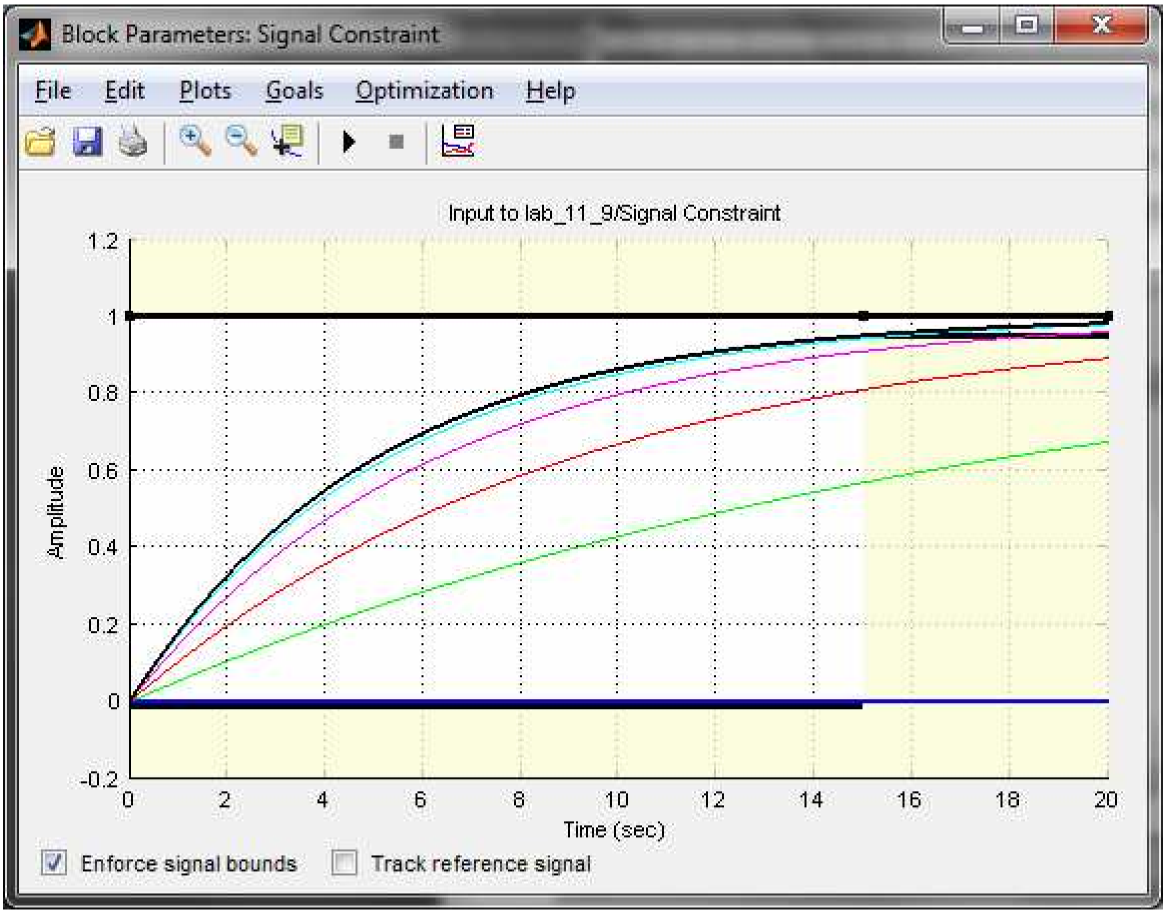

Figure 4 - The process of finding the optimal solution

Optimized transient response that fully comply with the specified quality indicators corresponds $K_{pb} = 132.85$.

To control tape dispenser use PID - controller with the transfer function:

$$W_p(s) = K_p + K_i \frac{1}{s} + K_d s \ . \qquad (6)$$

Statement of the problem optimization loop control of the tape dispenser. For the object structure control (fig. 2) find the values of the coefficients K_p, K_i, K_d, that will provide the following quality indicators:

- no overshoot,
- regulation time and time transition process should be minimal.

Construct a Simulink-model in accordance with the block diagram shown in fig. 2.

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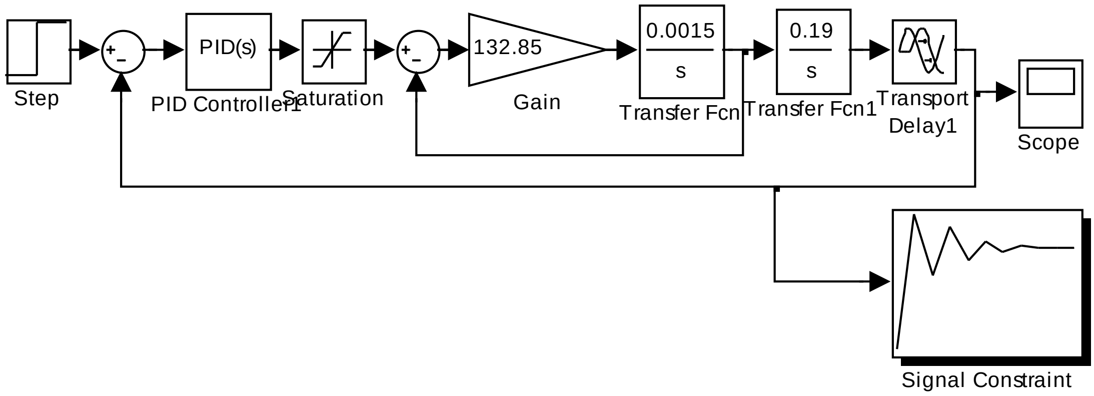

Figure 5 - Control loop model of the tape dispenser with Optimizer

Model control tape dispenser (fig. 5) is a closed structure consisting of the following components:

- loop control of the position flap, which in the model correspond to the amplifier (block Gain), integrator (Block Transfer Fcn), feedback circuit and node comparisons;
- the transfer function of the transporter $W_{т}(s)=\dfrac{0.19}{s}e^{-300s}$ which in model correspond to integrator (Block Transfer Fcn1) and link delay (block Transport Delay);
- PID - controller (block PID Controller);
- link that restrict the angle of rotation of the flap shaft (block Saturation);
- feedback circuit and node comparisons;
- input source (block Step);
- oscilloscope (block Scope);
- blockSignal Constrain, intended for tuning PID - controller.

Features of the system:

1. In developing small control signals PID - controller output does not reach the level of restriction. Over time equal to the transport delay, the reference signal for the opening of the flap is constant and determined by the expression $m_{сз}W_{pm}(s)$. According to expiration time delay system continues work how linear, providing refinement control signals to filling mixer. Since there is opportunity increase angle opening flap (instantaneous supply bulk material from hopper to tape transporter), then differentiating part regulator can have significant effect to time filling mixer.

2. When processing large control signals PID - controller output is limited to the instantaneous flow rate $m_{б_{max}}$ determined maximum angle opening flap $\varphi_{p_{max}}$. During time equal to Transport delay, the quantity of material entering to tape conveyor is maximal. For expiration time delay system in course some time continues work with maximum supply bulk material, providing refinement jobs to filling mixer. Since angle opening of the flap is maximum, then differentiating part regulator has poor effect to time filling mixer.

Fig. 6, 7 show the final optimization curves in mining control signals $m_{сз} = 1$ kg (fig. 6) and $m_{сз} = 25$ kg (fig. 7). Optimization regulators made in relation to the transport delay $\tau = 50$ s.

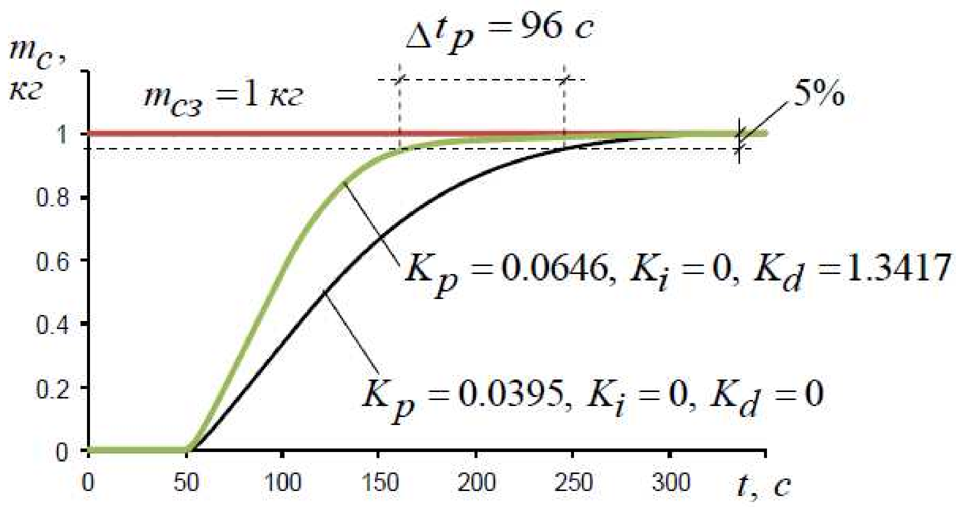

Figure 6 - Transient processes in the control system with tape dispenser $m_{сз} = 1$ kg

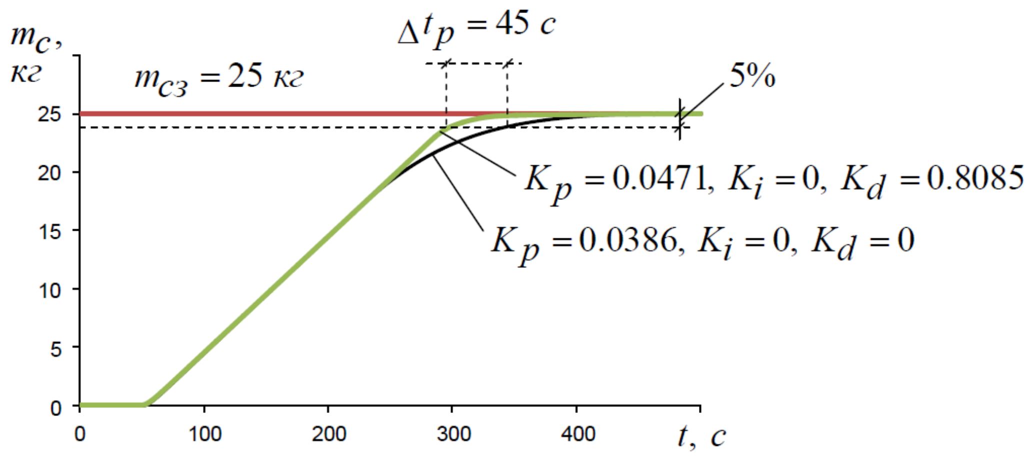

Figure 7 - Transient processes in the control system with tape dispenser $m_{сз} = 25$ kg

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As can be seen from the curves, the integral part of the PID - controller is zero. This is natural, because the control object comprises an integrator. As previously mentioned, differential part of the PID - controller when mining small control tasks (fig. 6) when the flap opening angle is smaller than the maximum value, has a stronger effect on the duration of the transient.

1.

СОДЕРЖАНИЕ

МАТЕМАТИЧНЕ ТА ПРОГРАМНЕ ЗАБЕЗПЕЧЕННЯ ІНТЕЛЕКТУАЛЬНИХ СИСТЕМ

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РЕФЕРАТИ

УДК 004:519.816

Бардачов Ю.М., Вишемирська С.В., Огнєва О.Є. **Модель підтримки прийняття рішень для визначення ефективності управління промисловим підприємством** // Системні технології. Регіональний міжвузівський збірник наукових праць.– Випуск 6 (95).– Дніпропетровськ, 2014. – С. 3-10.

Розроблена модель прогнозування економічних показників ефективності управління промисловим підприємством, заснована на спільному застосуванні інтервального прогнозу і нечіткої математики.

Бібл. 4, табл. 1.

УДК 004.032.26

Бодянський Є.В., Шафроненко А.Ю. **Відновлення даних за допомогою багатомірних нечітких екстраполяцій із таблиць з відсутніми даними** // Системні технології. Регіональний міжвузівський збірник наукових праць.– Випуск 6 (95).– Дніпропетровськ, 2014. – С. 11-17.

Запропоновано розв'язання проблеми заповнення таблиць з відсутніми даними за допомогою метода багатомірної нечіткої екстраполяції.

Бібл. 23, іл.2, табл. 1.

УДК 004.032.26

Бодянський Є.В., Дейнеко А.О., Дейнеко Ж.В., Шаламов М.А. **Еволюційна ієрархічна нейронна мережа для задачі аналізу головних компонентів та адаптивного навчання** // Системні технології. Регіональний міжвузівський збірник наукових праць.– Випуск 6 (95).– Дніпропетровськ, 2014. – С. 18-26.

Запропоновано архітектура еволюційної ієрархічної нейронної мережі для аналізу головних компонентів і швидкодіючі алгоритми її навчання, призначені для обробки багатовимірних стохастичних нестаціонарних сигналів в on-line режимі.

Бібл. 21, іл.2, табл. 1.

УДК 004.932.2

Богучарський С.І., Каграманян А.Г., Міхнова О.Д. **Сегментація зображень наоснові методу нечітких J-середніх** // Системні технології. Регіональний міжвузівський збірник наукових праць. – Випуск ? (??). – Дніпропетровськ, 2015. – С.27-34.

Причина розробки нового методу полягає у відсутності існуючих, які швидко б дозволяли виконати обробку невизначених сегментів зображень, що перетинаються, не потрапляючи у пастку локального екстремуму.Оскільки сегментація зображень щільно пов'язана з кластеризацією, границі між сегментами зображень вирішено представити у вигляді нечітких кластерів.У статті розглянуто чіткий і нечіткий варіанти обробки зображень, а також запропонована матрична модифікація методу нечіткої кластеризації J-середніх, в основу якого покладено модифікований алгоритм нечітких С-середніх.

Бібл. 14.

 ISSN 1562-9945

УДК 004.9

Булгакова О.С. **Методи аналізу даних основані на самоорганізації моделей** // Системні технології. Регіональний міжвузівський збірник наукових праць.– Випуск 6 (95).– Дніпропетровськ, 2014. – С. 35-42.

У статті розглянуті методи аналізу даних на основі самоорганізації моделей.Розглянуто основні ідеї модифікованого алгоритму МГУА (метод групового обліку аргументів) відомого як повністю автоматизоване вилучення знань на основі еволюції груп адаптивних моделей (GAME).Представлена ідея активних нейронів (використовуються різні функції активації), ця ідея може бути використана для підвищення ефективності моделей на основі узагальнення структур ітераційних і комбінаторних алгоритмів.

Бібл. 11, іл. 3.

УДК 004.89

Іващенко Г.С., Корабльов М.М. **Прогнозування часових рядів за допомогою методу висновку за прецедентами з використанням моделей штучних імунних систем** // Системні технології. Регіональний міжвузівський збірник наукових праць.– Випуск 6 (95).– Дніпропетровськ, 2014. – С. 43-52.

У статті запропоновано методи прогнозування часових рядів за допомогою штучних імунних систем.Розглянуто використання методу виведення з прецедентів за допомогою моделі штучних імунних мереж і моделі клонального відбору.У моделі на основі клонального відбору використовуются різнорідні антитіла, що створені за допомогою методу висновку за прецедентами та найпростіших методів прогнозування.Представлені результати експериментальних досліджень, що демонструють особливості запропонованих підходів.

Бібл.7, іл.2, табл. 1.

УДК 519.2:004.9

Кіріченко Л.О. **Метод розрізнення монофрактальних і мультифрактальних процесів за часовими рядами** // Системні технології. Регіональний міжвузівський збірник наукових праць.– Випуск 6 (95).– Дніпропетровськ, 2014. – С. 53-59.

На основе чисельного аналізу вибіркових мультифрактальних характеристик, отриманих методом мультифрактального детрендірованного флуктуаційного аналізу, запропонований статистичний критерій для прийняття гіпотези про монофрактальні властивості часового ряду.Представлено результати досліджень з виявлення моно- і мультифрактальних властивостей часових рядів різноматної природи.

Бібл.8 , табл.1, рис. 2.

УДК 681.5: 519.7

Коцовський В.М., Гече Ф.Е., Міца О.В. **Artificial complex neurons with half-plane-like activation function** // Системні технології. Регіональний міжвузівський збірник наукових праць.– Випуск 6 (95).– Дніпропетровськ, 2014. – С. 60-67.

Стаття присвячена проблемі реалізації булевих функцій на штучних нейронних елементах з комплексними коефіцієнтами.У роботі розглянуто питання про зв'язок між класами функцій, які можна реалізувати на комплексних нейронах із функціями активації, що породжуються розбиттям комплексної площини на дві півплощини.Також запропоновано поняття сепарабельності множин у n-вимірному просторі, яке вводиться на базі класифікації з використанням комплексних нейронів.Наведено ітеративний online алгоритм навчання комплексних нейронів та вказано достатні умови його збіжності.Отримані у роботі результати можуть бути використані при розробці інтелектуальних систем для розв'язування задач класифікації та розпізнавання образів.

Бібл. 5.

УДК 624.04+519.6

Кучеренко О.Є. **Пошук ефективної топології стержневих систем на основі напіввизначеної оптимізації** // Системні технології. Регіональний міжвузівський збірник наукових праць.– Випуск 6 (95).– Дніпропетровськ, 2014. – С. 68-73.

Розглядається модифікована задача опуклої - напіввизначеної - оптимізації топології стержневих систем з використанням пакету CVX для MATLAB. При вирішенні задачі бралися до уваги такі вимоги як деформативність, міцність та стійкість. Перевірка отриманого рішення виконувалася з використанням програмного комплексу ANSYS.

Бібл. 8, іл.2, табл. 2.

УДК 004.056.53:656.078

Лахно В.А., Петров О.С., Корченко О.Г. **Моделі, методи та інформаційні технології захисту інформаційних систем транспорту на основі інтелектуального розпізнавання загроз** // Системні технології. Регіональний міжвузівський збірник наукових праць.– Випуск 6 (95).– Дніпропетровськ, 2014. – С. 74-92.

Стаття містить результати досліджень, які спрямовані на подальший розвиток методів та моделей інтелектуального розпізнаванні загроз інформаційно-комунікаційному середовищу транспортної галузі (ІКСТГ) в умовах збільшення кількості дестабілізуючих впливів на доступність, схоронність і цілісність інформації.Розроблено метод інтелектуального розпізнавання загроз на основі дискретних процедур з використанням апарату логічних функцій та нечітких множин, що дозволяє підвищити ефективність розпізнавання, створювати ефективні аналітичні, схемотехнічні та програмні рішення СЗІ ІКСТГ.

Бібл. 19, іл.13, табл. 1

УДК 681.128+681.518.22

Мазуренко В.Б. **Застосування дискретного фільтра Калмана для вирішення задачі вимірювання рівня рідкого палива в умовах хитавиці**// Системні технології. Регіональний міжвузівський збірник наукових праць.– Випуск 6 (95).– Дніпропетровськ, 2014. – С. 93-104.

Статья присвячена побудові рекуррентного дискретного фільтру Калмана для вирішення задачі вимірювання рівня палива в баках ракети-носія при проведенні заправки в умовах коливань стартової платформи, а також деяким результатами дослідження ефективності застосування одержаного фільтру.

Бібл. 7, іл.2, табл. 1.

УДК 502/504:544.558

Ольшевський С.В., Танигіна О.М., Демченко В.Ф., Заєць Є.Р. **Моделювання кінетики плазмово-хімічного знешкодження стійких органічних забруднювачів в водних розчинах високовольтним імпульсним розрядом** // Системні технології. Регіональний міжвузівський збірник наукових праць.– Випуск 6 (95).– Дніпропетровськ, 2014. – С. 105-114.

В роботі розглянуті результати експериментальних та теоретичних досліджень впливу високовольтного імпульсно-періодичного розряду на водні розчини стійких хлорорганічних токсикантів. Показано, що експозиція розчинів p,p'–DDT, DDE та альдріна розрядом середньою потужністю ~ 100 Вт. протягом 60 хв. приводе до повного розкладання цих речовин.

Бібл. 12, іл.4, табл. 1.

УДК 621.372:538.56

Передерій В.І., Осипенко В.В., Олалі Н.В., Єременко А.П. **Інформаційна технологія підтримки прийняття рішень в ергатичних системах Інформаційна технологія підтримки прийняття рішень в ергатичних системах** // Системні технології. Регіональний міжвузівський збірник наукових праць.– Випуск 6 (95).– Дніпропетровськ, 2014. – С. 115-124.

Запропонованоудосконалення інформаційної технології підтримки прийняття рішень у складних гарантоздатних ергатичних системах. Запропоновані нечіткі адаптивні моделі формування альтернатив з урахуванням людського фактору та впливу параметрів зовнішнього середовища, а також загальний алгоритм відбору оптимальних рішень методом пропорціональної селекції.

Бібл. 11, іл. 3.

УДК 681.5

Вороненко М.О. Абрамов Г.С **Модель пошуку раціонального рішення з розподілення ресурсів** // Системні технології. Регіональний міжвузівський збірник наукових праць.– Випуск 6 (95).– Дніпропетровськ, 2014. – С. 125-130.

Розглянута модель визначення раціонального рішення керування ресурсами при знешкодженні проблемних санітарно-епідемічних ситуацій.Використовується формалізована логічна модель, яка допускає порівняльно просту комп’ютерну реалізацію.

Бібл.5, іл.1, табл.1.

УДК 621-83 681.51

Зворикін В.Б. Михальов О.І. Станчиц Г.Ю. **Моделювання перехідних процесів в системах з запізненням** // Системні технології. Регіональний міжвузівський збірник наукових праць.– Випуск 6 (95).– Дніпропетровськ, 2014. – С. 131-147.

У роботі досліджено перехідні процеси в системі дозування сипких матеріалів при наявності транспортного запізнювання.Сформульовано вимоги до системи регулювання.Виконано оптимізацію регуляторів, виходячи з отримання перехідного процесу дозування з максимальною швидкодією при відсутності

перерегулювання.Наведено особливості налаштування регуляторів при відпрацюванні великих і малих завдань.

Іл. 7, табл. 1.

УДК 004:519.816

Бардачев Ю. Н., Вышемирская С.В., Огнева О.Е.**Модель поддержки принятия решения для определения эффективности управления промышленным предприятием** // Системні технології. Регіональний міжвузівський збірник наукових праць.– Випуск 6 (95).– Дніпропетровськ, 2014. – С. 3-10.

Разработана модель прогнозирования экономических показателей эффективности управлении промышленным предприятием, основанная на совместном применении интервального прогноза и нечеткой математики.

Библ. 4, табл. 1.

УДК 004.032.26

Бодянский Е.В., Шафроненко А.Ю. **Восстановление данных с помощью многомерных нечетких экстраполяции из таблиц с пропущенными данными** // Системні технології. Регіональний міжвузівський збірник наукових праць.– Випуск 6 (95).– Дніпропетровськ, 2014. – С. 11-17.

Предложено решение проблемы заполнения таблиц с отсутствующими данными с помощью метода многомерной нечеткой экстраполяции.

Библ. 23, ил.2, табл. 1.

УДК 004.032.26

Бодянский Е.В., Дейнеко А.А., Дейнеко Ж.В., Шаламов М.А. **Эволюционная иерархическая нейронная сеть для задачи анализа главных компонентов и адаптивного обучения** // Системні технології. Регіональний міжвузівський збірник наукових праць.– Випуск 6 (95).– Дніпропетровськ, 2014. – С. 18-26.

Предложены архитектура эволюционной иерархической нейронной сети для анализа главных компонент и быстродействующие алгоритмы её обучения, предназначенные для обработки многомерных стохастических нестационарных сигналов в on-line режиме.

Библ. 21, ил.2, табл. 1.

УДК 004.932.2

Богучарский С.И., Каграманян А.Г., Михнова Е.Д. **Сегментация изображений на основе метода нечетких J-средних** // Системні технології. Регіональний міжвузівський збірник наукових праць.– Випуск 6 (95).– Дніпропетровськ, 2014. – С. 27-34.

Причина разработки нового метода заключается в отсутствии существующих, которые бы быстро позволяли выполнить обработку неопределенных перекрывающихся сегментов изображений, не застревая в области локального экстремума.Поскольку сегментация изображений тесно связана с кластеризацией, принято решение представить границы между сегментами изображений с помощью нечетких кластеров.В статье рассмотрены четкие и нечеткие варианты обработки изображений, а также предложена матричная модификация метода нечеткой кластеризации J-средних, в основу которого лег модифицированный алгоритм нечетких С-средних.

Библ. 14.

УДК 004.9

Булгакова А.С. **Методы анализа данных основанные на самоорганизации моделей** // Системні технології. Регіональний міжвузівський збірник наукових праць.– Випуск 6 (95).– Дніпропетровськ, 2014. – С. 35-42.

В статье рассмотрены методы анализа данных на основе самоорганизации моделей. Рассмотрены основные идеи модифицированного алгоритма МГУА (метод группового учета аргументов) известного как полностью автоматизированное извлечение знаний на основе эволюции групп адаптивных моделей (GAME). Представлена идея активных нейронов (используются различные функции активации), эта идея может быть использована для повышения эффективности моделей на основе обобщения структур итерационных и комбинаторных алгоритмов.

Библ. 11, илл. 3.

УДК 004.89

Иващенко Г.С., Кораблев Н.М. **Прогнозирование временных рядов на основе метода вывода по прецедентам с использованием моделей искусственных иммунных систем** // Системні технології. Регіональний міжвузівський збірник наукових праць.– Випуск 6 (95).– Дніпропетровськ, 2014. – С. 43-52.

В статье рассмотрены иммунные алгоритмы краткосрочного прогнозирования временных рядов на основе модели клонального отбора и модели иммунной сети, использующих метод вывода по прецедентам.Модель на основе клонального отбора использует разнородные антитела, построенные на основе вывода по прецедентам и простейших методов прогнозирования.Оценка эффективности моделей выполнена путем сравнительного анализа, представлены результаты экспериментальных исследований, демонстрирующие особенности предлагаемых подходов.

Библ. 7, илл.2, табл. 1.

УДК 519.2:004.9

Кириченко Л.О. **Метод распознавания монофрактальных и мультифрактальных процессов по временным рядам** // Системні технології. Регіональний міжвузівський збірник наукових праць.– Випуск 6 (95).– Дніпропетровськ, 2014. – С. 53-59.

На основе численного анализа выборочных мультифрактальных характеристик, полученных методом мультифрактального детрендированного флуктуационного анализа, предложен статистический критерий для принятия гипотезы о монофрактальных свойствах временного ряда.Представлены результаты исследований по выявлению моно- и мультифрактальных свойств временных рядов различной природы.

Библ.8 , табл.1, рис 2.

УДК 681.5: 519.7

Коцовский В.М., Гече Ф.Э., Мица А.В. **Artificial complex neurons with half-plane-like activation function** // Системні технології. Регіональний міжвузівський збірник наукових праць.– Випуск 6 (95).– Дніпропетровськ, 2014. – С. 60-67.

Статья посвящена проблеме реализации булевых функций на искусственных нейронных элементах.В работе рассмотрен вопрос, как связаны между собой классы функций, реализуемых на нейронных элементах, функции активации которых порождаются разбиением комплексной плоскости на две полуплоскости.Также предложено понятие сепарабельности множеств в n-мерном пространстве, которое вводиться на основе использования комплексных нейронов.Указан итеративный online алгоритм обучения комплексных нейронов и даны достаточные условия его сходимости.Полученные в статье результаты могут быть использованы при разработке интеллектуальных систем для решения задач распознавания и классификации образов.

Библ. 5.

УДК 624.04+519.6

Кучеренко А.Е. **Поиск эффективной топологии стержневых систем на основе полуопределенной оптимизации** // Системні технології. Регіональний міжвузівський збірник наукових праць.– Випуск 6 (95).– Дніпропетровськ, 2014. – С. 68-73.

Рассматривается модифицированная задача выпуклой - полуопределенной - оптимизации топологии стержневых конструкций с использованием пакета CVX для MATLAB. При решении задачи учитывались такие требования, как деформативность, прочность и устойчивость.Верификация полученного решения проводилась в программном комплексе ANSYS.

Библ. 8, ил.2, табл. 2.

УДК 004.056.53:656.078

Лахно В.А., Петров А.С., Корченко А.Г. **Модели, методы и информационные технологии защиты информационных систем транспорта на основе интеллектуального распознавания угроз** // Системні технології. Регіональний міжвузівський збірник наукових праць.– Випуск 6 (95).– Дніпропетровськ, 2014. – С. 74-92.

Статья содержит результаты исследований, направленных на дальнейшее развитие методов и моделей интеллектуального распознавания угроз информационно-коммуникационной среде транспортной отрасли (ИКСТО) в условиях увеличения количества дестабилизирующих воздействий на доступность, сохранность и целостность информации.Впервые разработан метод интеллектуального распознавания угроз на основе дискретных процедур с использованием аппарата логических функций и нечетких множеств, позволяющий создавать эффективные аналитические, схемотехнические и программные решения СЗИ ИКСТО.

Библ. 19, ил.13, табл. 1.

УДК 681.128+681.518.22

Мазуренко В.Б. **Применение дискретного фильтра Калмана для решения задачи измерения уровня жидкого топлива в условиях качки**// Системні технології. Регіональний міжвузівський збірник наукових праць.– Випуск 6 (95).– Дніпропетровськ, 2014. – С. 93-104.

Статья посвящена построению рекуррентного дискретного фильтра Калмана для решения задачи измерения уровня топлива в баках ракеты-носителя при проведении заправки в условиях колебаний стартовой платформы, а также некоторым результатам исследования эффективности применения полученного фильтра.

Библ. 7, ил.2, табл. 1.

УДК 502/504:544.558

Ольшевский С.В., Таныгина О.М., Демченко В.Ф., Заец Е.Р. **Моделирование кинетики плазмо-химического обезвреживания стойких органических загрязнителей в водных**

растворах високовольтным импульсним разрядом // Системні технології. Регіональний міжвузівський збірник наукових праць.– Випуск 6 (95).– Дніпропетровськ, 2014. – С. 105-114.

В работе рассмотрены результаты экспериментальных и теоретических исследований воздействия высоковольтного импульсно-периодического разряда на водные растворы стойких хлорорганических токсикантов. Показано, что экспозиция растворов p,p'–DDT, DDE и альдрина разрядом средней мощностью ~ 100 Вт. в течение 60 мин. приводит к полному разложению этих веществ.

Библ. 12, ил.4, табл. 1.

УДК 621.372:538.56

Передерий В.И., Осипенко В.В., Олали Н.В., Еременко А.П. **Информационная технология поддержки принятия решений в эргатических системах** // Системні технології. Регіональний міжвузівський збірник наукових праць.– Випуск 6 (95).– Дніпропетровськ, 2014. – С. 115-124.

Предложено усовершенствование информационной технологии поддержки принятия решений в сложных гарантоспособных эргатических системах. Предложены нечеткие адаптивные модели формирования альтернатив с учетом человеческого фактора и влияния параметров внешней среды, а также обобщенный алгоритм отбора оптимальных решений методом пропорциональной селекции.

Библ. 11, ил. 3.

УДК 681.5

Вороненко М.А., Абрамов Г.С. **Модель поиска рационального решения по распределению ресурсов** // Системні технології. Регіональний міжвузівський збірник наукових праць.– Випуск 6 (95).– Дніпропетровськ, 2014. – С. 125-130.

Рассмотрена модель определения рационального решения по управлению ресурсами при ликвидации проблемных санитарно-эпидемических ситуаций. Используется формализованная логическая модель, допускающая сравнительно простую компьютерную реализацию.

Библ.5, ил.1, табл.1.

УДК 621-83 681.51

Зворыкин В.Б. Михалев А.И. Станчиц Г.Ю. **Моделирование переходных процессов в системах с запаздыванием** // Системні технології. Регіональний міжвузівський збірник наукових праць.– Випуск 6 (95).– Дніпропетровськ, 2014. – С. 131-147.

В работе исследованы переходные процессы в системе дозирования сыпучих материалов при наличии транспортного запаздывания.Сформулированы требования к системе регулирования.Выполнена оптимизация регуляторов, исходя из получения переходного процесса дозирования с максимальным быстродействием при отсутствии перерегулирования.Приведены особенности настройки регуляторов при отработке больших и малых заданий.

Ил. 7, табл. 1.

UDC 004:519.816

Bardachev Y.N., Ogneva O.E., Vyshemirskaya S.V. **Model of support of decision-making for determination of effective management of the industrial enterprise** // System tecnologies. №6 (95). – Dnepropetrovsk, 2014. – pp. 3-10.

The model for economic indicators forecasting of the management efficiency on the industrial enterprise, which based on the joint application of interval forecast and fuzzy mathematics, is developed.

Ref. 4, tab. 1.

УДК 004.032.26

Bodyanskiy Ye.V., Shafronenko A.Yu.**Tables of data with gaps restoration using multivariate fuzzy extrapolation** // System tecnologies. №6 (95). – Dnepropetrovsk, 2014. – pp. 11-17.

The problem of the missing values in the data tables filling by using the method of multivariate fuzzy extrapolation is proposed.

Ref. 23, fig. 2, tab. 1.

УДК 004.032.26

Bodyanskiy Ye.V., Deineko A.O.,Deineko Sh.V., Shalamov M.O. **Evolving hierarchical neural network for principal component analysis tasks and its adaptive learning** // System tecnologies. №6 (95). – Dnepropetrovsk, 2014. – pp. 18-26.

Evolving hierarchical neural network architecture and adaptive learning algorithms for processing of multi-dimensional stochastic non-stationary signals in on-line mode were proposed.

Ref. 21, fig. 2, tab. 1.

UDC 004.932.2

Bogucharskiy S.I., Kagramanyan A.G., Mikhnova O.D.**Image segmentation with fuzzy J-means method** // System tecnologies. №6 (95). – Dnepropetrovsk, 2014. – pp. 27-34.

The reason for novel method development consists in absence of existing ones that could quickly cope with undefined overlapping image segments without trapping into local extremum. As image segmentation is closely related to clustering, boundaries between image segments are decided to be presented using fuzzy clusters. Crisp and fuzzy solutions to image processing are observed in this paper along with matrix modification of fuzzy J-means clustering that is proposed based on modified fuzzy C-means algorithm.

Ref. 14.

УДК 004.9

Bulgakova O.S. **Data mining methods based on self-organizing models** // System tecnologies. №6 (95). – Dnepropetrovsk, 2014. – pp. 35-42.

The paper proposes analysis of data mining methods based on self-organizing models. Reviewing the basic idea of the modified Group method of data handling (GMDH) known as the Group of Adaptive Models Evolution (GAME) network.Presents an original idea of active neurons (different activation function are sorted), this idea might be used to improve the efficiency of models based on the generalization of structures of iterative and combinatorial type algorithms.

Ref. 11, fig. 3.

UDC 004.89

Ivaschenko G.S., Korablev N.M. **Time series forecasting on the basis of the case-based reasoning using the models of artificial immune systems** // System tecnologies. №6 (95). – Dnepropetrovsk, 2014. – pp. 43-52.

This paper proposes the immune algorithms of short-term forecasting of time series based on the clonal selection model and the immune network model using the case-based reasoning. The clonal selection model uses heterogeneous antibodies on the basis of the case-based reasoning and the simplest forecasting methods. Evaluation of the effectiveness of the models is carried out by the comparative analysis; the results of experimental studies that demonstrate the features of the proposed approaches are presented.

Ref. 7, fig. 2, tab. 1.

UDC 519.2:004.9

Kirichenko L.O. **The method of distinction monofractal and multifractal process from time series** // System tecnologies. №6 (95). – Dnepropetrovsk, 2014. – pp. 53-59.

Based on the numerical analysis of the sample multifractal characteristics obtained by method of multifractal detrended fluctuation analysis the statistical criterion for accepting the hypothesis of monofractal properties of the time series is proposed. Results of investigations to identify mono- and multifractal properties of the time series of different nature are given.

Ref. 8, fig. 2, tab. 1.

UDC 681.5: 519.7

Kotsovsky V.M., Geche F.E., Mitsa O.V.**Artificial complex neurons with half-plane-like activation function** // System tecnologies. №6 (95). – Dnepropetrovsk, 2014. – pp. 60-67.

The paper deals with the problems of realization of Boolean functions on neural-like units with complex weight coefficients. The relation between classes of realizable function is considered for half-plane-like activation function. We also introduce the concept of sets separability, corresponding to our notion of neuron. The iterative online learning algorithm is proposed and sufficient conditions of its convergence are given.

Ref. 5.

UDC 624.04+519.6

Kucherenko A.E. **Using semidefinite optimization to find effective topology of truss-like elastic structures** // System tecnologies. №6 (95). – Dnepropetrovsk, 2014. – pp. 68-73.

A semidefinite optimization has been used to solve a convex problem of optimization of truss-like structures topology with CVX package of MATLAB simulation software. The solution fulfils the requirements of strength and buckling. A verification of the solution has been performed in ANSYS.

Ref. 8, fig. 2, tab. 2.

UDC 004.056.53:656.078

Lahno V.A., Petrov A.S., Korchenko A.G.**Models, methods and information technologies of protection of information systems of transport based on intellectual identification of threats** // System tecnologies. №6 (95). – Dnepropetrovsk, 2014. – pp. 74-92.

In article results of researches on development of methods and models of intellectual recognition of threats to information systems of transport. The article to contain results of the researches, allowing to raise level of protection of the automated and intellectual information systems of the transportation enterprises (AISTE) in the conditions of an intensification of transportations. The article to contain mathematical models and results of an estimation information systems having Internet connection through various communication channels. The article also considers the issues of research and protection of the AISTE under the condition of several conflict data request threads.

Ref. 19, fig. 13, tab. 1.

UDC 681.128+681.518.22

Mazurenko V.B.**Applying of discrete Kalman filter to problem of measuring of liquid propellant level under conditions of swing** // System tecnologies. №6 (95). – Dnepropetrovsk, 2014. – pp. 93-104.

The article is devoted to designing of a discrete Kalman filter for solving problem of measurement of propellant level in launch vehicle tanks during load operation under conditions of launch platform swing as well as to some results of study of effectiveness of designed filter.

Ref. 7, fig. 2, tab. 1.

UDC 502/504:544.558

Olszewski S.V., Tanygina O.M., Demchenko V.F., Zaiets E.R. **Modelling of kinetics plasma-chemical disposal of persistent organic pollutants in water solutions by high-voltage pulsed discharge** // System tecnologies. №6 (95). – Dnepropetrovsk, 2014. – pp. 105-114.

The paper considers the results of experimental and theoretical studies on the effects of high-voltage pulse-periodic discharge to water solutions of persistent organochlorine toxicants. It has been shown that exposure of solutions p, p'-DDT, DDE and aldrine by discharge an average power of ~ 100 watts. during 60 min. leads to complete degradation of these substances.

Ref. 12, fig. 4, tab. 1.

UDC 621.372:538.56

Perederiy V.I., Osipenko V.V. Olali N.V., Eremenko A.pp.**Information technology of support of decision making in ergatic system** // System tecnologies. №6 (95). – Dnepropetrovsk, 2014. – pp. 115-124.

The improved information technology to support decision-making in complex dependable human-machine systems has been offered. Proposed the fuzzy adaptive model to the formation of alternatives taking into account the human factor and influence of environmental parameters, as well as a generalized algorithm for choice the optimal solutions using proportionate selection.

Ref. 11, fig. 3.

UDC 681.5

Voronenko M.A., Abramov G.S. **The search model for rational solution of resource distribution.analysis**// System tecnologies. №6 (95). – Dnepropetrovsk, 2014. – pp. 125-130.

The model of rational decision is distinguished on carrying out the resources under the liquidation of the problem sanitary-epidemic situation. The formalized logical model is used which leads to the comparatively simple computer realization.

Ref. 5, fig. 1, tab. 1.

UDC 621-83 681.51

Zvorykin V.B., Mikhalyov A.I., Stanchyts G.Y. **Modeling of transient processes in systems with delay** // System tecnologies. №6 (95). – Dnepropetrovsk, 2014. – pp. 131-147.

The work dedicates to investigate the transient response of the system dosage of bulk materials in the presence of the transport delay. The demands for the control system are formulated. The optimization of controllers based on the receipt of the transient response at maximum speed with no overshoot. Peculiarities setting controls are shown when developing large and small tasks.

Fig. 7, tab. 1.

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