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DECISION-MAKING AT EVOLUTIONARY SEARCH DURING LIMITED NUMBER OF FUZZY EXPERIMENTS WITH MULTIPLE CRITERIA

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ABSTRACT

Context. The mechanism of decision-making during limited number of fuzzy experiments with multiple criteria are considered. The investigation object is process decision-making for project or control in complex systems with multiple criteria.

Objective. It is necessary to determine optimal (most preferred) parameters of the systems with multiple criteria. It is no the mathematical model of the system, there is limited number of fuzzy experiments only.

Method. experimental study of a process with several criteria (functions) depending on its parameters; the use of expert fuzzy evaluation to build a matrix of preferences for individual implementations; building a function of choosing preferred solutions based on a preference matrix by constructing a mathematical model of preference recognition, formulation and solving the problem of generalized mathematical programming as the final step in building the selection mechanism. The decision-making mechanism depends on the expert assessment procedure when comparing a limited set of results with each other, as well as on the statement of conditions when solving the problem of generalized mathematical programming. Comparison of a finite number of fuzzy experiments is convenient for expert evaluation. Presentation of the final choice as a result of solving the problem of generalized mathematical programming is convenient for using such a mechanism in automatic control systems already without human intervention. The proposed scheme of decision-making during limited number of fuzzy experiments has been applied to decision-making of project management for pellet burner.

Results. Experimental decision-making fuzzy results are presented in the presence of several criteria for a pellet burner of a tubular heater, which confirm the acceptability of the developed decision-making mechanism. It was proposed the new scheme for constructing a selection mechanism for decision-making in systems with several criteria where there is a sample of fuzzy experimental results.

Conclusions. The scheme of decision-making is includes the solving the generalized mathematical programming as the final step in building the selection mechanism. For the problem of generalized mathematical programming it may be applied the evolutionary search with choice function in form of preference or in form of lock.

KEYWORDS: decision-making, multiple criteria, fuzzy experiments, function of choosing, evolutionary search.

NOMENCLATURE

a_{1i}, a_{2i} are the choice function parameters;
x is a set of inlet system parameters;
x^i is a scalar parameters (continuous or discrete);
Ω is a set of admissible parameters;
z is a set of outlet system functions (parameters);
z^f is a one from output parameters;
R_S is a fuzzy binary choice relation;
R_G is a fuzzy generation relation;
$S(X)$ is a selection function;
$G(X)$ is a generation function;
$G_H(X)$ is a set of new solutions;
B_{ob} is a table of experimental results;
B is a matching matrix of experimental results;
$\Gamma(x)$ is a choice function;
N_{ob} is a number of experiments;
N_b is a number of branches for evolutionary search;
N_E is a number of new solutions;
N_{op} is a number of preferred solutions;
S_b is a burner area;
S_{fir} is an useful area for primary air;
Lp is a primary air flow;
L is a total air flow;
S, Sp are the square parameters of burner;
Y_A, Y_{CO}, Y_{NO} are the outlet parameters of burner;
X is a subset of parameters;
X_k is a set of preferred solutions according to the binary choice relation R_S at the iterate step k;
k is an iterate step;
X_{k-1} is a set of preferred solutions according to the binary choice relation R_S at the iterate step k–1;
X_{jk} is a set of preferred solutions according to the binary choice relation R_S at the iterate step k for the branch j of evolutionary search;
W is a power of burner.

INTRODUCTION

The basis of the research is a fuzzy experiment in which the permissible range of parameters determining the state of the system is comprehensively investigated. In each experiment, in addition to the input parameters of the system, the output functions (criteria) of the system under

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study are measured or calculated. If we confine ourselves only to the experimental sampling of fuzzy parameters, then it will not be possible to make decisions about the preference of the system parameters over the entire allowable area. It is advisable to build a mathematical model of the function of choice, which will allow to extend the rule of preferences of fuzzy parameters to the entire admissible region. Having an expression for the function of choice, we can formulate and solve the problem of finding the most preferable solutions. The search of the most preferable solutions can be implemented as a result of solving a generalized mathematical programming problem.

The object of study is the process of decision-making while developing or managing systems with some fuzzy parameters. The mathematical model of such system is used to make decisions for the development or management of systems. The mathematical model of the system can be built on the basis of deductive laws of functioning or on the basis of an experimental study of the system.

The subject of study is the process of decision-making for project or control in complex systems with multiple criteria when information about the system is presented in the form of a limited set of fuzzy experiment results.

The purpose of the work is to increase the speed the decision-making process for a system with several criteria when setting information about the properties of the system is a set of fuzzy experimental results.

1 PROBLEM STATEMENT

A system is characterized by a set of parameters $x = \{x^1, x^2, \ldots, x^n\}$, $x \in \Omega$ and a set of output parameters (functions, criteria) $z = \{z^1, z^2, \ldots, z^f\}$. There are training set of experimental results: $B_{ob} = \langle x_q\ y_q \rangle$, $q = 1,2, \ldots, N_{ob}$ and the result of the expert evaluation in the form of the of the evaluation table $B = \{b_{ij}\}$, $i = 1,2, \ldots, N_{ob}$, $j = 1,2, \ldots, N_{ob}$, which is obtained using expert choice relation $\widetilde{R}$, where b_{ij} – is the table of fuzzy relation.

It is required to find the choice function C for all set Ω with binary relation $\widetilde{R}_S$ such that binary relation $\widetilde{R}_S$ corresponds with expert choice relation $\widetilde{R}$, with the table of fuzzy relation $B = \{b_{ij}\}$, $i = 1,2, \ldots, N_{ob}$, $j = 1,2, \ldots, N_{ob}$ $B = \{b_{ij}\}$, $i = 1,2, \ldots, N_{ob}$, $j = 1,2, \ldots, N_{ob}$.

2 REVIEW OF THE LITERATURE

There is sufficient experience in using binary relations of choice in constructing a mechanism for choosing decisions, in particular, scientific results [1−4] and other.

If there is a system that does not have a reliable mathematical model based on deductive laws of functioning, then the inductive principles of mathematical modelling of such systems are known [5, 6] that have received significant development. In inductive modelling, according Ivakhnenko A. G. and others, various mathematical models were constructed from experimental data. In this case, it is possible to build functional dependencies for each of several output functions of the system. Having mathematical dependencies for several output functions, you can solve the decision problem as a multi-objective optimization problem. There is a fairly large number of scientific results in the field of multi-optimized optimization [7−10].

Most of these results relate to the situation where there are mathematical models for each of the output functions – Pareto optimization. In this case, the adoption of the final decision from the set of Pareto-optimal is an additional procedure. This scema is fulfil possible.

The formulation of an optimization problem as an optimization task with respect to choice relation is an alternative approach. Previously, generalized mathematical programming problems were formulated for which solution methods were proposed [11, 12] and other. Later works are also devoted to solving the problem of generalized mathematical programming, for example [13].

Effective methods for solving optimization problems are developed on the basis of evolutionary search algorithms, for example, [14−16]. Including evolutionary algorithms useful for solving problems of generalized mathematical programming [16, 17] without the convexity condition of choice relation.

The utilization of fuzzy sets and fuzzy relations [18, 19] is a new state of investigations of complex objects.

Multicriteria Fuzzy Decision-Making is presented in [20] and results today, for example [21].

Previously, it was offered a general scheme for constructing a selection mechanism for decision-making in systems with several criteria where there is a sample of experimental results only [22]. But constructing a selection mechanism for decision-making in systems with several criteria where there is a sample of fuzzy experimental results was not presented before. The scheme of decision-making includes the solving the problem of generalized mathematical programming as the final step of the selection mechanism. For the solving the problem of generalized mathematical programming may be applied the evolution search algorithm with choice function in form of preference or in form of lock [23, 24].

3 MATERIALS AND METHODS

The system is characterized by the set of parameters $x = \{x^1, x^2, \ldots, x^n\}$ and there are the set of output parameters (functions, criteria) $z = \{z^1, z^2, \ldots, z^f\}$.

After experimental investigation it was obtained the set of experimental results: $B_{ob} = \langle x_q\ y_q \rangle$, $q = 1,2, \ldots, N_{ob}$. In This results will be called presentation according to terminology of the theory of decision making [2–4]. We assume that according to expert evaluation it was formed the result of the expert evaluation in the form of the of the evaluation table $B = \{b_{ij}\}$, $i = 1,2, \ldots, N_{ob}$, $j = 1,2, \ldots, N_{ob}$, which is obtained using expert choice relation $\widetilde{R}$, where b_{ij} – is the table of fuzzy relation.

It is necessary to find the fuzzy binary relation $\widetilde{R}_S$ with membership function $\mu\widetilde{R}_S(x, x)$ that taking account the set of presentations of the training sample B_{ob} by ex-

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pert evaluation of output functions for any pair of presentations, so that the binary relation $\widetilde{R}_S$: $x_i \ \widetilde{R}_S x_j$ for $i, j = 1,2, ..., N_{ob}$. The result of the expert evaluation for the comparison of the presentations with each other will be represented in the form of the matching matrix $B = \{b_{ij}\}$, $i = 1,2, ..., N_{ob}$, $j = 1,2, ..., N_{ob}$, where $b_{ij} \in \{\alpha_1, \alpha_2, \ldots, \alpha_\zeta\}$, α_i – is a possible evaluation of pair preference.

The fuzzy binary relation $\widetilde{R}_S$ with the choice function obtained in this way can be used to search for the most preferable solutions on the entire Ω set, taking into account possible limitations as well.

The methods for solving the problems are based on the approach to the evolutionary search for R_S – optimal solutions. For subset X, $X \subset \Omega$ we denote the function of choice in the form

$$S(X) = \{x \in X \mid \forall y \in [X \setminus S(X)], x\widetilde{R}_S y\}. \quad (1)$$

We shall assume that set $S(X)$ contains the concrete number of elements N_{op}.

We shall that for the set **Ω** it was determined relation $\widetilde{R}_G$ with membership function $\mu_{\widetilde{R}_G}(x, y)$: $\Omega \times \Omega \to [0,1]$. Relation $\widetilde{R}_G$ will be termed generation relation.

For subset X, $X \subset \Omega$ we denote the function of generation in the form

$$G(X) = X \cup G_H(X). \quad (2)$$

We shall assume that set $G(X)$ contains the concrete number of elements N_E.

The algorithm to search R_S – optimal solution can be represented as

$$X_k = S(G(X_{k-1})), \ k = 1,2,... \quad (3)$$

The iterate algorithm (3) – is the general form of evolutionary search.

According to [15–17] we will consider the decomposition

$$X_k = \bigcup_{j=1}^{N_b} X_{jk}, \ X_{ik} \cap X_{jk} = \varnothing, \ i \neq j. \quad (4)$$

The algorithm (3) takes the form

$$X_{jk} = S(G(X_{jk-1})), \ j = \overline{1, N_b}, \ k = 1,2,... \quad (5)$$

These iterate algorithms (3), (5) are the general form of evolutionary search.

The evolutionary search algorithm converges to the most preferred solution of choice relation. This position has been theoretically and experimentally proven for clear choice relationships. For a fuzzy choice, this position is based on experimental results.

4 EXPERIMENTS

There are considered tubular gas heater [18]. Tubular heaters design parameters (inlet system parameters) are below:

– Burner area, S_b;
– Useful area for primary air passage, S_{fir};
– Primary air flow, L_1;
– Total air flow, L_{tot};
– Burner power, W.

There are criteria (outlet system functions) of the heater:

– Ash transfer by the time, A;
– Concentration CO at exhaust gases, C_{CO};
– Concentration NO_x at exhaust gases, C_{NOx}.

There are following requirements for parameters that characterize tubular heaters work: for CO it is less than 130 mg/m^3 and for NO_x – less than 250 mg/m^3. Therefore such tags as CO and NO_x are shown at tubular heater schematically block diagram. Also such parameter as ash is typical because of strengthened primary air supply creates unintended carrying out ash from the burner. It leads to tube clogging, which degrades heat transfer and reduces tube efficiency time. Tubular heater pellets burner principle diagram is shown in Fig. 1.

For expert evaluation the rating scale was used $b_{ij} \in \{0; 0.3; 0.4; 0.5; 0.6; 0.7\}$; which make sense: {much worse; worse; slightly worse; comparable; slightly better; better; much better}.

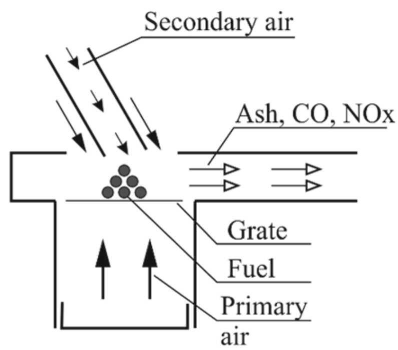

Figure 1 – Tubular heater pellets burner principle diagram

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Table 1 − Matching matrix for experimental data array 1

№	S	S_P	L	L_P	W	Y_A	Y_{CO}	Y_{NOx}
	m²	*m²*	*m³/h*	*m³/h*	*kW*	*g/*min	*mg/m³*	*mg/m³*
1	0.005	0.00286	572.4	25.2	33.5	2.1	510	293
2	0.005	0.00286	543.6	23.4	31.3	2.88	6734	207
3	0.005	0.00286	543.6	21.6	54.7	2.77	43	259
4	0.01	0.00643	633.6	46.8	18	0.21	4500	257
5	0.01	0.00643	651.6	54	32	0.47	694	205
6	0.01	0.00643	684	50.4	35.5	5.5	110	230
7	0.0025	0.00021	201	2.7	6.4	3.57	2765	89
8	0.0025	0.00021	168	4.1	9	7	2902	134
9	0.0025	0.00021	165	4.3	18	10	7214	109
10	0.0025	0.00021	151	5.1	18	7	7844	125
11	0.0025	0.00021	215	2.2	4.7	1.6	1429	146
12	0.0025	0.00021	201	2.8	11.3	4.9	1311	193
13	0.0025	0.00021	196	3	10	5	1019	210
14	0.0025	0.00021	182	3.9	12.8	3.6	779	212
15	0.0025	0.00021	178	2.5	5.3	1.8	812	201
16	0.0025	0.00021	167	2.8	4.5	0.7	2148	160
17	0.0025	0.00021	155	3	6	1.7	722	265
18	0.0025	0.00021	150	3.5	11.2	2.8	617	259
19	0.0025	0.00021	140	4	18	5.4	1144	240
20	0.0025	0.00021	136	4.5	22.5	10.5	853	257
21	0.0025	0.00021	128	7	22.5	11.3	783	261
22	0.0025	0.00021	127	2.5	8.2	1.9	1099	134
23	0.0025	0.00021	123	3	9	1	450	188
24	0.0025	0.00021	111	3.4	11.3	1.9	246	151
25	0.0025	0.00021	105	3.8	15	3	438	190
26	0.0025	0.00021	97	4.1	15	4.8	1225	238
27	0.0025	0.00021	85	5	22.5	10.3	830	203
28	0.0025	0.00021	80	6.5	18	10.8	945	217
29	0.0025	0.00021	210	2.75	3.9	1.3	2926	161
30	0.0025	0.00021	175	4.1	9	3.4	6663	56
31	0.0025	0.00021	172	4.3	7.5	5.6	2845	148
32	0.0025	0.00021	168	5.1	18	35	1986	131
33	0.0025	0.00021	152	2.2	5	5	1826	116

Table 2 − Matching matrix for experimental data array 1. Results of experiments for 33 modes

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DATA 0.5,0.3,0.5,0.6,0.7,0.7,0.7,0.5,0.7,0.5,0.7,0.7,0.7,0.4,0.4,0.4,0.5,0.6,0.7,0.7,0.7
DATA 0.7,0.5,0.7,0.7,0.7,0.7,0.7,0.7,0.7,0.7,0.7,0.7,0.7,0.7,0.6,0.6,0.7,0.7,1.0,1.0,1.0
DATA 0.5,0.3,0.5,0.6,0.7,0.6,0.6,0.5,0.7,0.6,0.6,0.6,0.5,0.4,0.3,0.4,0.5,0.6,1.0,1.0,1.0
DATA 0.4,0.3,0.3,0.5,0.7,0.5,0.4,0.4,0.5,0.4,0.4,0.4,0.4,0.3,0.3,0.3,0.3,0.3,0.6,0.6,0.6
DATA 0.3,0.3,0.3,0.3,0.5,0.3,0.3,0.3,0.4,0.3,0.4,0.3,0.3,0.3,0.0,0.3,0.4,0.4,0.5,0.5,0.5
DATA 0.3,0.3,0.4,0.5,0.7,0.5,0.5,0.5,0.6,0.4,0.5,0.4,0.4,0.3,0.0,0.3,0.3,0.5,0.7,0.7,0.5
DATA 0.3,0.3,0.4,0.6,0.7,0.5,0.5,0.5,0.6,0.5,0.5,0.5,0.5,0.3,0.0,0.3,0.5,0.5,0.7,0.7,0.6
DATA 0.5,0.3,0.5,0.6,0.7,0.5,0.5,0.5,0.6,0.5,0.5,0.5,0.5,0.4,0.0,0.3,0.5,0.5,0.7,0.7,0.7
DATA 0.3,0.3,0.3,0.5,0.6,0.4,0.4,0.4,0.5,0.4,0.4,0.4,0.4,0.3,0.0,0.3,0.4,0.4,0.5,0.5,0.5
DATA 0.5,0.3,0.4,0.6,0.7,0.6,0.5,0.5,0.6,0.5,0.6,0.5,0.5,0.3,0.0,0.3,0.5,0.5,0.7,0.7,0.7
DATA 0.3,0.3,0.4,0.6,0.6,0.5,0.5,0.5,0.6,0.4,0.5,0.5,0.4,0.3,0.0,0.3,0.5,0.5,0.6,0.6,0.6
DATA 0.3,0.3,0.4,0.6,0.7,0.6,0.5,0.5,0.6,0.5,0.5,0.5,0.5,0.3,0.0,0.3,0.5,0.5,0.6,0.6,0.6
DATA 0.3,0.3,0.5,0.6,0.7,0.6,0.5,0.5,0.6,0.5,0.6,0.5,0.5,0.3,0.0,0.3,0.5,0.5,0.6,0.6,0.6
DATA 0.6,0.3,0.6,0.7,0.7,0.7,0.7,0.6,0.7,0.7,0.7,0.7,0.7,0.5,0.3,0.5,0.6,0.7,1.0,1.0,1.0
DATA 0.6,0.4,0.7,0.7,1.0,1.0,1.0,1.0,1.0,1.0,1.0,1.0,1.0,0.7,0.5,0.6,0.7,0.7,1.0,1.0,1.0
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DATA 0.6,0.4,0.6,0.7,0.7,0.7,0.7,0.7,0.7,0.7,0.7,0.7,0.7,0.5,0.4,0.5,0.6,0.6,1.0,1.0,1.0
DATA 0.5,0.3,0.5,0.7,0.6,0.7,0.5,0.5,0.6,0.5,0.5,0.5,0.5,0.4,0.3,0.4,0.5,0.5,0.7,0.7,0.7
DATA 0.4,0.3,0.4,0.7,0.6,0.5,0.5,0.5,0.6,0.5,0.5,0.5,0.5,0.5,0.3,0.3,0.4,0.5,0.6,0.6,0.6
DATA 0.3,0.0,0.0,0.4,0.5,0.3,0.3,0.3,0.5,0.3,0.4,0.4,0.4,0.0,0.0,0.0,0.0,0.3,0.4,0.5,0.5,0.5
DATA 0.3,0.0,0.0,0.4,0.5,0.5,0.4,0.3,0.5,0.3,0.4,0.4,0.4,0.0,0.0,0.0,0.0,0.3,0.4,0.5,0.5,0.5
DATA 0.3,0.0,0.0,0.4,0.5,0.5,0.4,0.3,0.5,0.3,0.4,0.4,0.4,0.0,0.0,0.0,0.0,0.3,0.4,0.5,0.5,0.5

Table 3 − Matching matrix for experimental data array 2

DATA 0.5,0.5,0.0,0.3,0.5,0.3,0.3,0.3,0.3,0.3,0.5,0.3
DATA 0.5,0.5,0.0,0.5,0.6,0.3,0.3,0.3,0.3,0.3,0.6,0.4
DATA 1.0,1.0,0.5,1.0,1.0,1.0,1.0,1.0,1.0,1.0,1.0,1.0
DATA 0.7,0.5,0.0,0.5,0.6,0.3,0.3,0.3,0.4,0.4,0.6,0.6
DATA 0.5,0.4,0.0,0.4,0.5,0.3,0.3,0.3,0.3,0.3,0.5,0.4
DATA 0.7,0.7,0.0,0.7,0.7,0.5,0.5,0.4,0.5,0.5,0.6,0.5
DATA 0.7,0.7,0.0,0.7,0.7,0.5,0.5,0.5,0.5,0.6,0.7,0.5
DATA 0.7,0.7,0.0,0.7,0.7,0.5,0.5,0.5,0.5,0.4,0.7,0.6
DATA 0.7,0.7,0.0,0.6,0.5,0.5,0.5,0.5,0.5,0.5,0.6,0.6
DATA 0.7,0.7,0.0,0.6,0.7,0.5,0.4,0.6,0.5,0.5,0.6,0.5
DATA 0.5,0.4,0.0,0.4,0.5,0.4,0.3,0.3,0.4,0.4,0.5,0.3
DATA 0.7,0.6,0.0,0.4,0.6,0.5,0.5,0.4,0.4,0.5,0.7,0.5

5 RESULTS

There are presented results with choice function in the form (10).

$$\Gamma(x) = \Pi_{i=1}^{5} \cdot (1 + a_{1i} \cdot (a_{2i} - r_i)^2) \quad (10)$$

$$r_1 = x_1^{\,1} - x_2^{\,1};\ r_2 = x_1^{\,2} - x_2^{\,2};\ r_3 = x_1^{\,3} - x_2^{\,3};\ r_4 = x_1^{\,4} - x_2^{\,4};\ r_5 = x_1^{\,5} - x_2^{\,5}; \quad (11)$$

$$\Gamma(x_1) \geq \Gamma(x_2) \equiv x_1 \cdot \widetilde{R} \cdot x_2. \quad (12)$$

Parameters a_{1i}, a_{2i} were obtained after evolutionary search the choice function for array 1 of experimental data and for array 2 of experimental data.

The choice function in the form (10) with specific values of parameters A_1, A_2 ,…, Aa_6 was used to solve the problem of generalized mathematical programming: to find maximum MAX $\mu\widetilde{R}_S$ *(x,y) of* choice function with restrictions: $0.002 \leq x_1 \leq 0.1$; $0.0002 \leq x_2 \leq 0.007$; $80 \leq x_3 \leq 650$; $2 \leq x_4 \leq 50$; $4 \leq x_5 \leq 55$

The aim of this paper is to summarize the present position of fuzzy MCDM research area. This summary includes the classification of a mathematical decision-making model, the distributions of publications with respect to their subject areas, publication years, citation frequencies, authors, and publishing journals. We also classify the studies into three groups: The first group develops new fuzzy methodologies or modifies the existing approaches; second group uses the existing approaches in a specific problem area. Third group integrates different MCDM techniques. It also presents expected future trends on fuzzy MCDM.

Step 1: Determine key criteria and sub-criteria for a comprehensive assessment of the potential supplier. At this stage, the identification of key criteria and sub-criteria is based on a review of the literature, SCOR metrics and scientific reports related to the content of the research to determine the necessary criteria for the topic.

Step 2: Hybrid fuzzy set theory into the ANP model is the most effective tool for addressing complex problems of decision-making, which has a connection with various qualitative criteria. There are ten suppliers that are highly effective for providing plastic raw materials. In this step, an FANP is proposed to identify the weight of all criteria.

Step 3: For ranking potential suppliers list, VIKOR model is used in the final stage. VIKOR ranks alternatives and determines the solution named compromise that is the closest to the ideal.

Evolutionary search for solving the problem of generalized mathematical programming is illustrated at Table 5 and results of evolutionary search for three branches of evolution are presented in Table 6.

Table 4 − Evolutionary search the choice function

Iteration step of evolutionary search	Error at the training array 1	Error at the test array 2
1	0.3822	
2	0.3679	
4	0.2774	
8	0.1612	
15	0.1612	
20	0.1552	
25	0.1433	
35	0.1432	
75	0.1430	
500	0.1401	0.1646

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Table 5 − Evolutionary search for solving the problem of generalized mathematical programming

Iteration step of evolution	Maximum function Branch 1 of evolution	Maximum function Branch 2 of evolution	Maximum function Branch 3 of evolution
1	0.7462	0.7247	0.5972
2	0.8294	0.9682	0.7936
3	0.9727	0.9721	0.9353
…			
10	0.9727	0.9721	0.9691
300	0.9839	0.9837	0.9787

Table 6 − Result of evolutionary search for solving the problem of generalized mathematical programming

Branches of evolution	Parameter 1 x^1	Parameter 2 x^2	Parameter 3 x^3	Parameter 4 x^4	Parameter 5 x^5
Branch 1	0.00517	0.000508	251.6	5.297	16.73
Branch 2	0.00499	0.000537	273.0	6.809	15.98
Branch 3	0.00524	0.000525	186.5	2.000	8.192

6 DISCUSSION

Matrix of conformity (Table 3 and Table 4) is the result of expert assessment and is subjective. For expert assessment, it is obviously possible to use the whole variety of available pair-wise comparison methods and use a different scale for such an assessment. The choice function given in the article in the form of an algebraic function is certainly not the only possible one, here you can use the whole variety of pattern recognition methods.

At Literature Review [20] are presented different methods of mathematical decision-making models among them: Multicriteria decision-making (MCDM), fuzzy multiattribute decision-making (MADM), fuzzy multiobjective decision-making (MODM).

In [21] are presented the detail realisation of Fuzzy Multicriteria Decision-Making Model (MCDM). There are three stages of the mathematical modelling:

Step 1: At this stage it was determine key criteria and sub-criteria for a comprehensive assessment of the potential supplier. The identification of key criteria and sub-criteria is based on a review of the literature, SCOR metrics and scientific reports related to the content of the research to determine the necessary criteria.

Step 2: At this stage are applied hybrid fuzzy set theory into the ANP model for the most effective tool, which has a connection with various qualitative criteria. In this step, an FANP is proposed to identify the weight of all criteria.

Step 3: At the final stage the VIKOR model is used. VIKOR ranks alternatives and determines the solution named compromise that is the closest to the ideal.

As you can see, in the set of multicriteria decision-making methods (MCDM), the results of the experimental study of the object and their expert assessment are not used directly. The resulting compromise solution gives the final solution, but if the requirements for the compromise solution change, then the sequence of steps 1–3 must be repeated, that is, the resulting model is difficult to use in the research process. The proposed decision-making approach based on evolutionary search algorithms allows not only obtaining a model, but also makes it possible to solve new problems on its basis, using evolutionary search as a solution to a stochastic programming problem.

Comparison of the results of the development of a mathematical decision-making model based on a finite set of experimental results using the approach of fuzzy experiments and without this approach showed that using the approach of fuzzy experiments it is possible to increase the adequacy of the mathematical decision-making model and reduce the error of erroneous recognition of results for the verification (control) sequence.

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As you can see, in the set of Multicriteria decision-making (MCDM) methods, the results of the experimental study of the object and their expert assessment are not used directly. The resulting compromise solution gives the final solution, but if the requirements for the compromise solution change, then the sequence of steps 1–3 must be repeated, that is, the resulting model is difficult to use in the research process. The proposed decision-making approach based on evolutionary search algorithms allows not only obtaining a model, but also makes it possible to solve new problems on its basis, using evolutionary search as a solution to a stochastic programming problem.

CONCLUSIONS

Thus, the selection mechanism extends to the entire allowable range of input parameters. The constructed selection function is determined already on the whole admissible space of input parameters, and not only on the set of experimental points.

The decision-making includes the following procedures: an experimental study of a technical system with several fuzzy criteria (functions) depending on its parameters; the use of expert evaluation to build a matrix of preferences for individual implementations; building a function of choosing preferred solutions based on a preference matrix by constructing a mathematical model of preference recognition, formulation and solving the prob-

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lem of generalized mathematical programming as the final step in building the selection mechanism.

The scientific novelty is result presented as a holistic decision-making mechanism for a fuzzy system based on inductive modelling of complex systems, in which the following steps can be distinguished: an experimental study of a process with several fuzzy criteria (functions) depending on its parameters; the use of expert evaluation to build a matrix of preferences for individual implementations; building a function of choosing preferred solutions based on a preference matrix by constructing a mathematical model of preference recognition, formulation and solving the problem of generalized mathematical programming as the final step in building the selection mechanism.

The practical significance of obtained results is that the stated decision-making mechanism can be used for a wide range of complex fuzzy systems with several criteria.

Prospects for further research are to the improvement of methods and means for constructing a function of choice for a limited number of fuzzy experimental results.

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ПРИЙНЯТТЯ РІШЕНЬ ПРИ ЕВОЛЮЦІЙНОМУ ПОШУКУ ПРИ ОБМЕЖЕНІЙ КІЛЬКОСТІ НЕЧІТКИХ ЕКСПЕРИМЕНТІВ З КІЛЬКОМА КРИТЕРІЯМИ

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АНОТАЦІЯ

Актуальність. Розглянуто механізм прийняття рішень під час обмеженої кількості нечітких експериментів з кількома критеріями. Об'єктом дослідження є процес прийняття рішень щодо проекту або управління в складних системах з декількома критеріями.

Мета. Необхідно визначити оптимальні (найбільш переважні) параметри систем з кількома критеріями, користуючись не математичною моделлю системи, а лише обмеженою кількістю нечітких експериментів.

Метод. Експериментальне дослідження процесу з кількома критеріями (функціями) залежно від його параметрів; використання експертної нечіткої оцінки для побудови матриці уподобань для окремих реалізацій; побудова функції вибору кращих рішень на основі матриці переваг шляхом побудови математичної моделі розпізнавання переваг, формулювання та вирішення проблеми узагальненого математичного програмування як завершального етапу побудови механізму відбору. Механізм прийняття рішень залежить від процедури експертної оцінки при порівнянні обмеженого набору результатів між собою, а також від постановки умов при вирішенні задачі узагальненого математичного програмування. Порівняння кінцевої кількості нечітких експериментів зручно для експертної оцінки. Презентація остаточного вибору в результаті вирішення задачі узагальненого математичного програмування зручна для використання такого механізму в системах автоматичного управління вже без участі людини. Запропонована схема прийняття рішень під час обмеженої кількості нечітких експериментів була застосована до прийняття рішень з управління проектами паливних гранул.

Результати. Нечіткі результати експериментального прийняття рішень представлені за наявності кількох критеріїв для пелетного пальника трубчастого нагрівача, які підтверджують прийнятність розробленого механізму прийняття рішень. Запропоновано нову схему побудови механізму відбору для прийняття рішень в системах з декількома критеріями, де є вибірка нечітких експериментальних результатів.

Висновки. Схема прийняття рішень включає вирішення узагальненого математичного програмування як завершальний етап побудови механізму відбору. Для проблеми узагальненого математичного програмування може бути застосований еволюційний пошук з функцією вибору у формі переваги або у формі блокування.

КЛЮЧОВІ СЛОВА: прийняття рішень, множинні критерії, нечіткі експерименти, функція вибору, еволюційний пошук.

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ПРИНЯТИЕ РЕШЕНИЙ ПРИ ЭВОЛЮЦИОННОМ ПОИСКЕ ПРИ ОГРАНИЧЕННОМ КОЛИЧЕСТВЕ НЕЧЕТКИХ ЭКСПЕРИМЕНТОВ С НЕСКОЛЬКИМ КРИТЕРИЯМИ

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АННОТАЦИЯ

Актуальность. Рассмотрен механизм принятия решений во время ограниченного количества нечетких экспериментов с несколькими критериями. Объектом исследования является процесс принятия решений по проекту или управления в состав ных системах с несколькими критериями.

Цель. Необходимо определить оптимальные (наиболее предпочтительные) параметры систем с несколькими критериями, используя не математическую модель системы, а лишь ограниченное количество нечетких экспериментов.

Метод. Экспериментальное исследование процесса с несколькими критериям (функциями) в зависимости от его параметров; использование экспертной нечеткой оценки для построения матрицы предпочтений для отдельных реализаций; построение функции выбора лучших решений на основе матрицы преимуществ путем построения математической модели распознавания преимуществ, формулирования и решения проблемы обобщенного математического программирования как заключительного этапа построения механизма отбора. Механизм принятия решений зависит от процедуры экспертной оценки при сравнении ограниченного набора результатов между собой, а также от постановки условий при решении задачи обобщенного математического программирования. Сравнение конечного числа нечетких экспериментов удобно для экспертной оценки. Презентация окончательного выбора в результате решения задачи обобщенного математического программирования

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удобна для использования такого механизма в системах автоматического управления уже без участия человека. Предложенная схема принятия решений во время ограниченного количества нечетких экспериментов была применена к принятию решений по управлению проектами топливных гранул.

Результаты. Нечеткие результаты экспериментального принятия решений представлены при наличии нескольких критериев для пеллетного горелки трубчатого нагревателя, подтверждающие приемлемость разработанного механизма принятия решений. Предложена новая схема построения механизма отбора для принятия решений в системах с несколькими критериями, где есть выборка нечетких экспериментальных результатов. Выводы. Схема принятия решений включает решение обобщенного математического программирования как завершающий этап построения механизма отбора. Для проблемы обобщенного математического программирования может быть применен эволюционный поиск с функцией выбора в форме преимущества или в форме блокировки.

КЛЮЧЕВЫЕ СЛОВА: принятие решений, множественные критерии, нечеткие эксперименты, функция выбора, эволюционный поиск.

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