UDK 621.372:538.56

V.I.Perederiy, V.V. Osipenko, N.V.Olali, A.P.Eremenko

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.

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

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

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).

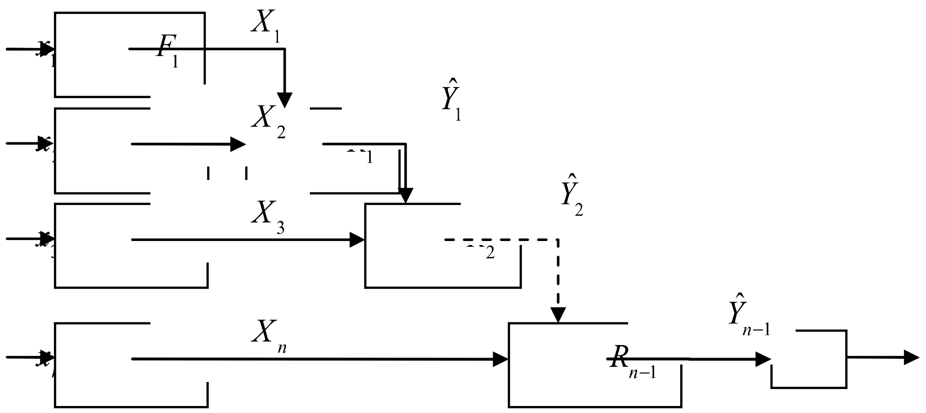


Fig. 2.Fuzzy hierarchical relational model.

This model constructed on the basis of operations fuzzification $F_1, F_2, \ldots, F_n$ of value factors $x_1, x_2, \ldots, x_n$ given in the form of real numbers, sum-prod-composition of fuzzy relations $R_1, R_2, \ldots, R_{n-1}$ [10] and defuzzification D by weighted average method of:

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

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]:

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

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

 ISSN 1562-9945

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 $\Delta_i, i = 1, \dots, N_p$.

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 $\Delta_{cj} \in [0; 1], j = 1, \dots, N_p / 2$ 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.

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

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

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.

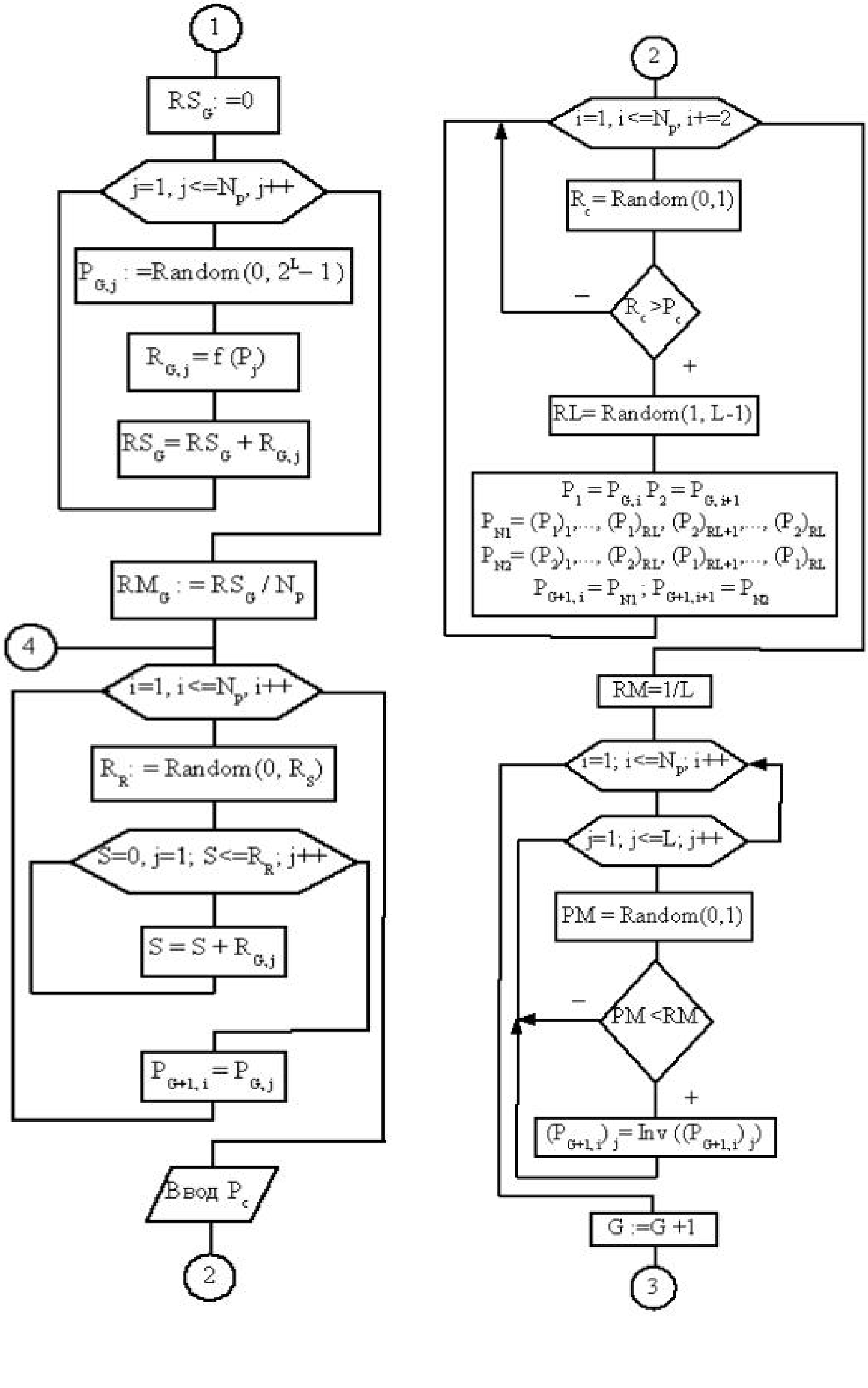
Step 6: Repetition of steps 3-5 until all bits of the current chromosomewould be processed.

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.

 ISSN 1562-9945


1
RSG: =0
j=1, j<=Np, j++
PG,j : =Random(0, 2L– 1)
RG,j = f (Pj)
RSG = RSG + RG,j
RMG : = RSG / Np
4
i=1, i<=Np, i++
RR: = Random(0, RS)
S=0, j=1; S<=RR; j++
S = S + RG,j
PG+1, i = PG,j
Ввод Pc
2
2
i=1, i<=Np, i+=2
Rc = Random(0,1)
Rc >Pc
–
+
RL= Random(1, L-1)
P1 = PG,i P2 = PG,i+1
PN1= (P1)1,..., (P1)RL, (P2)RL+1,..., (P2)RL
PN2= (P2)1,..., (P2)RL, (P1)RL+1,..., (P1)RL
PG+1,i = PN1; PG+1,i+1 = PN2
RM=1/L
i=1; i<=Np; i++
j=1; j<=L; j++
PM = Random(0,1)
PM <RM
–
+
(PG+1,i)j = Inv ((PG+1,i)j)
G :=G +1
3

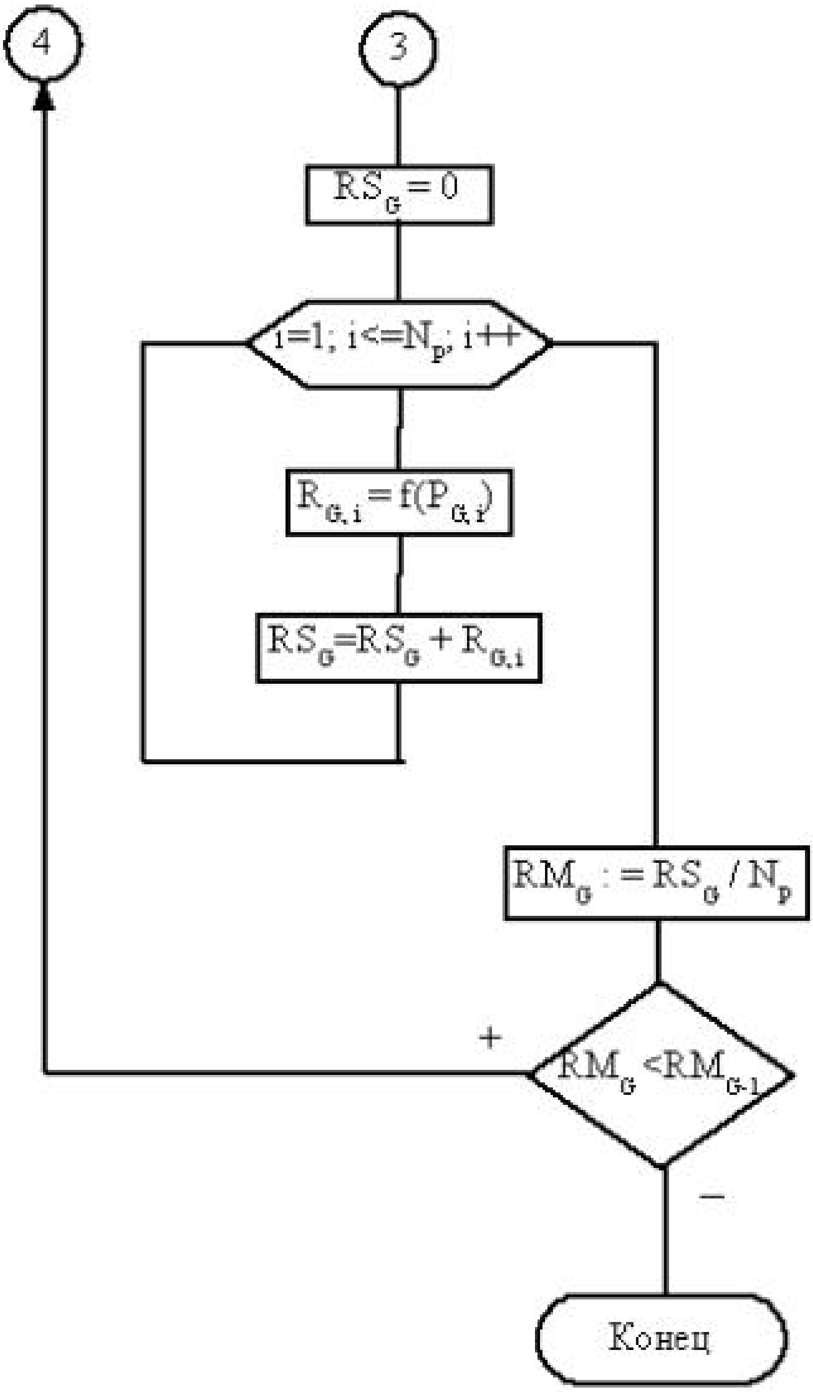


Fig. 3.A generalized algorithm of optimal solutions selection using proportionate selection method.

CONCLUSIONS

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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