UDC 004.93

V.I. Peredery, E.U. Borchik

INFORMATION TECHNOLOGY OF DETERMINING THE DEGREE OF INFLUENCE OF FACTORS ON THE ADOPTION OF RELEVANT DECISIONS IN ERGASIC SYSTEMS

Annotation*. We proposed an information technology of supporting the relevant decision making in complex guaranteed ergatic systems of critical use is proposed in the paper.*

It is shown that the application the mathematical apparatus of the Bayesian confidence networks and the methods of the fuzzy sets theory allow us to work with incomplete, inaccurate and contradictory information about the factors influencing on the human operator, and also to predict the probability of their positive or negative values while decisions-making. This fact considerably increases the efficiency of the ergatic systems.

Key words: *ergatic systems, real-time mode, decision-making, cognitive component, relevance of decision making, external factors.*

Relevance of the topic. This research targets at improving information technologies of decision-making support in complex, guaranteed ergatic systems.

Application of this information technology will allow us to determine and control in real-time the degree of factors influence, with their subsequent adaptation while making relevant decisions by the operator in critical situations of the technological object management. Thus the topic of this work acquires relevance.

Analysis of the publications on the problem. The questions of the theory and methods of decision-making were considered in the works of T. Saati, D.A. Pospelov, N. Nilsson, Larichev, P.I. Bidyuk, and others. The questions of the cognitive component accounting and the influence of the environmental factors on the ergatic systems are considered in the works of B.F. Lomov, G.Salvendi, V.V. Pavlov and etc.

In [1-3] the issues of creating comfortable working environment conditions for decision-maker person (DMP) within the system were considered. In [3-5] the systems for identifying psychological state of DMP, which are determined by the methods of indirect measurements in real time, are proposed.

In [5-7] mathematical models and algorithms for assessing the relevance of decision- making considering the influence of the environmental factors and the cognitive component of DMP on the safety of information management systems are proposed. In [8] the authors proposed formalization of the correlation algorithms between the environmental factors and the cognitive component of DMP on the basis of the fuzzy sets theory and the clonal selection algorithm for optimization of the taken decisions relevance.

However, the questions of the relevant decision-making considering the complex influence of environmental factors, the cognitive component of the DMP, with subsequent adaptation to the conditions of the dynamics change of the state of the controlled object.

Work objective. Information technology improvement allows monitoring and determining the degree of influence of factors in real-time, with their subsequent adaptation, in making relevant decisions by the operator, in critical situations of managing technological objects were not considered.

Statement of the main material.

The main task of the ergatic critical information systems is the ability to realize the prescribed information functions, to make relevant decisions, in conditions of external and internal destabilizing factors.

Modern ergatic systems used in real-time control process of the nuclear power engineering, petrochemical industry, transport are characterized by the direct participation of the human operator in the decision-making in uncertain conditions under the influence of the external factors of the technological environment (Fs) and its/their cognitive component (Fc).

Determination of the decision-making relevance, as a rule, requires a detailed analysis of both the system itself and the state of the DMP. Different users have different susceptibilities to external influences of the environment (for example, temperature, noise, vibration, etc.), which often leads to erroneous decision making. Determination of the optimal values of these factors is complicated because of their mutual influence, when one factor affects another one, which finally has incomplete, inaccurate and contradictory information.

To solve this problem, we propose an information technology for making relevant decisions considering the influence of the listed factors (Fig. 1).

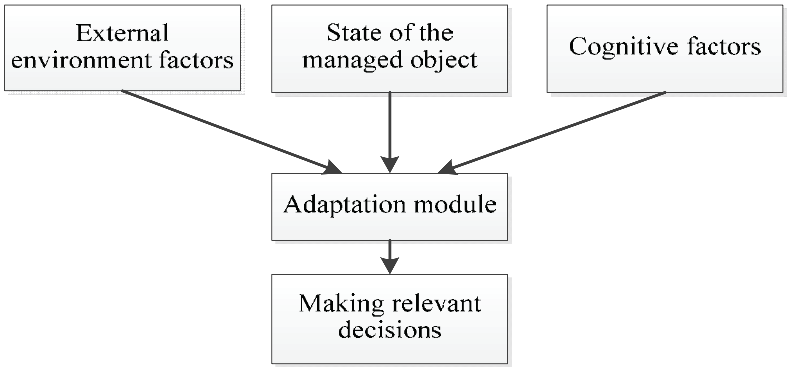

Fig. 1 - Information technology for making relevant decisions considering the influence the influence of factors

Today, one of the most appropriate mathematical devices designed to work with incomplete, inaccurate and contradictory information are Bayesian belief network (BBN) [9]. The mathematical apparatus of BBN is based on a probabilistic approach and is able to make maximum use of information which comes from the selected sources in order to achieve maximum effect.

BBN is one of the most widespread images of knowledge representation with uncertainty. The BBN in overall is a directed graph that does not contain directed cycles. The graph is made up of nodes and arcs which connect these nodes (Pic. 2). Nodes are represented as random variables that can be discrete or continuous. Arcs display causal relationships between variables, due to this BBN sometimes are called causal relationships networks. In the causal relationships networks, the parent vertices are the causes, and the child vertices are effects. These dependencies are modeled using the corresponding arcs.

Formally (BBN) can be represented as:

$$BNN = < U, T >; \qquad (1)$$

$U = \{ H_1, \ldots, H_n \}$ - is the finite ordered set of random variables (network nodes) such that for any $H_i \in U, i = \overline{1, n}$; the condition is satisfied:

$$\exists\, \Pi_i \subseteq \{ H_1, \ldots, H_{i-1} \} \mid P(H_i \mid H_1, \ldots, H_{i-1}) = P(H_i \mid \Pi_i). \qquad (2)$$

This condition determines the direction of connections between Network nodes, realizing the conditional independence property of

 ISSN 1562-9945

variables. Each variable takes a value from a finite set of values, i.e., $H_i = \left\{ h_{i1}, \ldots, h_{ir_i} \right\}$ herewith $\sum_{j=1}^{r_i} P(h_{ij}) = 1$.

$T = \left\{ P(H_1 \mid \Pi_1), \ldots, P(H_n \mid \Pi_n) \right\}$ - is the variety of the conditional probabilities tables of each variable-descendant H_i with variable-ancestors Π_i. If variable H_i has not ancestor, then unconditional probabilities are used $P(H_i)$.

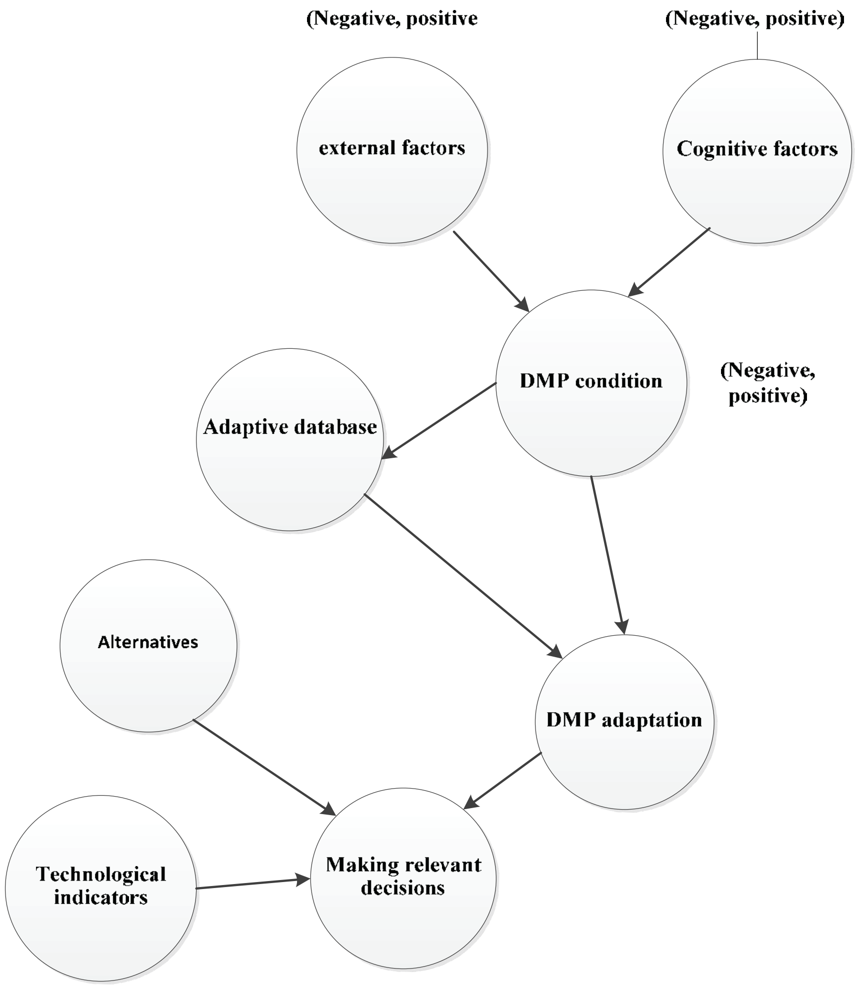

Fig. 2 - Bayesian belief network

For predicting the values of unconditional probabilities of the random variable "External factors" (Fig. 2), it is suggested to use fuzzy logic inference based on the developed fuzzy knowledge base [10,11]. Application of the fuzzy sets theory is caused by the fact that the statistical determination of the probability values of the random variable "External factors" is practically very difficult to implement because of the simultaneous action of a significant number of different factors on DMP (it is necessary to determine the probabilities under different numerical values of the factors and for their different combinations). Application of the methods of the fuzzy sets theory will allow us to predict the probability of their positive or negative values.

Let the values of external factors are measured at a certain point in time. Let us consider the random variable "the degree of the external factors influence of on the DMP". Let this value take only two meanings: "negative" and "positive." The more differences of the external factors values from the normative ones, the more is the probability that the impact on DMP will be negative. The question arises: what is the probability P that the random variable "the degree of influence of external factors on the DMP " takes the "negative" value”?

To answer this question, we will create a system for predicting the values of probabilities, based on formalized fuzzy knowledge base of linguistic statements of the rule type "If - Then". Mamdani's algoritm is implemented to a fuzzy knowledge base, in which the values of the input and output variables are given by fuzzy sets:

RULE 1: IF x_5 is "not a norm" THEN y is a "high"

RULE 2: IF x_3 is "not a norm" And x_5 is "norm" And x_6 is "norm"

THEN y is "above average"

RULE 3: IF x_6 is "not a norm" And x_5 is "norm" And x_3 is "norm" THEN y is "above average"

RULE 4: IF x_3 is "not a norm" And x_6 is "not a norm" THEN y is "high"

RULE 5: IF x_1 is "not a norm" And x_5 is "norm" And x_3 is "norm" And x_6 is "norm" THEN y is "average"

RULE 6: IF x_2 is "not a norm" And x_1 is "norm" And x_5 is "norm" And x_3 is "norm" And x_6 is "norm" THEN y is "below average"

RULE 7: IF x_4 is "not a norm" And x_1 is "norm" And x_5 is "norm" And x_3 is "norm" And x_6 is "norm" THEN y is "below average"

RULE 8: IF x_1 is "norm" And x_2 is "norm" And x_3 is "norm" And x_4 is "norm" And x_5 is "norm" And x_6 is "norm" THEN y is "low"

Here, x_i (i = (1,6) denotes the linguistic variables "temperature", "humidity", "vibration", "air velocity", "Noise", "illumination", respectively, and through y – is the linguistic variable "the probability that the random variable" the degree of influence on the DMP of external factors "takes the meaning" negative ".

To describe the linguistic variables x_i ($i = (1,6)$ we will use the term "set" ("norm", "not norm"), and for the variable y - the term "set" {"low," "below average, "average", "above average", "high "}.

The membership functions $\mu_н(x_i)$ the term "norm" of the linguistic variables x_i ($i = (1,6)$) will be given in the form of a P - function:

$$\mu_н(x_i) = gauss2fm(x_i, [\sigma_1^i,\ c_1^i,\ \sigma_2^i,\ c_2^i]) =$$

$$= \begin{cases} e^{-(x_i - c_1^i)^2 / 2(\sigma_1^i)^2}, если\ 0 \le x_i \le c_1^i, \\ 1, если\ c_1^i < x_i < c_2^i, \\ e^{-(x_i - c_2^i)^2 / 2(\sigma_2^i)^2}, если\ c_2^i \le x_i \end{cases}, \quad (3)$$

where the parameters $\sigma_1^i,\ c_1^i,\ \sigma_2^i,\ c_2^i > 0$, $c_1^i < c_2^i$.

Taking into consideration the values of the left and right ends of the intervals of normal external factors, we determine the values of the parameters c_1^i и c_2^i ($i = \overline{1,6}$). Then the membership functions $\mu_н(x_i)$ can be written in the form:

$$\mu_н(x_1) = gauss2fm(x_1, [\sigma_1^1,\ 22,\ \sigma_2^1,\ 24]),\ x_1 \in [0, 46];$$

$$\mu_н(x_2) = gauss2fm(x_2, [\sigma_1^2,\ 40,\ \sigma_2^2,\ 60]),\ x_2 \in [0, 100];$$

$$м_н(x_3) = gauss2fm(x_3, [\sigma_1^3,\ 0,\ \sigma_2^3,\ 15]),\ x_3 \in [0, 150];$$

$$\mu_н(x_4) = gauss2fm(x_4, [\sigma_1^4,\ 0,\ \sigma_2^4,\ 0.1]),\ x_4 \in [0, 0.7]; \quad (4)$$

$$\mu_н(x_5) = gauss2fm(x_5, [\sigma_1^5,\ 0,\ \sigma_2^5,\ 50]),\ x_5 \in [0, 150];$$

$$\mu_н(x_6) = gauss2fm(x_1, [\sigma_1^6,\ 250,\ \sigma_2^6,\ 250]),\ x_6 \in [100, 400].$$

Cconsidering that the statement "the external factor x_i gets the value "not norm"" is the opposite to the statement "the external factor x_i takes the value " norm ", we come to the conclusion that the membership functions $\mu_{нен}(x_i)$ the term" not norm "of the linguistic variables x_i is the following:

$$\mu_{нен}(x_i) = 1 - \mu_н(x_i),\ (i = \overline{1,6}).$$

We denote the membership functions of the terms "low", "below average", "average", "above average", "high" of the linguistic variable y through $\mu_i(\quad)$ ($i = \overline{1,5}$) respectively. We shall define $\mu_i(y)$ in Gauss form of a П function:

$$\mu_i(y) = gaussfm(y, [\sigma_i, c_i]) = e^{-(y-c_i)^2 / 2\sigma_i^2}, \text{если } 0 \le y \le 1, \qquad (5)$$

where the parameters $\sigma_i, c_i > 0$, $0 \le y \le 1$ ($i = \overline{1,5}$).

Calculation of the probability P based on the proposed knowledge base was carried out using MATLAB application package for the following parameter values: $\sigma_1^1 = \sigma_2^1 = 6.25$, $\sigma_1^2 = \sigma_2^2 = 13.59$, $\sigma_1^3 = \sigma_2^3 = 20.38$, $\sigma_1^4 = \sigma_2^4 = 0.095$, $\sigma_1^5 = \sigma_2^5 = 20.38$, $\sigma_1^6 = \sigma_2^6 = 40.76$; $\sigma_1 = 0.17$, $c_1 = 0$; $\sigma_2 = 0.1598$, $c_2 = 0.3$; $\sigma_3 = 0.17$, $c_3 = 0.5$; $\sigma_4 = 0.17$, $c_4 = 0.7$; $\sigma_5 = 0.17$, $c_5 = 1$.

Table 1

Calculation of the results of the external factors influence probabilities

	Temperature C	Humidity %	Vibration Hz	Air speed m/s	Noise dB	Illumination Lk	P
Norm	22-24	40-60	<15	<0.1	50	250	
External factors value	23	50	10	0.1	**100**	250	0.87
	23	50	**60**	0.1	50	250	0.66
	23	50	10	0.1	50	**100**	0.68
	23	50	**80**	0.1	50	**100**	0.86
	23	**90**	10	0.1	50	250	0.31
	23	50	10	**0.5**	50	250	0.31
	33	50	10	0.1	50	250	0.49
	23	50	10	0.1	50	250	0.13

In Table 1, the external factors values, which differ from the normative ones, are highlighted in bold type. As one can see, the probability P takes the greatest value - 0.87 with the deviation from the norm of the "noise" factor (with the normative values of the other factors). The least value is 0.31 and **P** probability takes it on deviation from the norm of either factor "humidity" or factor "air speed". If all values of the external factors are normative, then P takes a substantially low value - 0.13. On the whole results of the calculations fully correspond to the proposed knowledge base.

In future the authors set themselves the task of turn the proposed fuzzy model on the basis of statistical data.

Conclusions

Application of this information technology will allow us real-time monitoring and determining the degree of factors influence, with subsequent adaptation of these factors, when making relevant decisions by the operator, in critical situations of managing the technological object, thereby improving the efficiency of the ergatic systems as a whole.

The use of mathematical apparatuses of Bayesian belief network and methods of the fuzzy sets theory allows us to work with incomplete, inaccurate and contradictory information about the influencing factors, and also to predict the probability of their positive or negative values, when making relevant decisions by the human operator as part of ergatic systems of critical application.

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 ISSN 1562-9945