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DEVELOPMENT OF A METHOD OF MULTI-CRITERIA EVALUATION UNDER UNCERTAINTY

The object of research is decision-making support systems. Local wars and armed conflicts of recent decades are characterized by high dynamics of operations (combat operations) and a significant amount of diverse information circulating in information systems. These features determine the search for new approaches to increase the efficiency of decision-making support systems, given their reliability. This article solves the problem of developing a method of multicriteria evaluation in conditions of uncertainty.

In the course of the research, the authors used the main provisions of the theory of artificial intelligence, automation theory, theory of complex technical systems and general scientific methods of cognition, namely analysis and synthesis. The proposed methodology was developed taking into account the practical experience of the authors of this work during the military conflicts of the last decade. The method of multicriteria evaluation is universal and can be used to assess the state of the objects of analysis of any architecture. The results of the research will be useful in:

– development of new control algorithms in decision-making support systems;

– substantiation of recommendations for improving the efficiency of operational management;

– analysis of analysis (monitoring) objects in the course of hostilities (operations);

– creation of perspective technologies to increase the efficiency of operational management;

– assessment of the adequacy, reliability, sensitivity of the scientific and methodological apparatus of operational management in decision-making support systems;

– development of new and improvement of existing management models.

Areas of further research will be aimed at developing a methodology for intelligent management in special-purpose decision-making support systems.

Keywords: *decision-making support systems, operational management, data transmission systems, multicriteria evaluation.*

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1. Introduction

Local wars and armed conflicts of recent decades are characterized by high dynamics of operations (combat operations) and a significant amount of diverse information [1, 2]. This determines the search for new approaches to increase the efficiency of decision-making by those who make them, given their reliability.

The process of decision-making support consists in generating possible alternatives to decisions, evaluate them and choose the best alternative from the set. While choosing alternatives, one has to take into account a large number of conflicting requirements and, therefore, evaluate solutions according to many criteria.

Decision-making in most cases consists in generating possible alternatives to decisions, evaluate them and choose the best alternative. To make the «right» decision means to choose an alternative from among the possible ones, which, taking into account all the various factors and conflicting requirements, will maximize the achievement of the goal [3, 4].

Thus, decision-makers are forced to proceed from their subjective perceptions of the effectiveness of possible alternatives and the importance of different criteria.

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Under the criterion of the effectiveness of decision-making by those who make them, let's consider the efficiency of decision-making with a given degree of reliability.

To solve the problem of forming generalized performance indicators used in the evaluation of various alternative solutions, it is proposed to use a fuzzy approach to formalize uncertainty in decision-making [5, 6].

Thus, *the object of research* is decision-making support systems. And *the aim of this research* should be considered to increase the efficiency of decision-making on the object state of analysis with a given reliability.

2. Research methodology

The influence of different indicators on the evaluation of options from the set of alternatives is proposed to be carried out by constructing a constructive λ-fuzzy Sugeno measure on a finite set of partial indicators.

The analysis conducted in the work [2] shows that taking into account the factors of uncertainty and incompleteness of information is an integral part of the decision-making process. Normally, and in some cases, it is often impossible to obtain sufficient statistics on the initial data used in decision-making. Moreover, the traditional way of taking into account the factors of uncertainty on the basis of probabilistic and statistical modeling in some situations may be inadequate to solve the problem and lead to incorrect results.

To solve the problem of forming generalized indicators of the analysis object state used in the evaluation of various alternative solutions, it is proposed to use a fuzzy approach to formalize the uncertainty about the analysis object state and solve multicriteria uncertainty.

The advantage of the theory of possibilities, based on the idea of fuzzy set, is that it allows to qualitatively describe the judgments that characterize the uncertainty and model the inaccuracy in the decision-making process about the analysis object state.

Let's suppose that the generalized indicator of the analysis object state from the set of alternatives is described as a hierarchy of n partial indicators of the analysis object state $E=\{E_i, i=1,2...,n\}$, which evaluate the solutions of the set $W=\{w\}$. In practice, the number of possible states of the object of analysis W is finite, so they can be listed directly.

Partial indicators of the assessment of the state of the object $E_i(X_1, X_2, ..., X_m, Z)$ depend on various parameters and the influence of the external environment (Z) during the entire stage of the observation period. This relationship between the parameters and indicators of the analysis object state can be set not only in analytical form but also in algorithmic form by building various models of functioning of the analysis object state (multistructural, multimodel approach [7–9]).

At the same time, information about the parameters and the external environment are inaccurate, uncertain, especially at the stages of formalization of the source data used in decision-making.

3. Research results and discussion

The method of multicriteria evaluation in conditions of uncertainty consists of the following sequence of actions (Fig. 1):

1. Introduction of initial data and formalization of multicriteria evaluation. In this regard, let's assume that the capabilities of the implementation parameters are given in the form of fuzzy sets:

$$E_j=(x_j, \mu_j(x_j)),\ Z=(z, v(z))\cdot\eta, \tag{1}$$

where $\mu_j(x_j), v(z)$ are the possibilities that parameters X_j and environmental characteristics Z can take the appropriate values e_j, z, η is the degree of uncertainty of the initial data on the influence of the external environment.

2. Construction of the estimation function. Given the above, let's believe that the partial indicators of the analysis object state assessment will be presented in the form of a fuzzy event:

$$E_i: W\to\Re(Y_i), \tag{2}$$

where for each variant $w\in W$ $E_i(w)\subseteq Y_i$ is a fuzzy set; $E_i(w)=\left(e_i, \mu_{E_i(w)}(e_i)\right)$, $e_i\in Y_i$ is the indicator value E_i; $\mu E_i(w)$ is the membership function. Thus $\mu_{E_i(w)}(e_i)$ interpreted as the possibility that the performance indicator E_i takes value e_i for the case $w\in W$.

3. Formulation of a generalized indicator for analysis object state assessment. At this stage, the formulation of a generalized indicator for assessing the analysis object state (E), which consists of some operation in fuzzy events:

$$F(w)=H\left(F_1(w), F_2(w), ..., F_n(w)\right)\forall\in W.$$

It combines partial indicators to assess the condition of the object. The aggregate indicator also takes into account their impact on the evaluation of decision options at different stages of the decision-making process.

A common method of ranking criteria by importance is to assign a weight value to each of them, followed by a convolution operation. This approach, as the analysis shows [2, 10], leads to losses in the effectiveness of its application. These losses happens because of the fact that the coefficients in the convolution of partial performance indicators do not take into account the nonlinear nature of the impact of E_i indicators on each other and in general on the considered generalized indicator of the analysis object state.

4. Construction of the Sugeno fuzzy measure. In order to overcome these shortcomings and take into account the fuzzy representation of partial indicators of the object state, it is considered while constructing a generalized indicator of the object state to use fuzzy coagulation based on fuzzy degree and fuzzy integral [3, 4].

Let it be that $g_i\left(i=1,...,n\right)\left(0<g_i<1\right)$ are the the coefficients of importance of individual partial indicators of the analysis object state in the construction of a generalized indicator of the analysis object state. This information can be obtained from experts through the use of expert evaluation methods [3].

Taking into account the influence of a set of different indicators E_i, $i\in M\left(M=\{1,2,...,n\}\right)$ on the evaluation of variants from the set W is planned to be carried out by constructing a constructive Sugeno λ-fuzzy measure on a finite set of partial indicators:

$$E_i, i\in M.$$

Sugeno measure for this case is as follows [3, 4]:

$$G_\lambda\left(\{E_i, i=\in M^1\}\right)=\left[\prod_{i\in M^1}(1+\lambda g_i)-1\right]\Big/\lambda, M^1\subseteq M, \tag{3}$$

where g_i is the distribution density of this Sugeno fuzzy measure.

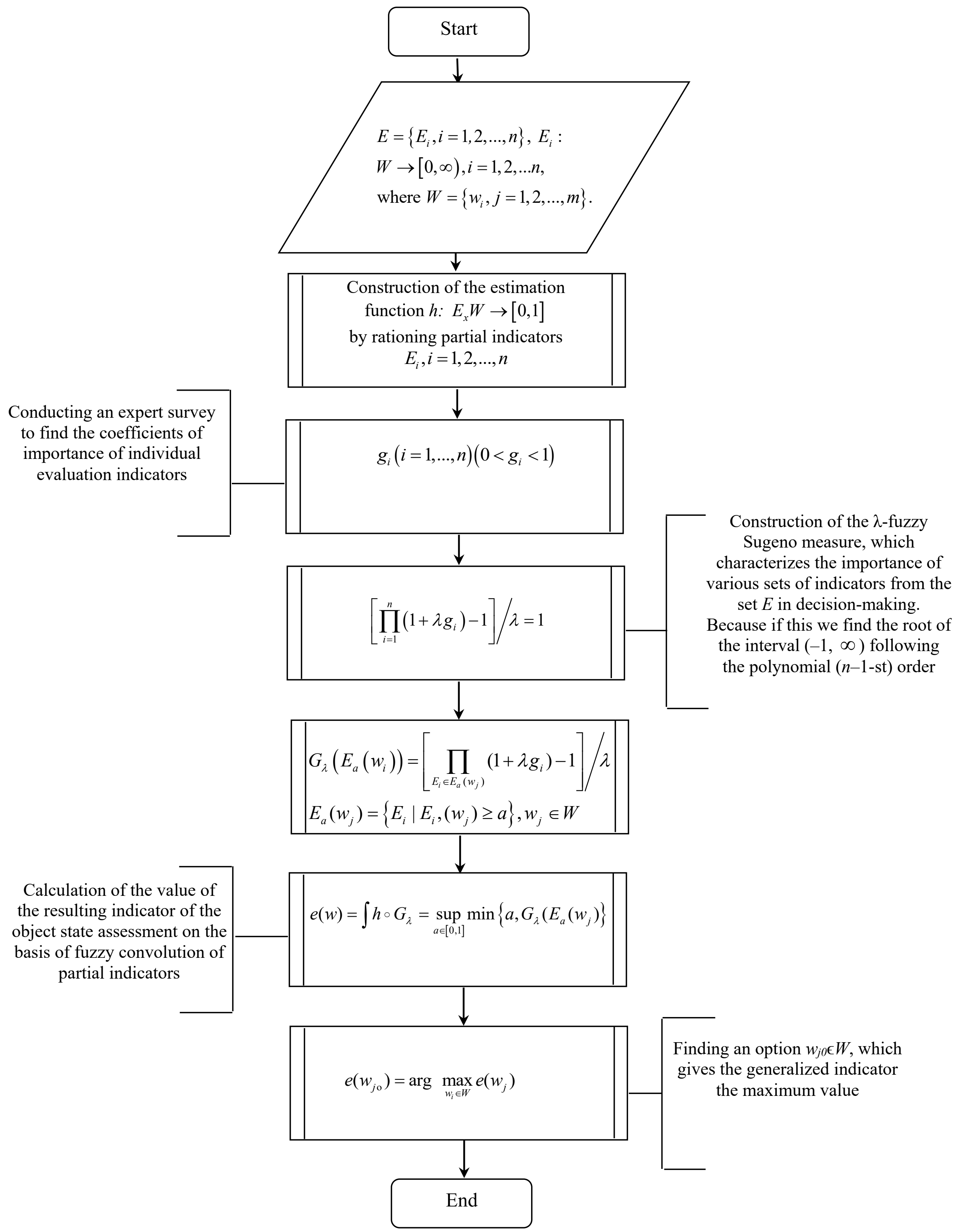

Fig. 1. Algorithm for implementing the method

It should be noted that the value of λ is found from the condition of normalization of the Sugeno λ-fuzzy measure:

$$\left[\prod_{i\in M}^{n}(1+\lambda g_i)-1\right]\Big/\lambda=1,-1<\lambda<\infty. \quad (4)$$

5. Carrying out the operation of fuzzy convolution of the generalized evaluation indicator. It is proposed to obtain a generalized indicator of the state object assessment in the form of fuzzy folding, which allows to flexibly take into account the nonlinear nature of the impact of partial indicators. Why do we use the concept of fuzzy integral on the λ-fuzzy measure of Sugeno [3, 4]:

$$e(w)=\int h\circ G_\lambda=\sup_{a\in[0,1]}\min\{a,G_\lambda(E_\alpha(w))\}, \quad (5)$$

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where $E_\alpha(w)=\{E_i \mid h(E_i,w)\geq\alpha\}$ is the set of indicators, the degree of influence of which on the assessment of the option $w\in W$ exceeds the threshold *a*; $h: E_E W\rightarrow[0,1]$ is the evaluation function.

As an estimation function *h* let's consider the values of partial indicators of analysis object state estimation, reduced to a dimensionless form with a carrier of fuzzy set $E_i(w)(i=1,...n;w\in W)$ in the interval [0, 1] by the following transformation:

$$E_i(w_i)=\left(e_i/K_i,\mu_{E_i(w)}(e_i)\right), \tag{6}$$

where

$$K_i=\max_{w\in W}\max_{\mu_{E_i(w)}(f_i)>0}\{e_i\}. \tag{7}$$

Based on the proposed approach, a method of solving multicriteria uncertainty and choosing alternatives to the analysis object state is presented.

This approach is proposed to be used in decision-making support systems. The proposed technique will increase the efficiency of decision-making while maintaining a given degree of reliability.

The developed methodology is universal and can be adapted to assess the analysis object state of arbitrary architecture and complexity.

The novelties of the developed technique are:
– the type of uncertainty about the analysis object state is taken into account;
– the formation of generalized indicators for assessing the analysis object state is a universal procedure. Presentation of generalized indicators of assessment of the analysis object state allows to adapt to a specific task;
– there is an improved procedure for reducing the number of possible solutions to the object state.

The limitations of this research should be considered:
– taking into account time constraints on the transmission of a specific type of message (formalized report);
– an availability of the primary database;
– restrictions on the quality of data channels.

Areas of further research will be aimed at developing a method for intelligent management in special-purpose decision-making support systems.

4. Conclusions

In this research, a methodology for multicriteria evaluation under uncertainty was developed.

The essence of this method is that this technique allows:
– to get a generalized assessment of the object state on many indicators (criteria);
– to evaluate objects of different structure and to evaluate indicators of different nature and origin;
– to take into account the type of uncertainty about the object state (complete uncertainty, partial uncertainty and full awareness);
– to formulate a system of indicators for the evaluation of a separate component of the evaluation object.

The research results will be useful in:
– development of new control algorithms in decision-making support systems;
– substantiation of recommendations for improving the efficiency of operational management;
– analysis of objects of analysis (monitoring) in the course of hostilities (operations);
– creation of perspective technologies to increase the efficiency of operational management;
– assessment of the adequacy, reliability, sensitivity of the scientific and methodological apparatus of operational management in decision-making support systems;
– development of new and improvement of existing management models.

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