COMPLEX-STRUCTURED OBJECTS OPTIMIZATION DURING MODELING ON THE POPULATION ALGORITHMS ADAPTATION BASIS

Ya.E.Lvovich[1,2], B.N.Tishukov[2], A.P.Preobrazhenskiy[1], A.V. Pitolin[2], O.Ja.Kravets[2]

[1]Voronezh Institute of High Technologies, [2]Voronezh State Technical University
e-mail: Komkovvivt@yandex.ru
Russian Federation

Abstract: The paper discusses the characteristic features of complexly structured objects, identifies the type of objects with structurally variable control. The properties of objects of the considered type are determined. The analysis of the features of the management process of such objects is carried out, on the basis of the results of which the problems arising from their functioning are highlighted. Research on the methods of increasing the efficiency of their use based on the results of optimization modeling is carried out. The generalized scheme can be represented as follows: the formation of the parameters of the optimization model of the object; determining the degree of significance of the criteria of optimality; formalized representation of the optimization model of the problem being solved; selection of numerical methods and algorithms for finding the optimal solution; verification of the values obtained during the solution for optimality.

Key words: an object with structurally-variable control, optimization modelling, population-based algorithms, efficiency increase.

1. INTRODUCTION

At the present stage of accelerated development of industrial and technical systems associated with increasing complexity and the predominance of modularity of construction, the spread of infocommunication, technological and transport systems, the efficiency of which is achieved by purposeful variation of their structural components. Therefore, there is a need to allocate complex objects belonging to the class of complex structures. The problems associated with ensuring high quality of functioning of such objects are caused by the need to develop mathematical tools for structural modeling and optimization [1].

In the studies of many authors, two approaches are mainly used. One is based on the transition to equivalent problems of parametric optimization and the application of the entire Arsenal of numerical methods for finding the extremum oriented on them. However, this transformation leads to a significant increase in the dimension of the problems and increase the complexity of the computational process. The second approach is characterized by the transition to the equivalent problem due to randomization and smoothing mechanisms with preservation of the dimension of the initial variables specified on a finite discrete set. Here, the complexity of the computational process in some cases increases due to the lack of control over the stochastic search schemes. At the same time, the possibilities of using simulation modeling, neural network modeling, as well as the joint use of simulation and neural network approaches in the structural optimization of the studied class of objects are not fully presented in the problems of the studied class. Thus, the relevance of the topic is determined by the need to integrate these approaches of structural modeling within the integrated software environment of numerical optimization of complex structured objects on sets of discrete and continuous variables by expanding the mechanisms of randomization and smoothing, complexing stochastic and population algorithms [2].

The purpose of the paper is the analysis of complex-structured objects optimization during modeling on the population algorithms adaptation basis.

2. FEATURES OF OBJECTS WITH A STRUCTURALLY VARIABLE FORM OF CONTROL

One of the examples of innovative type of objects is an object with structurally variable management. We formulate a definition for a given type of object, and then consider its properties [3, 4]. To do this, we give the concept of structural and variable forms of management.

The structural form of management is such a form of management, a feature of which the structure of the object of research is created before the beginning of the management process, while its architecture and element base do not change in its course. Great attention to the description and characteristics of the structural form of managing objects is given in [5, 6].

Structural management (structural optimization) is the search for such a structure of the object of study that will be the most rational and effective under the existing conditions.

Variable form of control is such a form in which a solution that allows to increase the efficiency of the management process of a selected object is determined by choosing from the set of acceptable options the most suitable for a particular condition [6, 7].

Based on the above, we formulate a definition for a structurally-variable form of control.

The structurally-variable form of management is the form in which the effectiveness of the management process is achieved by searching for the structure of the object of study that will be the most rational and effective under existing conditions by choosing from a set of acceptable options the most suitable for a particular condition [9]. As an object with a structurally-variable form of management, we will consider a certain organizational whole system, the achievement of the set goals of which is carried out by varying the components of the structure, which are a set of elements united by various kinds of connections].

Based on the analysis of optimizing objects of various types [10], we formulate the properties that objects with a structurally variable form of control [11] have:

1. Variable structural components in a formalized form are represented by a vector X, including three subsets of X^1, X^2, X^3 variables:

$\mathrm{X}^1 = (x_1^1, ..., x_j^1, ..., x_J^1)$ - a subset of alternative variables

$$x_j^1 = \begin{cases} 1, \text{ if some j-th element or link is included in the object structure,} \\ 0, \text{ otherwise, } j = \overline{1,J}; \end{cases}$$

$\mathrm{X}^2 = (x_1^2, ..., x_l^2, ..., x_L^2)$ - a subset of variables with discrete values;

$x_l^2 = (x_{l_1}^2, ..., x_{l_m}^2, ..., x_{l_M}^2),\ x_{l_m}^2 \geq 0,\ m = \overline{1,M};$

$\mathrm{X}^3 = (x_1^3, ..., x_n^3, ..., x_N^3)$ - a subset of continuous variables, the change of which is limited to a certain interval $x_n^{3_{MIN}} \leq x_n^3 \leq x_n^{3_{MAX}},\ x_n^{3_{MIN}} \geq 0,\quad n = \overline{1,N},$ and characterizes the parameters of structural components [12, 13].

2. It is necessary to consider the dynamic, depending on the time $ф \in [ф_0; ф_g]$ and static modes of operation of an object with structurally variable control.

3. Adequate representation of the relationship between the indicators of a full-scale object $y = (y_1, \ldots, y_i, \ldots, y_I)$ characterizing specified targets and variable structural components is identified by some computing environment, which allows determining the values of the component of the vector y with a fixed version of the structure s^0 and the corresponding value of the vector X^0: $y = f_{вс}(X^0) \sim f_н(s^0)$, where the sign ~ denotes likeness. Further, as a basic computing environment $f_{вс}$ we will consider a simulation model.

4. Achieving a given goal is determined by a set of experimental

$$y_{i1} = f_{i1}(x) \rightarrow max\ (min),\ i_1 = \overline{1, I_1}$$

and boundary

$$y_{i2} = f_{i2}(x) \rightarrow b_{i2},\ i_2 = \overline{1, I_2}$$

requirements, where b_{i2} is the permissible level of the indicator y_{i2}.

5. As the main groups of natural objects with structurally variable management, we will consider network [14, 15] information and communication, technological and transport systems.

After we have a formalized description of a class of objects with a structurally-variable form of control in the form of $f_{вс}(X)$, we turn to the problems of optimizing such objects.

3. BUILDING AN OPTIMIZATION MODEL OF AN OBJECT WITH STRUCTURALLY VARIABLE CONTROL

The optimality of the structure of the object will be determined by any of the criteria that most affect it. It is this criterion that will be the criterion of the optimality of the structure of the object and will be expressed by the objective function in the mathematical model of the problem [16, 17].

Schematically, the cycle of work with an optimization task for an object with a structurally-variable form of control can be represented as a diagram (Figure 1).

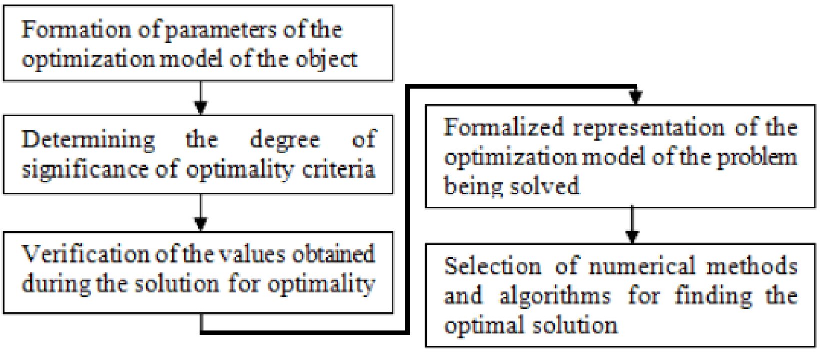

Figure 1. Scheme of the formation cycle of the model for the optimization problem and finding its solution

Based on the considered properties 1 and 4, an object with a structured control suggests the problem of choosing an optimization solution in the general case to be represented by the following invariant model (μ_1):

$$f_{i1} = (x^1, x^2, x^3) \to max, i_1 = \overline{1, I_1},$$

$$f_{i2} = (x^1, x^2, x^3) \le b_{i2}, i_2 = \overline{1, I_2},$$

$$x_j^1 = \begin{cases} 1, \\ 0, \end{cases} j = \overline{1,7},$$

$$x_l^2 = (x_{l1}^2, ..., x_{lm}^2, ..., x_{lm}^2), l = \overline{1, L}, x_{lm}^2 \ge 0, m = \overline{1, M},$$

$$x_n^{3min} \le x_n^3 \le x_n^{3max}, n = \overline{1, N}, x_n^{3min} \ge 0, n = \overline{1, N}.$$

- single-criterion optimization model (μ_2):

$$f_{i1} = (x^1, x^2, x^3) \to max, i_1 = \overline{1, I_1},$$

$$x_j^1 = \begin{cases} 1, \\ 0, \end{cases} j = \overline{1,7},$$

$$x_l^2 = (x_{l1}^2, ..., x_{lm}^2, ..., x_{lm}^2), l = \overline{1, L}, x_{lm}^2 \geq 0, m = \overline{1, M},$$

$$x_n^{3min} \leq x_n^3 \leq x_n^{3max}, n = \overline{1, N}, x_n^3 \geq 0, n = \overline{1, N}.$$

- multicriterial without restrictions (μ_3):

$$\psi_{l2} = (x^1, x^2, x^3) \to \max$$

$$f_{l2} = (x^1, x^2, x^3) \leq b_{i2}, i_2 = \overline{1, I_2},$$

$$x_j^2 = \begin{cases} 1, \\ 0, \end{cases} j = \overline{1,7},$$

$$x_l^2 = (x_{l1}^2, ..., x_{lm}^2, ..., x_{lm}^2), l = \overline{1, L}, x_{lm}^2 \geq 0, m = \overline{1, M},$$

$$x_n^{3\min} \leq x_n^3 \leq x_n^{3\max}, n = \overline{1, N}, x_n^{3\min} \geq 0, n = \overline{1, N}.$$

- including alternative and discrete variables *(μ_4)*:

$$f_{ij}(x^1, x^2) \to \min, \quad i_1 = \overline{1, I_1}$$

$$f_{i2}(x^1, x^2) \leq b_{i2}, \quad i_2 = \overline{1, I_2}$$

$$x_j^1 = \begin{cases} 1, \\ 0, \end{cases} \quad j = \overline{1,7}$$

$$x_l^2 = (x_{ls}^2, ..., x_{lm}^2, ..., x_{lm}^2), \quad l = \overline{1, L}, x_{lm}^2 \geq 0, m = \overline{1, M}$$

- single-criterion without restrictions, including only discrete variables *(μ_5):*

$$f(x_k, x_l, ..., x_m) \to \max,$$

$$\begin{cases} x_k = \{x_k^1, x_k^2, ..., x_k^K\}, \; x_k \in K', \\ x_l = \{x_l^1, x_l^2, ..., x_l^L\}, \; x_l \in L', \\ \quad ... \\ x_m = \{x_m^1, x_m^2, ..., x_m^M\}, \; x_m \in M', \\ x_k > 0, \; x_l > 0, \; ..., \; x_m > 0. \end{cases}$$

where $K', L', ..., M'$ - the set of valid options for the parameters of the object under study (a set of solutions).

From this we have that the objective function, expressed in the form of f $f(x_k, x_l, \ldots, x_m)$, will display the relationship between the optimality criterion and the main parameters of the object.

Restrictions on variables in the constructed optimization model will be set in a discrete form, and their values will be chosen from finite sets $K', L', \ldots, M'$ respectively, and may take values strictly greater than 0.

We will search for the solution of the problem in the form of a vector X:

$$X = \begin{Bmatrix} x_k^{n1} \\ x_l^{n2} \\ \ldots \\ x_m^{nN} \end{Bmatrix}$$

After this, it is necessary to carry out preliminary transformations [18] of the initial tasks $\overline{\mu_1, \mu_n}$ and the variables entering them [19].

The process of solving this problem by classical optimization methods is laborious and, in some cases, impossible. This is due to a number of factors: nonlinearity, multiextremality, high computational complexity of the function being optimized, high dimensionality of the region of the search for solutions, etc.

Algorithmization of the solution of the problem of increasing the efficiency of functioning of objects with structurally variable control [20, 21]. In order to increase the efficiency of functioning of objects with structural-control, it is necessary to consider the solution of this problem in the aggregate of two control modes (static and dynamic) [22, 23]. For each of these modes, the model will have the form discussed earlier. The algorithm for solving the problem for each of the modes is described in detail below:

$$f(x_k(\tau), \ldots, x_v(\tau), x_{v+1}, x_{v+2}, \ldots, x_m, \tau) \rightarrow \max,$$

$$\begin{cases} x_k(\tau) = \{x_k^1(\tau), x_k^2(\tau), \ldots, x_k^K(\tau)\}, \; x_k(\tau) \in K', \\ x_l(\tau) = \{x_l^1(\tau), x_l^2(\tau), \ldots, x_l^L(\tau)\}, \; x_l(\tau) \in L', \\ \quad \ldots \\ x_v(\tau) = \{x_v^1(\tau), x_v^2(\tau), \ldots, x_v^V(\tau)\}, \; x_v(\tau) \in V', \\ x_{v+1} = x_{v+1}^{opt}, \; x_{v+2} = x_{v+2}^{opt}, \; \ldots, \; x_m = x_m^{opt}; \\ x_k(\tau) > 0, \; x_l(\tau) > 0, \; \ldots, \; x_m(\tau) > 0. \end{cases}$$

For the static mode, the block diagram of the algorithm will look like that shown in Figure 2, for the dynamic mode in Figure 3.

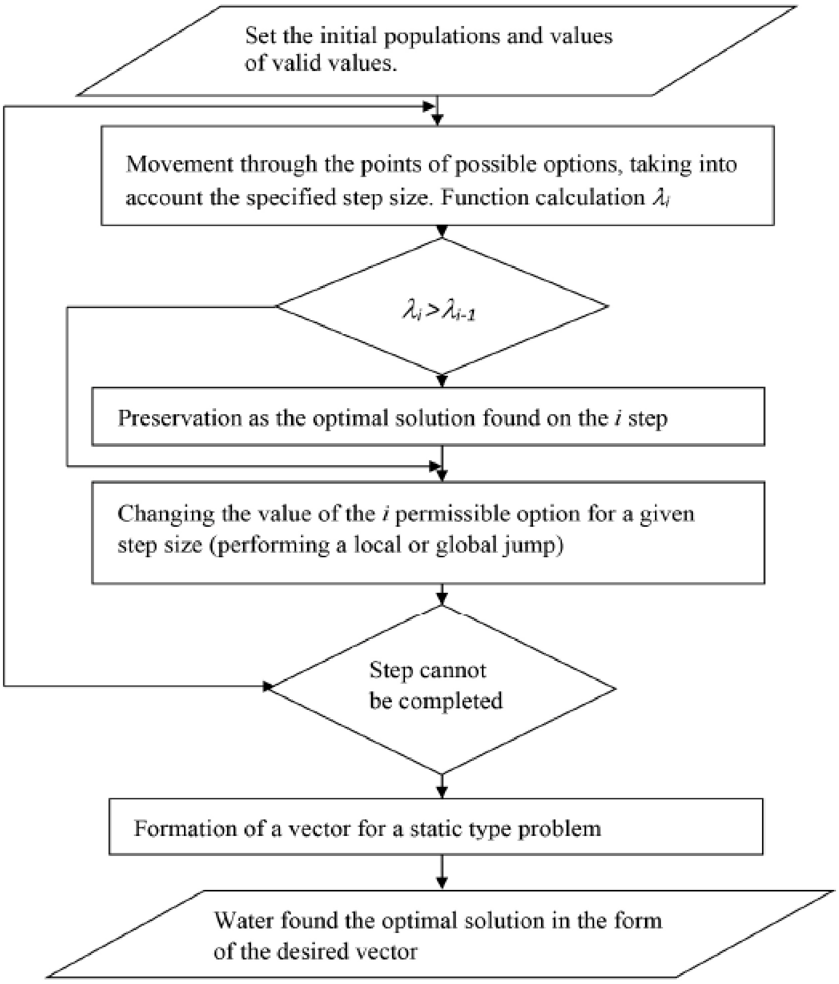

Figure 2. Structural diagram of the numerical procedure for a static type problem based on an adaptive algorithm of monkey behavior

4. CONCLUSION

Thus, for the effective functioning of objects with a structurally variable form of control, it is advisable to take into account the static and dynamic modes of operation. In this case, it is advisable to use optimization modeling based on modifications of the monkey search algorithm. A complex of simulation models for analysis of variants is developed structures of objects of the studied class, allowing to take into account the features object-specific modeling and support-oriented computational schemes for numerical optimization. A complex of optimization models for complex structured objects reflecting a variety of variables, extreme and boundary requirements for their functioning, due to the variation of which the choice of an adequate variant of the model for the object under study is provided.

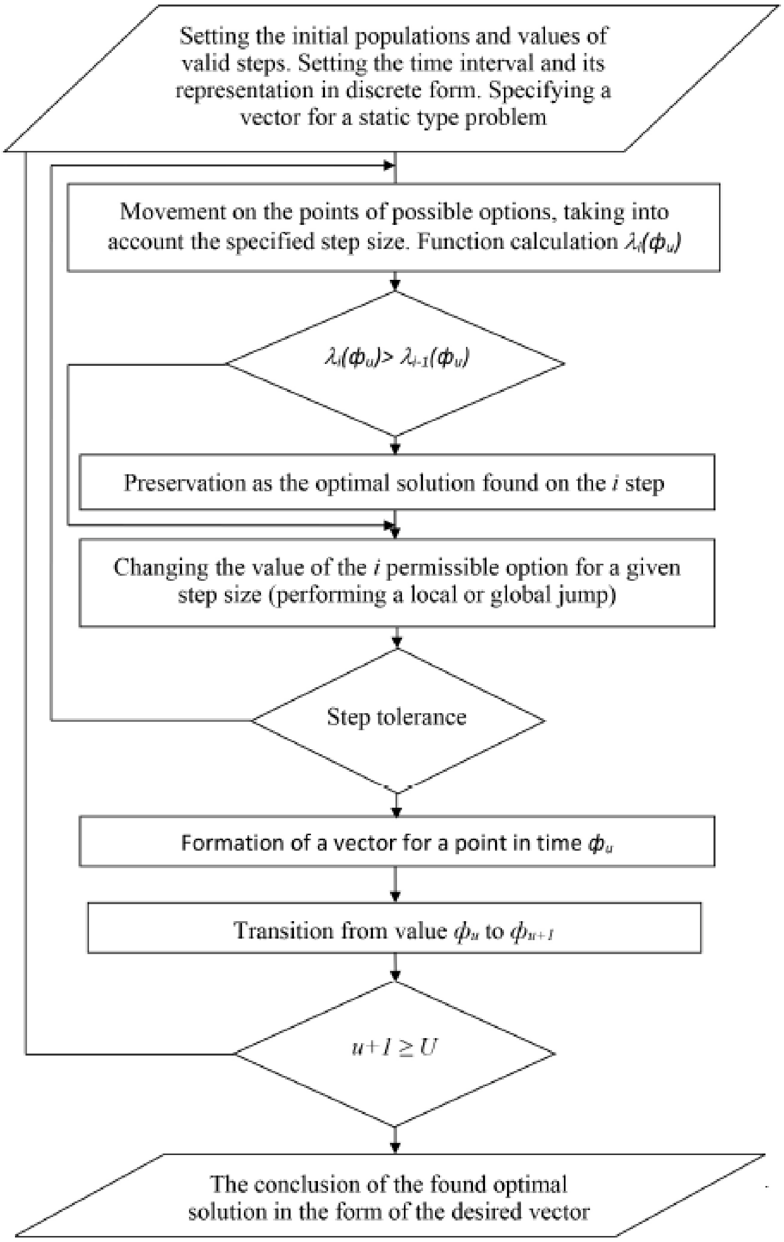

Fig. 3. The block diagram of the numerical procedure for the dynamic type problem based on the adaptive algorithm of the behavior of monkeys

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Information about the authors:

Yakov Yevseevich Lvovich – Doctor of Sciences (Engineering), Professor, president at Voronezh State Technical University, full professor at Voronezh State Technical University.

Boris Nikolaevich Tishukov – PhD student of Voronezh State Technical University.

Andrey Petrovich Preobrazhenskiy – Doctor of Sciences (Engineering), Associate Professor, professor at Voronezh Institute of High Technologies.

Andrey Vladimirovich Pitolin – PhD (Engineering), Assistant Professor of Voronezh State Technical University.

Oleg Jakovlevich Kravets – Doctor of Sciences (Engineering), Professor, full professor at Voronezh State Technical University.

Manuscript received on 07 June 2019