PROBLEM AND MATHEMATICAL MODELS FOR RESCUE TECHNICS ACQUISITION

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***Abstract**: In this paper the problem decision technology for resque technics acquisition with use multiobjective optimization, method of the variant's consecutive analysis and evolutionary modeling is considered. Models, serving information-analytical base of the integral objective forming, is suggested.*

***Keywords**: evolutionary modeling, objective function, rescue technics.*

***ACM Classification Keywords**: I.2 Artificial Intelligence, H.4 Information Systems Applications, J.6 Computer-aided Engineering*

Description of the problem-solving area

Actuality of the resque technics acquisition problem (RTAP) is defined by the increase dynamics of situations, in which necessary is its use, as well as increase of environments technogenic danger. In practice, the RTAP problem decision is taken by responsible person, coming from own experience. In consequence of this by performing the resque work often is an absence necessary toolbox in general, or impossibility of the problem performing fully.

In present time significantly extended assortment fire-prevention and resque product, taken off restrictions on import foreign technics, but exists the certain deficit of financial resource. It is impossible also not to notice of wide functionality and maximum power necessity.

Obviously that problem of the RTAP has much common aspects with the known problem of the bin packing [Lodi, 2002]. The bin packing problem is concluded in accomodation object predestined form by such way that number used container was most or volume object was least. In problem of the RTAP objective function of bin packing problem changes in restrictions on overall dimensions elements. The objective functions are functionality, power, cost, other features of RTA elements. So, priority problem is a forming integral objective function and presentations of the potential decisions of the problem. Aspects of its solving are offered below.

Problem of the resque technics acquisition

Let the sets $X=\{X_1,X_2,...,X_n\}$ presents the assortment of the resque technics. Each element from X belongs to one of the set classes $C=\{C_1,C_2,...,C_k\}$, where $k<<n$. Assume, that in complete set must enter equipment from each of $\{C_1,C_2,...,C_m\}$ classes, $m<k$, i.e. $\{X^1_{i_1},X^1_{i_2},...,X^1_{i_{j_1}}\}\subset C_1,...,\{X^m_{i_1},X^m_{i_2},...,X^m_{i_{j_m}}\}\subset C_m$. each element of X will to correspond with value set:

$$X_q \to < F_{1_q}, F_{2_q}, F_{3_q}, a_q, b_q, c_q >, \quad (1)$$

where F_{1_q} − functionality value for q element; F_{2_q} − its power value; F_{3_q} − its cost; a_q,b_q,c_q − its overall dimensions, $q=\overline{1,n}$.

We shall do the simplifying remarks. Let all elements have a form of the right-angled parallelepiped and they must be placed in right-angled bit. Besides, in the bit must be one element from each class.

The RTAP is reduced to multiobjective optimization problem

$$F_1(x) \to \max, F_2(x) \to \max, F_3(x) \to \min, \quad (2)$$

where $x = (x^1_{i_{l_1}}, x^2_{i_{l_2}}, .., x^m_{i_{l_m}}), x^j_{i_{l_j}} \in C_j$ by restriction

$$F_1(x^j_{i_{l_j}}) > 0, F_2(x^j_{i_{l_j}}) > 0, 0 < F_3(x^j_{i_{l_j}}) < F_3^{j_{\max}}, \quad (3)$$

$$0 < a_q(x^j_{i_{l_j}}) < \max\{a,b,c\},\ 0 < b_q(x^j_{i_{l_j}}) < \max\{a,b,c\},\ 0 < c_q(x^j_{i_{l_j}}) < \max\{a,b,c\}, \quad (4)$$

where a,b,c − bit's overall dimensions.

It is known that such problems refer to NP-hard problems. But, obviously that in problem (2)-(4) can be made suggestions, simplifying process of its solving. We consider rational to use the ideas of the multiobjective optimization problems decision [Chernoruzkiy, 2005], [Voloshin, 2006], method of the variant's consecutive analysis [Volkowitch, 1993] and evolutionary modeling [Michalewicz, 1996].

Information-analytical models of complex systems

As the basis of the efficient problem (2)-(4) solving lays such preconditions:

1. Forming a models set, which will allow realizing the objective function identification.

2. The development integral objectives function, which values reception will allow installing the preferences on the variants set.

We shall consider the problem of the forming the models set, which work out an information-analytical research basis. It is known that by the complex systems construction traditionally [Timchenko, 1991] use the models of the construction, operation and development.

In our case the construction model is such:

$$M_s < X_1, X_2, ..., X_n >, \quad (5)$$

where n − the number of RTA elements. The construction model is a basis, which is intended for forming an element s set and structures by RTA acquisition.

The operation model

$$M_f =< G_1, G_2, ..., G_n >, \quad (6)$$

where $G_i, i = \overline{1,n},$ − transformations, which is realized by i element, and $Y_i = G_i(I_i, R_i, P_i), Y_i$ − same feature, which is defined by transformation G_i and pointing to its result, I_i − a priori information about RTA types, their scale and possible consequence, R_i − material and energy facility required for operating the element X_i and receptions values Y_i, P_i − features of transformation process $< I_i, R_i > \to Y_i, i = \overline{1,n}.$

The third model − development model will present, using belonging elements to classes

$$M_d =< (X^1_{i_1}, X^1_{i_2}, ..., X^1_{i_{j_1}}), ..., (X^m_{i_1}, X^m_{i_2}, ..., X^m_{i_{j_m}}) > \quad (7)$$

where m is the number of RTA elements classes, which execute like functions. Elements from each subset can be ranked on functionality, power and cost levels. Possible also are variants of the overall dimensions order.

The offered models form the basis for receipt of objective function, which will used by decision making for choice of the RTA completing optimum variant in conditions of resources deficit.

Construction features of integral objective function

The RTA problem has a features, to which concern multiobjectivity, different dimension objective functions values, weak structuring. We shall consider aspects of the integral objective function, coming from the known methods of solving of the multiobjective optimization problems [Larichev, 2003]. Notice that objective functions (2) can be both constant and analytical dependences.

1. Main objective function method. Assume main objective function to be a cost of the RTP element. Then problem (2)-(4) is converted to such type:

$$F_3(x) \to \min,\ x = (x^1_{i_{l_1}}, x^2_{i_{l_2}}, .., x^m_{i_{l_m}}),\ x^m_{i_{l_j}} \in C_j, \tag{8}$$

$$x \in D,\ D = \{x / F_{i\min} < F_i(x),\ i = \overline{1,2}\} \tag{9}$$

and (4) is executed. In the problem (8) - (9), $F_{j\min}, i = \overline{1,2},$ − minimum possible values i^{th} odjective function. In that way we get the multiobjective optimization problem. Its solving in case of known values F_1, F_2, F_3 for all elements is reduced to searching

$$x_1^* = \max_{x \in D^{'}} F_3(x), \tag{10}$$

where $D^{'}$ is the area, in which are executed restrictions (3) and (4). If $x_1^* \in D$, then solution is found, if no – do search

$$x_2^* = \max_{\substack{x \in D^{'} \\ x \neq x_1^*}} F_3(x)\ . \tag{11}$$

If $\exists x_i^* :\ x_i^* = \max_{x \in D^{'}} F_3(x),\ x_i^* \in D$, then problem has a solution, otherwise the solution is absent.

2. Method of linear convolution. The necessary conditions to realization of the method are:

- Normalization of objective functions values;
- Determination weight coefficients of objective functions.

Then integral objective function and problem will be such:

$$F(x) = \alpha_1 F_1(x) + \alpha_2 F_2(x) - \alpha_3 F_3(x) \to \max, \tag{12}$$

where $\alpha_i > 0,\ i = \overline{1,3},\ \sum_{i=1}^{3} \alpha_i = 1$. If the objective functions values and integral objective function value on the elements (from RTA) of control set are known, then coefficients $\alpha_1, \alpha_2, \alpha_3$ can be calculated, for instance, on least squares method. However, this is not always possible, more so that most likely in array of initial data will exist a multicollinearity factor and result will be biased. At other times necessary to use a processing techniques for expert estimations.

3. Method of ideal point. The point (x_1^*, x_2^*, x_3^*) is ideal, if $x_i^* = \max_{x \in D} F_i(x),\ i = \overline{1,3}.$ The solution of oneobjective optimization problems - ideal point will be founded. Then the solving process is concluded in searching for of such point:

$$x^* = Arg\min_{x \in D} (\sum_{i=1}^{3} (F_i(x) - x_i^*)^2)^{\frac{1}{2}}. \tag{13}$$

Objective functions values must be normalized and if objective functions have a weight coefficients then problem (13) will be such:

$$x^* = Arg\min_{x \in D}(\sum_{i=1}^{3}\alpha_i (F_i(x) - x_i^*)^2)^{\frac{1}{2}}, \quad (14)$$

where $\alpha_i > 0, i = \overline{1,3}, \sum_{i=1}^{3}\alpha_i = 1.$

Exist and other methods for decision of the multiobjective optimization problems such as choice on number of dominant objective function, method of the consequtive concessions, consequtive entering the restrictions and etc, but all of these require attraction to additional information, which can be not. Therefore for our problem solving we stopped on afore-cited three methods.

Preliminary steps for shortening variants number of solving problem

1. Removing possible variant of the problem solving, which strictly dominated at least one of other variant. We shall notice that such operation can be executed at the beginning to initially realization of searching of the problem solving, if the power of variants set is relatively small. If this is not so, that checking for dominating is realized in process of the problem solving for each element separately.

2. Necessary to realize preliminary check, does not exist such element RTA that

$$(a_q > \max\{a,b,c\}) \vee (b_q > \max\{a,b,c\}) \vee (c_q > \max\{a,b,c\}) \quad (15)$$

does not exist such RTP elements set that

$$(\sum_{q=1}^{3}a_q > \max\{a,b,c\}) \vee (\sum_{q=1}^{3}b_q > \max\{a,b,c\}) \vee (\sum_{q=1}^{3}c_q > \max\{a,b,c\}). \quad (16)$$

If elements or elements sets satisfying (15) or (16) accordingly exist that their necessary to delete a priori, or in process of the problem solving. Similarly, using scheme of the consequtive analysis variant, we delete the variants, the total functionality or power which less minimum possible, as well as that, which the cost exceeds the possible value.

Main directions of problem solving

Since is necessary to find the function optimum, given tabular, under specified restrictions, and about characteristic which nothing not known, then we introduce rational using evolutionary modeling. The choice of the evolutionary modeling method is a researcher prerogative.

Assume that we use the genetic algorithm [Holland, 1994]. It is known that its realization accompanies two problems: forming of objective function and presentation of the potential solutions as binary chromosomes. In our problem objective function is already received. For forming chromosomes-solutions we shall offer such approach. Since solution is a set with m elements, then length of the chromosome will be m. Each its position corresponds to one RTP element. All elements of the chromosome belong to one class.

Each element has 3 fragments. The first fragment corresponds to functionality value, the second – to a power, but the third − to a cost. Thereby, chromosome-solution will have $3m$ fragments. On initial stage all features element values were normalized, their values are found in $[0,1]$. Further all known procedures of the genetic algorithm are used. We shall neither notice that got solution can not correspond to nor one potential variant. Then necessary to find nearest to it on criterion of the minimum middle square distances. Genetic algorithm application is preferably, when known a particular objective functions values. For solving of the problem also rational is an using evolutionary strategy [Rechenberg, 1994].

Conclusion

The considered problem of resque technics acquisition is a complex multiobjective problem. Its complexity depends on quality RTA elements and carriers, to which they will, are installed. The new samples of technics, their evolution point to optimality of RTA problem solving. Technology, which is offered in this paper, is based on element of three components: multiobjective optimization, consequtive variant analysis and evolutionary modeling and unites their advantage in itself.

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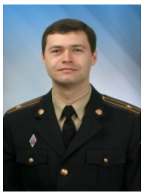
Major Fields of Scientific Research: Decision making processes under uncertainty, Evolutionary modeling



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