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The Algorithm of Selection and Functions Distribution of Multifunctional Personnel - Case when the Number of Functions is Greater than the Number of Personnel

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Abstract

The paper deals with the development of algorithm of selection and functions distribution of multifunctional personnel. The work identifies the objective and sub-objectives of selection and functions distribution of multifunctional personnel. A mathematical model and algorithm of the objective were developed which provide the solution for the objective and sub-objectives of optimal selection and functions distribution of multifunctional personnel.

Keywords: Multifunctional personnel, matrix of functional capacities, selection, functions distribution, algorithm, optimal, model, jection.

Introduction

Multifunctional Operator (MFO) is called a specialist with a functional abundance who has the ability to perform one definite f function in the timing of its functional capacities

(1) $F_a = \{f_e / e \in [1,k]\}, k>1$

Compared to monofunctional operator, multifunctional operators allow us to create organizational structures of systems that have ability, in case of partial failure of any specialist to re-adjust the whole system and facilitate its successful functioning (Tsiramua, 2000; Tsiramua & Basheleishvili, 2015).

The partial failure of the MFO is the case when he/she loses the ability to perform the function assigned to him/her but maintains the ability to perform other functions imposed on the system based on his/her functional capabilities and may be altered to perform other functions (Tsiramua, 2000; Tsiramua & Basheleishvili, 2015; Tsiramua & Kashmadze, 1993). It has been shown in the work that multifunctional staff has a much higher performance indicator than a system composed by mono functional specialists.

Problem definition

The objective of selection and functions distribution of multifunctional personnel can be formulated as follows:

We have a set of functions $f_j, j=1,..,m$ to be exercised, and we have $a_i, i=1,..,n$ candidates for exercising these functions, each i candidate from which exercises *j* function with some *p* probability. The task is aimed at selecting the candidates so that all functions can be exercised, that is, at selecting one candidate for all functions so that product of the probabilities is the maximum value.

In order to give more concrete form to the objective of selection and deployment of multifunctional personnel, we will obtain the following types of sub-objectives:

The number of functions to be exercised is equal to the number of the candidates, i.e. $n = m$, where $a_i, i=1,..,n$ - the number of the candidates involved in the selection process, and f_j ,$j=1,..,m$ - the number of functions to be exercised. Which is resolved - (Basheleishvili & Tsiramua, 2017).

The number of functions to be exercised is fewer than the number of the candidates involved in the selection process, i.e. $n > m$, where $a_i, i=1,..,n$ - the number of the candidates involved in the selection process, and f_j ,$j=1,..,m$ - the number of functions to be exercised. Which is resolved (Basheleishvili & Tsiramua, 2017).

The number of functions to be exercised is higher than the number of the candidates involved in the selection process, i.e. $n < m$, where $a_i, i=1,..,n$ - the number of the candidates involved in the selection process, and f_j ,$j=1,..,m$ - the number of functions to be exercised. Here, in the form of the comments, we should note that in the given particular case of selection and deployment, it will not be possible to perform functions in the parallel regime.

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We need to develop an algorithm that provides multifunctional personnel optimal selection and functions distribution based on the matrix of functional capabilities (Basheleishvili, 2017).

The functional capability matrix is the result of the assessment of the personnel that is organized by matrix. It contains the probability of each personnel to perform each function. The functional capability matrix has the following format:

$$\begin{pmatrix} p_1(f_1) & p_1(f_2) & \cdots & p_1(f_{m-1}) & p_1(f_m) \\ p_2(f_1) & p_2(f_2) & \cdots & p_2(f_{m-1}) & p_2(f_m) \\ \cdots & \cdots & \ddots & \cdots & \cdots \\ p_{n-1}(f_1) & p_{n-1}(f_2) & \cdots & p_{n-1}(f_{m-1}) & p_{n-1}(f_m) \\ p_n(f_1) & p_n(f_2) & \cdots & p_n(f_{m-1}) & p_n(f_m) \end{pmatrix} \qquad (2)$$

Where

a_i, $i=1,..,n$ - Personnel (human-operator);

f_j, $j=1,..,m$ - Functions;

Whereas $p_i(f_j)$ is a probability of the performance by personnel ai of the function f_j from the set (1).

Matematical model of selection and functions distribution

Structure of the selection and functions distribution problem is similar to the structure of the assignment problem.

The assignment problem is one of the fundamental combinatorial optimization problems in the branch of optimization or operations research in mathematics.

Selection and functions distribution problem:

$$\prod_{i=1}^{m}\prod_{j=1}^{n} p_i(f_j)x_{ij} \rightarrow \text{Max} \qquad (3)$$

Where

$$\sum_{j=1}^{n} x_{ij} = 1, i = 1, \dots, m$$

$$\sum_{i=1}^{m} x_{ij} = 1, j = 1, \dots, n$$

$$x_{ij} = \begin{cases} 1, & \textit{if the i candidate is appointed to exercise j function} \\ 0, & \textit{if the i candidate is not appointed to exercisej function} \end{cases}$$

Algorithm for Selection and Functions Distribution of Multifunctional Personnel

We use the Hungarian algorithm modification for the personnel selection and functions distribution.

The Hungarian method is a combinatorial optimization algorithm that solves the assignment problem in polynomial time and which anticipated later primal-dual methods. It was developed and published in 1955 by Harold Kuhn, who gave the name "Hungarian method" because the algorithm was largely based on the earlier works of two Hungarian mathematicians: Dénes Kőnig and Jenő Egerváry (Korte & Vygen, 2006; Craven & Islam, 2005).

James Munkres reviewed the algorithm in 1957 and observed that it is (strongly) polynomial. Since then the algorithm has been known also as the Kuhn–Munkres algorithm or Munkres assignment algorithm.

Steps of the algorithm for the selection and functions distribution of multifunctional personnel are:

Step 1. Determine the matrix of functional capabilities - Matrix [n,m].

Step 2. Assign to each matrix element this element itself subtracted from 1. This step is required for obtaining the optimal maximum value based on the mathematical model (3) of selection and deployment.

Step 3. Subtract from all elements of each column the minimal element of the corresponding column.

Step 4. In the obtained matrix, subtract from all elements of each row the minimal element of the corresponding row.

Step 5: Provide balancing of the obtained matrix. Matrix balancing means that we should transform the given matrix into the square matrix, subject to the following conditions:

1. If the number of functions (m) is equal to the number of personnel to be selected (n), in this case there is no need for matrix balancing and we will move directly to the 6th step;

2. If the number of functions (m) is higher than the number of personnel to be selected (n), that means that selection of some or all personnel (this depends on the number of functions) should be carried out in one or more functions, in order to allow all functions to exercise. By rounding m/n upwards, first we should replicate rows in the matrix and if the number of rows in the matrix after that is higher than the number of columns, we should add to the matrix as many zero columns as needed for transforming it into the square matrix, and then we will move to the 6th step.

3. If the number of functions (m) is fewer than the number of personnel to be selected (n), in this case, we should add in the matrix as many zero columns, as are needed for transforming it into the square matrix, and then we shall move to the 6th step.

Step 6. At this step, in the matrix, there must exist at least one 0, then draw a minimal number of lines in the matrix in the columns and rows so that all zeros are covered.

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Step 7. If the number of drawn lines in the obtained matrix is m, this means that it is possible to select m pieces of zeros, only one in each column and in each row, and it is they which correspond to the optimal solution. Afterwards we will be able to carry out selection and deployment of personnel and complete the algorithm. In the contrary case, we will move to the 8th step.

Step 8. Find the minimal element between the uncrossed elements, subtract it from all matrix elements, which are not crossed and add thosewhich were crossed twice. Let's move to the 6th step.

The algorithm presented in the work is implanted in the programming language c#.

Examples of functionality of algorithm

Consider the performance of the algorithm in a variety of functional capacities matrix:

a) Case when the number of functions is greater than the number of personnel (m>n)

	f1	f2	f3	f4	f5	f6
a1	0,8	0,7	0,74	0,6	0,7	0,9
a2	0,7	0,58	0,71	0,87	0,95	0,6
a3	0,84	0,95	0,75	0,85	0,9	0,74
a1	0,8	0,7	0,74	0,6	0,7	0,9
a2	0,7	0,58	0,71	0,87	0,95	0,6
a3	0,84	0,95	0,75	0,85	0,9	0,74

Fig.1. *Program execution result*

The selection and the functions distribution results have the following look:

$a_1 \rightarrow f_3, f_6$

$a_2 \rightarrow f_4, f_5$

$a_3 \rightarrow f_1, f_2$

b) The case when the number of functions is equal to the number of personnel (m=n)

	f1	f2	f3	f4
a1	1	0,7	0,79	0,9
a2	0,7	0,58	0,71	0,59
a3	0,84	0,71	0,75	0,79
a4	0,89	0,95	0,65	0,85

Fig. 2. *Program execution result*

The selection and the functions distribution results have the following look:

$a_1 \rightarrow f_1$

$a_2 \rightarrow f_3$

$a_3 \rightarrow f_4$

$a_4 \rightarrow f_2$

c) The case when the number of personnel is greater than the number of functions (n>m):

	f1	f2	f3	f4
a1	0,8	0,7	0,74	1
a2	0,7	0,58	0,71	0,9
a3	0,84	0,95	0,75	0,8
a4	0,84	0,41	0,89	0,7
a5	0,69	0,86	0,47	0,9
a6	0,6	0,58	0,75	1

Fig.3. *Program execution result*

The selection and the functions distribution results have the following look:

$a_1 \rightarrow f_1;$

$a_3 \rightarrow f_2;$

$a_4 \rightarrow f_3$

$a6 \rightarrow f4$

Comclusion

The Algorithm suggested in this paper gives the opportunity to make optimal selection and optimal distribution of functions of multifunctional personnel in the following cases:

- The number of functions to be exercised is equal to the number of the personnel involved in the selection process;
- The number of functions to be exercised is fewer than the number of the personnel involved in the selection process;
- The number of functions to be exercised is higher than the number of the personnelinvolved in the selection process.

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