

The choice of an optimal methodology for the retraining organization of psychologists based on the use of mathematical methods

La elección de la metodología óptima para la organización de la recapacitación de expertos psicólogos en base al uso de métodos matemáticos

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ABSTRACT:

The effective authorized methodology for the retraining organization of psychologists is presented, in view of both the difference in their training programs and the procedure for their subsequent appointment to vacant positions. This methodology is based on the task of selecting the optimal plan for the retraining program of psychologists and their subsequent appointing to vacant positions. The algorithm for obtaining the optimal solution (plan) of the specified problem is proposed, as well as the meaningful example illustrating the theoretical provisions presented in the article.

Keywords: The methodology of psychologists' retraining, the theory of graphs, fuzzy sets, fuzzy logic, the problem of appointment, the optimal problem solution

RESUMEN:

Aquí se presenta la metodología autorizada y eficiente para la organización de la recapacitación de expertos psicólogos, que considera tanto la diferencia en los programas de educación, como el orden de su nombramiento a las vacancias. En base a este método, se tiene la tarea de elegir el mejor plan de implementación del programa de la recapacitación de expertos psicólogos con su posterior nombramiento a las vacancias. Se propone un algoritmo para resolver de la manera mas óptima (un plan) la tarea respectiva, así como un ejemplo que ilustra la parte teórica que se menciona en este artículo.

Palabras clave: metodología para la organización de la recapacitación de psicólogos, teoría de los grafos, conjuntos indistintos, lógica indistinta, tarea de nombramiento, la solución óptima de la tarea

1. Introduction

Mathematical methods are applied practically in all the spheres of human activity. Psychological sciences also tend to use mathematics as evidence-based methods. Since the 1970s, the theory of fuzzy sets has been playing an increasingly important role in the use of mathematics, which is widely employed in solving technical problems, decision-making tasks in management, the probability theory is used in conflict studies and economics. The first pioneers in creating a realistic theory of making rational decisions in conflict situations were J. von Neumann & O. Morgenstern (1970), N. Howard (1971), and many others (Mamdani & Assilian, 1975; Piegat, 2001; Sibgatova et al., 2016; Efimova et al., 2017; Enyashina et al., 2017; Ganieva et al., 2015; Kalinina et al., 2017; Masalimova & Chibakov, 2016; Mitin et al., 2017a; Mitin et al., 2017b; Salakhova et al., 2017a; Salakhova et al., 2017b; Salakhova et al., 2017c; Klepach & Borodovitsyna, 2017; Galushkin, 2017a,b).

The latter circumstance also predetermined the use of the specified mathematical system by the authors in order to determine the maximum level of reliability of the fulfillment by each of the retrained (additional education, advanced training) candidates of their official duties in a position for which it is advisable to appoint one.

The fact that the problem is solved within the assumption that the information about the relevance of a candidate after training to competencies of a candidate's respective specialty and the level of his relevance to a job has an ambiguous, fuzzy character gives this article topicality and novelty.

2. Methodological Framework

We will present the required information for further reasoning from the graph theory (Berg, 1962; Chernykh & Vilkov, 2016; Ore, 1968; Masalimova et al., 2014; Mitin, 2016).

The subject of the graph theory is the study of relationships between knots (within the framework of the article – the retraining elements of candidates). The knots are called vertices, and the links between them are edges.

We need to note that in order to reduce the volume of this article, we will sometimes not replace these two terms with terms from the candidates' retraining process that is analyzed in the article.

A graph $G = (V, E)$ is the pair of sets including the set of vertices V and the set of edges E . The examples of graphs are: the plans of complexes of measures; hierarchical structures, systems of relationships between people and organizations; structured programs of education and retraining, etc.

Let u and v be vertices of the graph G . The edge joining these vertices will be denoted by (u, v) , say that the vertices u and v are incidents to the edge (u, v) , and the edge (u, v) is incident to the vertices u and v . The vertices u and v are called finite for the edge (u, v) .

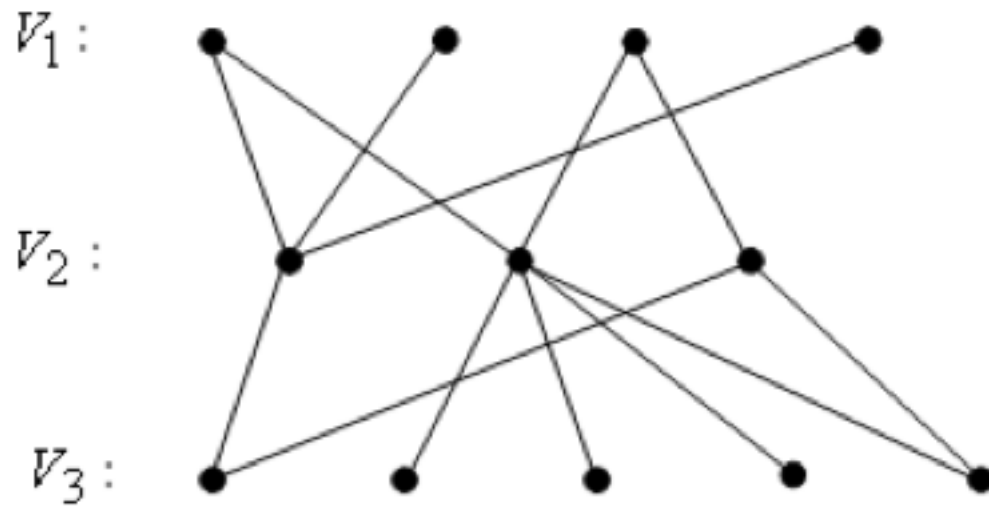
A weighted edge is an edge that corresponds to a certain number. For example, if the edge (u, v) means that the candidate u was retrained for the program v , then the weight of this edge can be the quality assessment of the material learnt or the reliability of the candidate's successful mastering the retraining program.

A weighted graph is a graph whose entire edges are weighted. If $(u, v) = (v, u)$, then the edge (u, v) is called non-oriented. A continuous sequence of non-oriented edges is called a chain.

A sub-graph of the graph $G = (V, E)$ is the graph $F = (W, D)$, all of whose vertices and edges are respectively the vertices and edges of the graph G . A three-vertex ensemble is the chain consisting of two edges and containing three distinct vertices.

By a three-vertex combination P in the graph $G = (V, E)$ we mean a set of three-vertex ensembles of G such that any two distinct ensembles of P are not adjacent; i.e. they have no common vertices. If all the vertices of a graph are vertices of edges of the three-vertex combination under consideration, then this combination is called complete. The graph $G = (V, E)$ is called a tripartite one, by analogy with a bipartite one, if the set of its vertices splits into three disjoint parts V_1, V_2, V_3 , if so, then either or either and (Figure 1).

Figure 1
The tripartite graph



Within the framework of the proposed methodology, we will give some concepts of the theory of fuzzy sets and fuzzy logic (Kofman, 1982; Terano, Asai & Sugeno, 1993; Shtovba, 2001).

The concept of a fuzzy set is an attempt of mathematical formalization of fuzzy information for constructing mathematical models. It is assumed that the elements composing a given set, possessing some common property, can possess this property in different degrees and, consequently, belong to a given set with different degrees. Speaking of the fact that an element belongs to a given set, it is necessary to indicate to what extent it satisfies the properties of this set. The following concepts and results of the theory of fuzzy sets and fuzzy logic are given, for example, in the works (Zadeh, 1976; Leonenkov, 2005; Orlovsky, 1981; Chernykh et al., 2015; Vilkov & Chernykh, 2016; Yakhyaeva, 2006; Zadeh, 1965).

A fuzzy set A^* on a universal set U is the collection of pairs $(\mu_{A^*}(u), u)$, where $\mu_{A^*}(u)$ is the membership function (degree of membership, reliability), i.e. the degree of an element's belonging $u \in U$ to a fuzzy set U . The degree of membership is a number from the interval $[0; 1]$, the higher it is, the more the element corresponds to the properties of the fuzzy set, the more likely it is an element of this fuzzy set.

A fuzzy number is a fuzzy set with a piecewise continuous and convex membership function defined on a universal set of real numbers. We, without loss of generality, confine ourselves to triangular fuzzy numbers, which can be regarded as linear approximations of fuzzy numbers of a more general form.

A triangular fuzzy number is a fuzzy set, denoted $\langle a, b, c \rangle$ and having the membership function

$$\mu(v) = \begin{cases} \frac{v-a}{b-a}, & \text{if } v \in [a, b], \\ \frac{c-v}{c-b}, & \text{if } v \in [b, c], \\ 0, & \text{otherwise.} \end{cases}$$

The intersection of fuzzy sets A^* and B^* given on U , is a fuzzy set C^* with membership function $\mu_{C^*}(u) = \min\{\mu_{A^*}(u), \mu_{B^*}(u)\}$ for all $u \in U$. (1)

We need logical operations with fuzzy statements (Berg, 1962; Wagner, 1972; Piegat, 2001). In fuzzy logic statements are considered that can be true or false to some extent, such statements are called fuzzy. The degree of truth of a fuzzy statement takes values from the closed interval $[0; 1]$. The fuzzy statement with a degree of truth zero is perceived as a "lie", with a degree of truth 1 - as - "truth".

Over fuzzy statements are introduced logical operations, in particular, the conjunction operation.

The degree of truth of the fuzzy statement C will be denoted μ_C .

Let fuzzy statements C and B be given. Fuzzy logical operation И(conjunction) by analogy with the set-theoretic

operation of intersection is performed according to the rule: $\mu_{C \text{ И } D} = \min\{\mu_C, \mu_D\}$. (2)

3. Results

Let us return to the problem, the verbal statement of which is given at the beginning of the article. Let us give it a clear statement in terms of the graph theory.

A non-oriented tripartite weighted graph $G = (V, E)$ with l vertices in each fraction is given $V = V_1 \cup V_2 \cup V_3$. The candidates from the set V_1 (specialists sent for retraining), the vertices from the set V_2 - the retraining programs, the vertices from the set V_3 - vacant positions. In addition i ($i = 1, 2, \dots, l$) is the candidate number (vertices from V_1), j ($j = 1, 2, \dots, l$) - the number of the retraining program (vertices from V_2), k ($k = 1, 2, \dots, l$) - the position number (vertices from V_3).

The presence of the edge on the graph (i, j) means that the candidate with the number i is retrained according to the program with the number j . The presence of the edge (j, k) - that a candidate who has been retrained under the program with the number j occupies the position with the number k .

The weight of the edge is the reliability of fulfilling the corresponding requirement (obtaining the necessary competencies, qualitative performance of official duties). By the weight of a sub-graph (combination), by virtue of the formula (2), is meant the minimal weight of the edge weights that are included in this sub-graph (combination). It is required to build a complete three-peak combination of the maximum weight.

Let us formulate separately the conditions within which it is necessary to implement the methodology to organize the retraining course for specialists-psychologists.

1. It is assumed that candidates have already been trained in some specialty and, depending on the level of their preparation, they master the program of the retraining course with a certain evaluation, measured on a one hundred point scale.

The degree of matching to this assessment with the requirements for mastering the necessary competencies is

not unambiguous and is fuzzy. Without the loss of generality, we will assign it a fuzzy number D_{ij}^p , $D_{ij}^p = \langle a_{ij}^p, b_{ij}^p, c_{ij}^p \rangle$, whose membership function we will mark as $\mu_{D_{ij}^p}$. We believe that candidate i has acquired the necessary competencies if his score is 90 points or higher. Then the degree of truth of the fuzzy statement "the candidate has reliably mastered the required competencies" is equal $\mu_{D_{ij}^p}(90)$, if the score does not exceed 90 points, and it is equal to one if it is greater than 90.

2. The preparedness extent for the performance of k position by a candidate, who has completed retraining courses on the j program is also estimated on a one hundred point scale and is a fuzzy number $D_{jk}^d = \langle a_{jk}^d, b_{jk}^d, c_{jk}^d \rangle$, which membership function we will mark as $\mu_{D_{jk}^d}$.

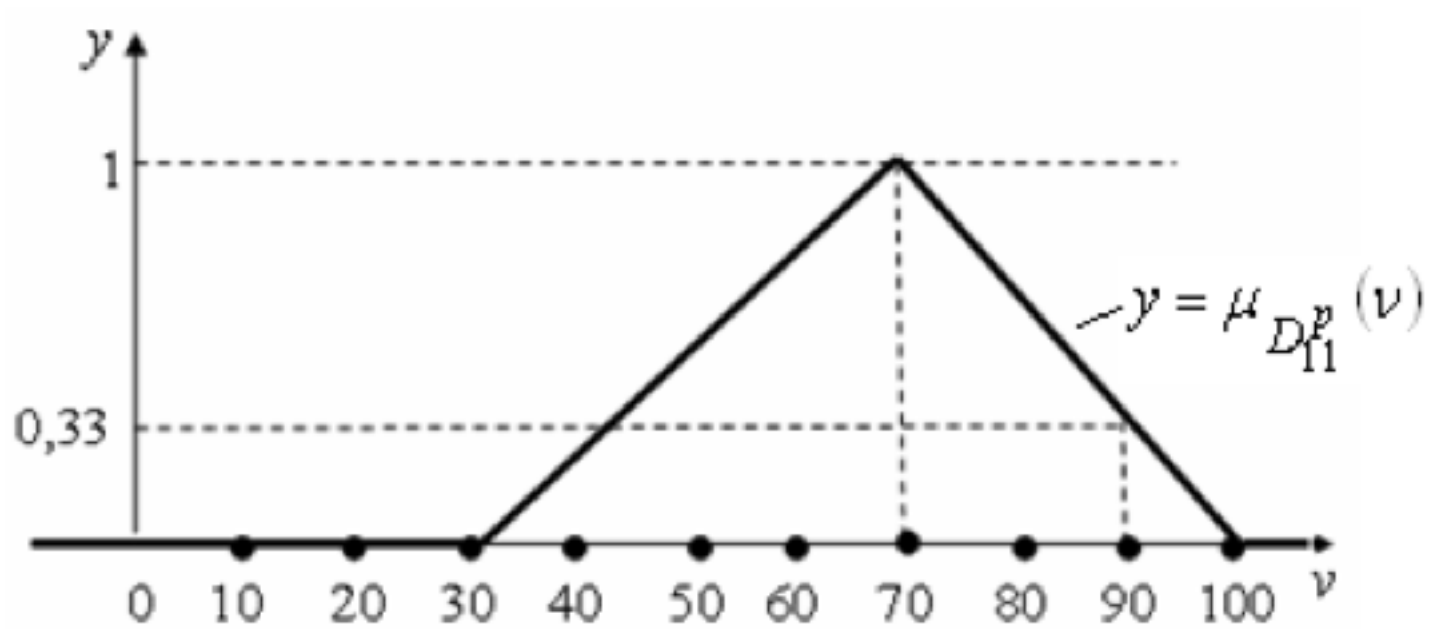
Wherein we will consider that the candidate will be competent to perform the duties of the position, if his assessment at the end of the course is 90 points or higher. Then the truth degree of the fuzzy statement "the candidate is ready to perform the position competently" - is $\mu_{D_{jk}^d}(90)$, if the estimate does not exceed 90 points, and is equal to one if it is not more than 90.

As the explanation, we will provide here the graph of the fuzzy number membership function

$D_{11}^p = \langle 30, 70, 100 \rangle$ and the value $\mu_{D_{11}^p}(90) = 0,33$ in Figure 2.

Figure 2

The graph of the fuzzy number membership function



We will get back to consideration of the task of choosing the optimal plan for the implementation of the psychologists' retraining program and their subsequent appointment to vacant positions (hereinafter, the appointment task).

In the terms formulated above, this is the task of constructing a complete three-peak combination.

To solve this task, we will use the algorithm for solving the transport task with intermediate points, for example, from H.M. Wagner's (1972) monograph.

Let us formulate the statement of the transport problem with intermediate points in terms of the appointment task.

The following points are given: the set of candidates – V_1 ; the set of retraining programs – V_2 ; the set of vacant positions – V_3 .

Elements of the set V_1 we will consider as warehouses with a stock equal to one on each of them, elements of the set V_2 as warehouses with stocks equal to ones and as consumers with needs equal to ones, elements of the set V_3 – as consumers with needs equal to ones.

By the distance between the points $i \in V_1$ and $j \in V_2$, we will understand the degree of inconsistency of the i candidate's estimate with the requirements for acquiring necessary competences of the j retraining program, i.e. amount $1 - \mu_{D_{ij}^p}(90)$. By the distance between the points $j \in V_2$ and $k \in V_3$ we will

understand the degree of unpreparedness of the candidate who completed the retraining program for the performance of k position, i.e. value $1 - \mu_{D_{jk}^d}(90)$. Let us suppose that the remaining distances are

sufficiently large (for example, equal to 100), which make it obviously not advantageous to use the corresponding route.

Remark 1. Within the framework of the algorithm for solving the appointment problem, we will minimize the indicated degrees of inconsistencies.

Let us give an algorithm for solving the appointment problem.

Step 1. Solving the problem of appointment, we will get Z^* the optimal plan (solution) of the task:

$$z^* = (x_{11}^*, x_{12}^*, \dots, x_{1l}^*, x_{21}^*, \dots, x_{2l}^*, \dots, x_{l1}^*, \dots, x_{ll}^*, y_{11}^*, \dots, y_{ll}^*).$$

We will keep in mind that in any i and j $x_{ij}^* \in \{0,1\}$ and $y_{ij}^* \in \{0,1\}$. Equality $x_{ij}^* = 1$ means assigning i candidate to have retraining in the j retraining program, equality $y_{jk}^* = 1$ - the appointment of a candidate who has completed retraining in the j program to a k vacant position.

Remark 2. The desired three-peak combination (the solution of the appointment problem) consists of pairs of edges $\{(i, j), (j, k)\}$, for which $x_{ij}^* = 1$ and $y_{jk}^* = 1$.

Step 2. If the desired combination does not exist, then the problem does not have a solution (plan) and the transition to Step 5 is carried out.

Step 3. Let us find the weight (let it be equal to m) of the resulting three-peak combination of the graph and remove all edges from the graph under consideration whose weight does not exceed m , for which we will assume that the weight of such edges is equal to a large number, for example, 100, that making it unacceptable to use such edges for the retraining of candidates in retraining programs corresponding to these edges or appointing candidates who have completed retraining programs to fill vacant positions that correspond to these edges.

Step 4. Considering the resulting graph as the initial information for solving the appointment problem, we go on to Step 1.

Remark 3. The iteration of the algorithm (steps 1-4) is performed until we obtain a graph that does not have the desired three-peak combination. The combination obtained in the previous step is the one we are looking for.

Step 5. Stop.

Let us illustrate the theoretical basis of the proposed algorithm on an informative example.

Four candidates must undergo retraining in one of the four retraining programs and then fill four vacant positions.

The weights of the corresponding edges b_{ij}^p and b_{jk}^d are indicated in Tables 1 and 2, respectively.

In these tables and further, as $\alpha_1, \alpha_2, \alpha_3, \alpha_4$ we will consider four candidates for retraining, as $\beta_1, \beta_2, \beta_3, \beta_4$ - four retraining programs, as $\chi_1, \chi_2, \chi_3, \chi_4$ - four vacant positions.

Table 1

Initial data for determining the order of candidates' retraining

Candidates for retraining (V_1)	Retraining programs (V_2)			
	β_1	β_2	β_3	β_4
α_1	0.6	0.7	0.8	0.9
α_2	0.7	0.5	0.9	0.8
α_3	0.9	0.7	0.9	0.6
α_4	0.8	0.8	0.7	0.9

The initial data of the appointment problem (transport problem) are given in Table 3.

Remark 4. Due to the fact that for the solution of the appointment problem we use the algorithm for solving the transport problem, in which the objective function is minimized, the differences between the maximum (unit) and the resulting reliability values are used as the characteristics of the edges.

Table 2

Initial data for determining the procedure to fill vacant positions

Retraining programs (V_2)	Vacant positions (V_3)			
	χ_1	χ_2	χ_3	χ_4
β_1	0.8	0.5	0.7	0.9
β_2	0.9	0.8	0.9	0.7
β_3	0.6	0.9	0.6	0.9
β_4	0.5	0.9	0.8	0.7

Table 3

Initial data for the appointment problem (transport problem)

Candidates (α_i) and programs (β_i)	Programs (β_i) and vacant positions (χ_i)								Availability of candidates
	β_1	β_2		β_4	χ_1	χ_2	χ_3	χ_4	
α_1	00.4	0.3	0.2	0.1	100	100	100	100	1
α_2	00.3	0.5	0.1	0.2	100	100	100	100	1
α_3	00.1	0.3	0.1	0.4	100	100	100	100	1
α_4	00.2	0.2	0.3	0.1	100	100	100	100	1
β_1	100	100	100	100	0.2	0.5	0.3	0.1	1
β_2	100	100	100	100	0.1	0.2	0.1	0.3	1
β_3	100	100	100	100	0.4	0.1	0.4	0.1	1
β_4	100	100	100	100	0.5	0.1	0.2	0.3	1
Needs for candidates	1	1	1	1	1	1	1	1	

As a result of solving the appointment problem using the method of solving the transport problem, we obtain the optimal solution (plan) in the form of a full three-peak combination of maximum weight (the reliability of the three-peak ensembles is shown in brackets):

$$\alpha_1 - \beta_4 - \chi_3^{(0.8)}, \alpha_2 - \beta_3 - \chi_2^{(0.9)}, \alpha_3 - \beta_1 - \chi_4^{(0.9)}, \alpha_4 - \beta_2 - \chi_1^{(0.8)}. \quad (3)$$

We would like to note that the reliability of the three-peak ensemble is equal to the minimum of the reliability of its edges, the reliability of the complete three-peak combination, in accordance with formula (2) is equal to the minimum of the reliability of the three-peak ensembles of its components, and, consequently, is 0.8.

In accordance with the instructions of step 3, we prohibit the use of edges by reliability of 0.8 and less - (in Table 3 - 0.2 and more) and we carry out the decision of the appointment problem with the received data. For the example considered in this article, this problem does not have possible solutions (plans) and, therefore, the optimal solution (plan) of the problem is the solution (3) obtained at the previous iteration.

Let us give a verbal formulation of the optimal solution (3) of the appointment problem: the first candidate was trained in the fourth program and took the third position; the second candidate was trained in the third program and took the second position; the third candidate was trained according to the first program and took the fourth position; the fourth candidate was trained in the second program and took the first position.

4. Discussion and Conclusion

Since the 80-s of the last century, the so-called "boom of fuzziness" has begun, associated with the very intensive application in the various fields of human activity of the methods of the theory of fuzzy sets, created in 1965 by Professor L.A. Zadeh (1965).

This article is a continuation of publications in this direction, it is devoted to the application of this theory to solve problems of considerable interest for specialists involved in the organization of the educational process.

New results comprise the formulation of the problem considered in the article using fuzzy numbers and tripartite graphs; the method of solving it with the use of the algorithm for solving the transport problem of linear programming with intermediate points; the algorithm for constructing a full three-peak combination of maximum weight, in the sense considered above, on a tripartite graph.

Thus the methodology has been proposed that provides the optimal procedure for the retraining organization of psychologists that simultaneously takes into account the difference in their training programs and the procedure for their subsequent appointment to vacant positions which with the software application can be used to solve a wide range of tasks in various fields, not only education, but also management, national economy.

5. Recommendations

The proposed methodology for organizing psychologists' retraining is universal, because it can be used not only by human resource departments, psychologists, but also by other personnel services to select the most competent employees. It can be of use to staff members of the Ministry of Education and Science who solve the problems of the required competence structure of the graduates of educational institutions. In addition, it can be useful for researchers in various fields of the national economy that carry out development work in solving similar problems.

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