UDC 519.171.1:004.942(045)
DOI: 10.18372/2306-1472.1.13653

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GRAPHIC MODEL OF PROFESSIONAL ACTIVITY. GRAPHICAL ANALYSIS METHOD

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Abstract

*Currently, various scientific schools use several methods for analyzing the work, which, as a rule, are based on one of the four methods developed at the beginning of the twentieth century. There are also no scientific papers that would consider professional activity from the point of view of systems analysis, as a complex open socio-technical system of interrelated operations (tasks). In this regard, the issues of developing a graphical model of professional activity and assessing the characteristics of its elements is a relevant scientific task.***Analysis of recent research and publications, problem statement**. *The article discusses the main disadvantages inherent in existing methods and systems. The solution of these shortcomings is possible by resolving the contradiction, which is the need to simultaneously ensure the universality of the model on the one hand and its adequacy on the other. The solution of this contradiction is possible through the development of completely new approaches in the provision of professional activities, including in the form of a graphical model.***The purpose and objectives of the study**. *The purpose of the study is to obtain the necessary and sufficient for the analysis of professional activity a number of characteristics that describe its components - operations (tasks). The main task to achieve this goal is to build a graphical model and study the main characteristics of its nodes.***Materials and research methods**. *To solve the problem of the study were used: the method of expert evaluation (in the process of evaluating the characteristics of the work); parametric and non-parametric methods of mathematical statistics; graph theory for constructing a graphical model and its research*. **Research results**. *A method of graphical analysis of professional activity has been developed, which provides for the analysis of data on operations and relations between them, the automatic formation of adjacency matrices, incidents, and the calculation of the coefficients of operations and activities in general*. **The discussion of the results.** *All the considered coefficients exhaustively characterize operations in terms of their importance and place in their professional activities.*
The developed method of graphical analysis of professional activity is aimed at solving the problem of evaluating the characteristics of each operation as a structural element of the "professional activity" system.

Keywords:job analysis; professional activityestimation; graph theory

1. Introduction

Analysis of professional activity as a managerial technique developed around 1900 [1]. The developed technology has become a tool for managers of organizations to implement management processes. F.V. Taylor in the framework of improving work efficiency made her study one of the principles of the scientific organization of labor [2]. His ideas created the basis for studying the time of performing operations and the movements themselves in the operations themselves. Early theorists of the organization and functioning of organizations focused on the purpose of the work and its integration into the overall production process. Only after the 1960s, in connection with the development of various schools of management and psychology and sociology, the focus of research shifted from the goals of work in general to its content, knowledge, skills and abilities of employees who perform it.

In the 1970s, due to changes in technology, the further development of management schools and the human resources management paradigm, there are changes in theoretical approaches to analysis methods for the expansion of functional and, consequently, information models [3].

At the moment, various scientific schools use several methods for analyzing the work, which, as a rule, are based on one of the four methods developed at the beginning of the twentieth century. [4 - 6].

This situation with the development of work analysis methods and related information systems led to the absence of a clearly structured classification of occupational factors, methods of modeling and evaluating a person's professional activities. There are also no scientific papers that would consider professional activities from the point of view of systems analysis as a complex open socio-technical system of interrelated operations (tasks) that have significant mutual influence [7]. In this regard, the issues of developing a graphical model of professional activity and assessing the characteristics of its elements is a relevant scientific task.

2. Analysis of recent research and publications, problem statement

As studies have shown of the existing theoretical foundations for building systems for the analytical assessment of professional activity [8–13], there is no approved and standardized approach to this issue.

There are many different models of work (professions), each of which has its own characteristics and, as a rule, focuses on certain tasks of analysis. However, with such a variety of methods and models, as well as the corresponding information systems, they all have certain disadvantages that can be divided into several large groups:

1. Weak formalization of methods for describing factors and characteristics of models. Up to 40% of factors are described by abstract concepts that relate to semi-structured data.

2. Lack of a systematic approach to the consideration of the domain model. Professional activity, as noted in the introduction, is not considered as a system of interrelated structural elements that influence each other.

3. Standardization of models. Lack of standardized mathematical models that meet the requirements of universality.

4. The adequacy of subject area models. The existing approaches have significant limitations in terms of the subject area modeling, that is, they do not ensure the adequacy of the description of the domain.

Solving these shortcomings is possible by resolving the contradiction, which is the need to simultaneously ensure the universality of the model with the minimum number of structural elements in terms of algorithmic implementation on the one hand, and the need to ensure the adequacy of the model on the other hand [14].

The solution of this contradiction is possible by developing completely new approaches to the description of professional activity in the form of a graphical model and analysis of the characteristics of its elements.

3. The purpose and objectives of the study

The purpose of the study is to obtain necessary and sufficient for the analysis of professional activity the number of characteristics that describe its components - operations (tasks). The main task for achieving this goal is to build a graphical model and study the main characteristics of its nodes.

4. Materials and research methods

To solve the problem of the study were used: the method of expert evaluation (in the process of evaluating the characteristics of the work); parametric and non-parametric methods of mathematical statistics; graph theory for constructing a graphical model and its research. The main materials used were existing descriptions of types of professional activity in various industries and state classifications of occupations.

5. Research results

In the course of the research [15], a formal model was developed that allows calculating estimates of operations and professional activity using the mathematical apparatus. But it does not take into account the interconnection and influence between operations, significantly reduces the accuracy of estimates in terms of the weights of operations ω_i. The presented studies and the construction of professional activity models provided for their consideration at the level of a set of interrelated operations.

A professional activity can be described by an undirected graph, the analysis of which will allow identifying operations that are important for relationships and using their characteristics in analytical calculations [16]. A pair $<V, E>$ is called an unoriented graph$G$, inwhich$V$ – a set of operations, E– a set of connections between them. Professional activity is represented by matrices of adjacency and incidence.

Adjacency matrix – symmetric square matrix $A_a = [a_{ij}]$ order n, in which element $a_{ij} = r_{ij}$, wherer_{ij} - connectionwheight, iftereisaconnection$\{v_i, v_j\}$, that is, operations $v_i$andv_j adjacent, and$a_{ij} = 0$, if there are not connection between operations, that isthey are independent.

The incidence matrix $B = [b_{ij}]$ – rectangular matrix of size $n \times m$ (*n* – the number of operations within the professional activity, *m* – the number of connections between operations), in which element $b_{ij} = 1$, if operationv_i incident communicatione_i, i $b_{ij} = 0$, otherwise.

Consider the main coefficients that describe the nodes (operations) of the model, based on the theory of graphs [17].

Total power – the degree of operation, which is defined as the sum of all the links that are included and coming out of the operation:

$$C_S(v) = \deg(v).$$

Eccentricity is the maximum distance from the selected initial operation to the most remote operation:

$$e(v_i) = \max_{w \epsilon V} d(v, w).$$

The average distance to all other operations is the average distance from the selected initial operation to all other operations.

Frequency of finding in a short way is the calculation of the frequency of placing an operation on a shorter path between certain two operations.

The importance of the operation and the importance of the links of the operation – the calculation of the importance of the operation and its relationships, based on the characteristics of professional activity, its density, eccentricity, total capacity, etc., ω_{2_i},ω_{3_i}.

Ranking of operations – the ranking of operations, depending on how often the expert, passing the links, will fall into this operation, ω_{4_i}.

Clustering factor refers to the extent to which operations tend to make a connection if they are connected through a third operation, C_i (ω_{5_i}) (1):

$$C_i = \frac{2\left|\{e_{jk}: v_j, v_k \in N_i, e_{jk} \in E\}\right|}{k_i(k_i - 1)}, \qquad (1)$$

wherek_i – the number of operations on the set of adjacent operations:

$$N_i = \{v_j: e_{ij} \in E \vee e_{ji} \in E\}.$$

The weight of the operation based on relationships is the calculation of the weight of the operation based on its relationships within the framework of the activity — a recursive characteristic that is calculated from the sum of the importance of the related operations and determines the effect of the operation on the activity as a whole, x_i (ω_{6_i}):

$$x_i = \frac{1}{\lambda}\sum_{j \in G} a_{ij}x_j, \qquad (2)$$

where λ - constant.

The importance of the operation in terms of the switching function (located on the short path between the two other operations) $C_D(v)$ (ω_{7_i}):

$$C_D(v) = \sum_{i \neq v \neq j \in V} \frac{\sigma_{ij}(v)}{\sigma_{ij}}, \qquad (3)$$

where σ_{ij} – total number of shortest paths between verticesi, j;

$\sigma_{ij}(v)$ – the number of shortest paths that pass through the vertices**v**.

The importance of the operation from the point of view of the minimum average distance to other operations $C_L(v_i)$ (ω_{8_i}) (4):

$$C_L(v_i) = \sum_{j} \frac{1}{d(v_j, v_i)}, \qquad (4)$$

where $d(v_j, v_i)$ - distance between vertices v_j, v_i .

Thus, the introduction of additional characteristics in the form of total power in the weights of each operation, obtained using graphical analysis, will increase the accuracy of the estimates for taking into account not only the characteristics of each individual operation, but also their mutual relationship.

Obviously, an increase in the intrinsic power and clustering ratio leads to an increase in the estimates of the characteristics of the elements of the information model due to the increased links between operations and the creation of groupings, or clusters with the center in this operation. In addition to its own characteristics of each operation and relationships, professional activity has its own characteristics that describe its properties.

The order of professional activity is determined by the number of operations (tasks) within it.The average degree is calculated as the arithmetic average of the power of each operation $C_S(v)$.

The diameter of the professional activity is determined according to the maximal eccentricity:

$$d(G) = \max_{v \epsilon V} e(v).$$

The density of professional activity is defined as the ratio of the number of links to their maximum number (5):

$$D = \frac{2E}{V(V-1)} \qquad (5)$$

The density of professional activity characterizes the homogeneity of performed operations, that is, how they are interconnected. So sparse professional activity gives reason to assert the weak link between operations, heterogeneity, or description of the technological chain.

The average clustering factor is calculated on the basis of (1):

$$\overline{C_C} = \frac{1}{n}\sum_{i=1}^{n} C_i.$$

The clustering factor of this operation is the probability that the two nearest operations themselves are the closest neighbors, that is, the transactions are related and dependent. The average clustering factor can be calculated for any kind of professional activity and becomes its integral indicator.

Within the ranking of types of professional activity, the most important are density factors and clustering.

The use of the clustering coefficient of operations $C_i$in their weight index should be carried out after ranking the obtained characteristics by the clustering quality index. There are several approaches to assessing the quality of the division of professional activities into groups of operations, among which the most common calculation of the indicator of modularity and normalized mutual information. In the tasks of analytical assessment it is necessary to use normalized mutual information - an information criterion for comparing two groups in connection with a small-scale graphic model [18].

The criterion involves the introduction of a metric on the groupings of the vertices and the calculation of the distance between the true and the obtained breakdowns. As a measure of difference, normalized general information is used (6):

$$I_N = \frac{2\big(H(X) - H(X|Y)\big)}{H(X) + H(Y)}, \qquad (6)$$

where $H(X)$ – distribution entropy X;

$H(X|Y)$ conditioned entropy;

X, Y – probable values (distribution of labels x, y communities), which have a joint distribution $n_{x,y}/n$, with total number of transactions*n*.

The task of finding dedicated communities of operations in professional activities is to find such C_i, which maximize the value of the criterion (6).

There are a large number of community isolation methods that have strengths and weaknesses. As an algorithm, the walktrap method is considered, the essence of which lies in random transitions from operation to operation, using the idea that it will not lead to leaving the community. On operations introduced metric (7):

$$r_{ij} = \sqrt{\sum_{k=1}^{n} \frac{\left(P_{ik}^t - P_{jk}^t\right)^2}{d_k}} = \left\| D^{-\frac{1}{2}} P_{i\circ}^t - D^{-\frac{1}{2}} P_{j\circ}^t \right\| \qquad (7)$$

where *D* matrix, on the diagonal of which there are degrees of operations d_i;

$P_{i\circ}^t$ – vector of a column in whose position j stands value P_{ij}^t, which determines the probability of transition from operation i to operation j in t steps.

A generalized metric of distance for two communities of operations $C_1, C_2 \subset V$ (8) Given the likelihood of getting out of the community C inoperation $j$in$t$steps (9) [19]:

$$r_{C_1C_2} = \left\| D^{-\frac{1}{2}} P_{C_{1\circ}}^t - D^{-\frac{1}{2}} P_{C_{2\circ}}^t \right\| = \sqrt{\sum_{i=1}^{n} \frac{\left(P_{C_{1i}}^t - P_{C_{2i}}^t\right)^2}{d_k}} \qquad (8)$$

$$P_{C_j}^t = \frac{1}{|C|}\sum_{i\in C} P_{ij}^t, \qquad (9)$$

where $P_{C_{1\circ}}^t$ – probability vector $P_{C_j}^t$

The task of allocating communities is reduced to the clustering of operations by the following algorithm:

1. Initialization$P_1 = \{(v), v \in V\}$.
2. Calculation of the distance between all related operations.
3. Step by step iterative procedure:

a) The choice of two communities C_1 and C_2 from P_1 on the criterion of minimizing the average square of distances between each operation and their community:

$$\sigma_i = \frac{1}{n}\sum_{C\in P_i}\sum_{i\in C} r_{iC}^2 \to \min.$$

b) Union $C_3 = C_1 \cup C_2$.

Update distance between communities by

minimizing the value:

$$\Delta\,\sigma(C_1, C_2) = \frac{1}{n}\left(\sum_{i\in C_3} r_{iC_3}^2 - \sum_{i\in C_1} r_{iC_1}^2 - \sum_{i\in C_2} r_{iC_2}^2\right) \rightarrow \min_{C_1, C_2}.$$

The method of graphical analysis of professional activity (Fig. 1) is aimed at solving the task of evaluating the characteristics of each operation (1 - 5) as a structural element of the system "professional activity" and provides a systematic set of steps (Fig. 2).

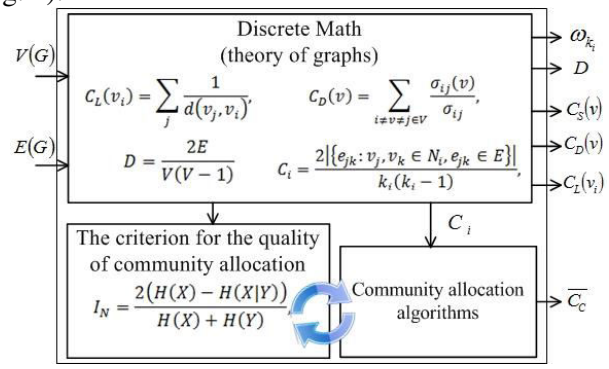

Fig. 1. Structural diagram of the graphical analysis method

The input data of the method are the characteristics of the professional activity, presented in the form of a graph, represented by a set of operations and connections between them. The algorithmic part of the method (7–9) is presented by the algorithms for identifying communities and the criterion for the quality of identifying communities (groups of operations). Outputs are presented by the characteristics of the operations, describing their importance according to various criteria, in the system of professional activity and the characteristics of the activity as a whole, describing its uniformity in terms of the performance of technological processes.

The method involves the introduction of data on operations and relations between them, the automatic formation of adjacency matrices, incidents and the calculation of the coefficients of operations and activities in general. The calculation of the coefficient of clustering operations is carried out according to the algorithm described in the work in order to ensure the maximum value of the criterion (6).

The last step involves the transfer of data to the calculation module of the analytical evaluation method. To analyze the density of professional activity is necessary in a concrete context in pairs with the coefficient of clusterization. The growth of the clustering factor increases the evaluation of each operation.

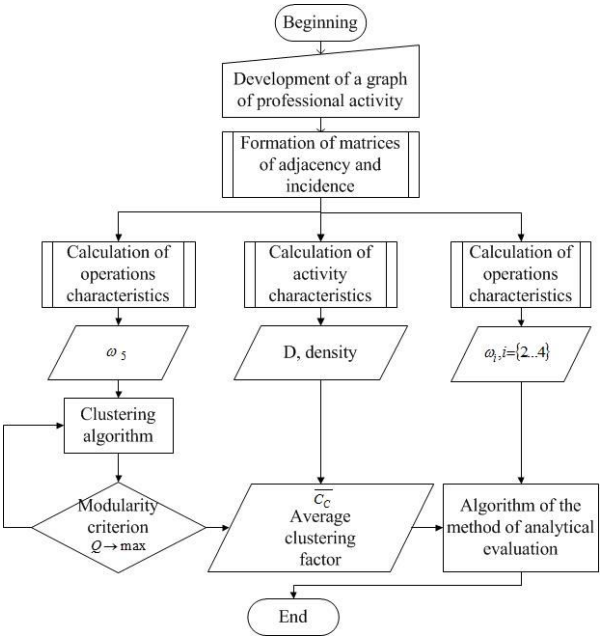

Fig. 2. Stages of the graphical analysis method

6. The discussion of the results

As a result of the research, the main coefficients of the nodes of graphs, the algorithms of their calculations and the possibility of using them to describe operations of the professional activity model were considered. All the coefficients considered exhaustively characterize operations in terms of their importance and place in their professional activities. Since the graphic models of professional activity are small in size, normalized mutual information was adapted - an information criterion for comparing the two groups, which proved itself well during the test calculations of real models. A developed algorithm for working with profession models for a standardized method for isolating walktrap communities has also proven effective in terms of the quality of clustering operations.

7. Conclusions

The developed method of graphic analysis of professional activity is aimed at solving the task of evaluating the characteristics of each operation as a structural element of the system "professional activity".

Consideration of professional activity from the point of view of the theory of graphs allowed to

carry out the analysis of operations taking into account their mutual influence and to determine the characteristics of operations and professional activity in general, which were not considered in the previously existing methods, which was a significant limitation in the subject area.

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Графічна модель професійної діяльності. Метод графічного аналізу

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Натепер різними науковими школами використовуються декілька методів аналізу робіт, які, як правило, ґрунтуються на одному з чотирьох методів, розроблених на початку ХХ ст. Також відсутні наукові роботи, які б розглядали професійну діяльність з погляду системного аналізу, як складну відкриту соціо-техніяну систему взаємопов'язаних операцій (задач). В звязку з цим, питання розроблення графічної моделі професійної діяльності та оцінювання характеристик її елементів є актуальним науковим завданням. **Аналіз останніх досліджень та публікацій, постановка проблеми**. Як показали дослідження існуючих теоретичних основ побудови систем аналітичного оцінювання професійної діяльності не існує затвердженого та стандартизованого підходу до цього питання. В статті розглянуто основні недоліки, притаманні існуючим методам і системам. Вирішення зазначених недоліків можливе через вирішення суперечності, яка полягає в необхідності одночасного забезпечення універсальності моделі з одного боку та її адекватності з другого. Вирішення зазначеної суперечності можливе шляхом розроблення абсолютно нових підходів щодо подання професійної діяльності, в тому числі і у вигляді графічної моделі. **Мета та задачі дослідження**. Мета дослідження – отримання необхідної та достатньої для аналізу професійної діяльності кількості характеристик, які описують її складові – операції (завдання). Основним завданням для досягнення поставленої мети є побудова графічної моделі та дослідження основних характеристик її вузлів.**Матеріали та методи дослідження**. Для вирішення завдання дослідження використовувалися: метод експертного оцінювання (у процесі оцінювання характеристик роботи); параметричні та непараметричні методи математичної статистики; теорія графів для побудови графічної моделі та її дослідження. **Результати досліджень**. Розроблено метод графічного аналізу професійної діяльності, який передбачає аналіз даних щодо операцій та зв'язків між ними, автоматичне формування матриць суміжності, інцидентності та розрахунок коефіцієнтів операцій і діяльності в цілому.**Обговорення результатів**. Всі розглянуті коефіцієнти вичерпно характеризують операції з погляду їх важливості та місця в професійної діяльності.

Розроблений метод графічного аналізу професійної діяльності направлений на вирішення задачі оцінювання характеристик кожної операції як структурного елементу системи «професійна діяльність».

Ключовы слова: аналіз роботи; оцінка професійної діяльності; теорія графів

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Графическая модель профессиональной деятельности. Метод графического анализа

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На данный момент различными научными школами используются несколько методов анализа работ, которые, как правило, основываются на одном из четырех методов, разработанных в начале ХХ в. Также отсутствуют научные работы, которые бы рассматривали профессиональную деятельность с точки зрения системного анализа, как сложную открытую социо-техническую систему взаимосвязанных операций (задач). В связи с этим, вопросы разработки графической модели профессиональной деятельности и оценки характеристик ее элементов является актуальным научным задачнием. **Анализ последних исследований и публикаций, постановка проблемы.** Как показали исследования существующих теоретических основ построения систем аналитического оценивания профессиональной деятельности не существует утвержденного и стандартизированного подхода к этому вопросу. В статье рассмотрены основные недостатки, присущие существующим методам и системам. Решение указанных недостатков возможно путем решение противоречия, которое заключается в необходимости одновременного обеспечения универсальности модели с одной стороны и ее адекватности с другой. Решение указанного противоречия возможно путем разработки совершенно новых подходов в предоставлению профессиональной деятельности, в том числе и в виде графической модели. **Цель и задачи исследования.** Цель исследования - получение необходимого и достаточного для анализа профессиональной деятельности количества характеристик, которые

описывают ее составляющие - операции (задания). Основной задачей для достижения поставленной цели является построение графической модели и исследование основных характеристик ее узлов**.**
Материалы и методы исследований. Для решения задачи исследования использовались: метод экспертной оценки (в процессе оценки характеристик работы); параметрические и непараметрические методы математической статистики; теория графов для построения графической модели и ее исследования.**Результаты исследований.** Разработан метод графического анализа профессиональной деятельности, который предусматривает анализ данных об операциях и связей между ними, автоматическое формирование матриц смежности, инцидентности и расчет коэффициентов операций и деятельности в целом.**Обсуждение результатов.** Все рассмотренные коэффициенты исчерпывающе характеризует операции с точки зрения их важности и места в профессиональной деятельности.
Разработанный метод графического анализа профессиональной деятельности направлен на решение задачи оценивания характеристик каждой операции как структурного элемента системы «профессиональная деятельность».

Ключевые слова: анализ работы; оценка профессиональной деятельности; теория графов

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