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INFORMATION-ANALYTICAL SYSTEM FOR EVALUATING THE SCIENTIFIC PERFORMANCE OF STRUCTURAL UNITS OF UNIVERSITIES AND RESEARCH INSTITUTES BASED ON THE APPROACH OF CONSTRUCTING COMPLEX INTEGRAL EVALUATION

Abstract: The article discusses the creation of an information-analytical system for evaluating the scientific performance of structural units of universities and research institutes based on the approach of constructing complex integral evaluation. A model of information technology for evaluating the results of scientific activity is proposed, consisting of four modules: an information collection module, an information storage module, an analytical module, and a module for user interaction and data visualization. The modular structure of the technology will allow expanding and modifying the capabilities of each of the modules independently of the others, as well as increasing the stability and flexibility of the technology. The implementation of this system is performed using microservices technology. A conceptual model of the information system and a structural model of the functioning of the information

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collection module, as well as a structural model of the information system database, are proposed.

It is shown that most of the well-known indices for evaluating the performance of subjects of scientific activity, for example, h-index, g-index, e-index, I-10 index, etc., do not fully take into account information about citation. Therefore, the method for calculating the evaluation of scientific research activities of scientists was proposed, which does not lose information about any citation of the author and publication. This method determines the scalar evaluation of the results of scientific activity, and it is based on determining a few coefficients. The coefficients define one scientist's citation in the publications of other scientists. As a result, assessment is obtained by solving a system of linear algebraic equations that are constructed based on calculated coefficients. Most of the known evaluation approaches have their own calculation features and disadvantages, which are associated with the loss of some information. Therefore, it is not recommended to give preference to one of them. For the purposes of a comprehensive assessment of the productivity of research activities of scientists, the authors proposed a method of vector evaluation of the results and the construction of the integral assessment. This method is based on the construction of vectors and scalar estimates for each scientist in a multidimensional metric space. The dimensionality of the space is determined by the number of calculated scalar estimates. The method is also based on the construction of an ideal point, which consists of scalar estimates that are the best in terms of achieving maximum performance. The assessment of each subject of scientific activity is calculated as the metric distance from the ideal point to the vector of scalar estimates of this subject of scientific activity.

Keywords: information-analytical systems, microservices, ratings of scientists, rating of scientific departments, integrated performance assessment, site parser.

Introduction

The dynamic development of each state's information-educational scientific system is the main factor that contributes to the rise of its prestige, as well as economic development and the appearance of new technologies in various spheres of human activity. The main goal that the researchers have been dealing with is the creation of mechanisms for effectively managing educational and scientific systems. This can be realized by attracting private organizations, financial support from government authorities at various levels, and expanding international cooperation within certain scientific and educational projects (Horizon 2020, Erasmus +). Therefore, the main task for private companies which are interested in the development of high technologies, and the task for foreign partners is the creation of effective criteria for evaluating the performance of research activities of scientists, higher educational institutions, as well as structural divisions of these educational institutions: departments, faculties, institutes.

Evaluation of the productiveness of scientific research activity allows checking the compliance of the research progress with the goals specified at the planning stage and, if necessary, adjusting the progress of those studies.

One of the components of rating scientific research work is the evaluation of the main results of this work: scientific publications. The results of these publications in other scientific studies can be used as a criterion for the significance of the publication. That is why the assessment of results of scientific research work can be implemented by finding different bibliographic indexes of citing publications.

The assessment of scientific research work can be based on the personal assessments of the scientists working on it. Generally accepted criteria for evaluating the results of the scientific research work of scientists are the indexes of citing publications published by these scientists. These characteristics are usually scalar values. This approach to the construction of such

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quantities has a few advantages, but at the same time, there are disadvantages. These failures include the loss of part of incoming dates and the existence of such borderline cases when the parameter does not change its value at the rising of a few citing and publications. That is why it is relevant to create new or modificative present methods of rating of results of scientific research activity of scientists who do not have these shortcomings. For instance, the scientist made a publication that later became fundamental in a certain line of research, and ended his career. If di > n' then traditional bibliometric indexes will be equal to n', then the result of the research work of this scientist is not very saucerful and important, but such the assessment is not adequate. Therefore, new methods must avoid these cases when the scientific research work is carried out, and the evaluation of the scientific-research work results does not change.

Overview of the industry

The task of assessment of the performance of scientific-research work is traditional under the task of managing educational and scientific-research institutions. The work [1] proposes a project-vector approach to the management of higher education institutions.

The functioning of higher educational institutions is considered as a set of projects, each of which is represented by a vector in the space of scientific, educational, and administrative activities. To determine the coordinates of these vectors, it is necessary to evaluate the results of the corresponding type of activity. The paper [2] describes an approach to assessing the quality of functioning of a higher education institution by constructing a parametric model. This model requires tracking changes in the results of various activities, including scientific, as well as forecasting for the next period. The paper [3] describes an approach to managing an educational institution based on predicting the transition between states, which is represented by a Markov chain. Determining the probability of transitions requires a comprehensive assessment of the results of the research and teaching activities of the institution and forecasting its values for the next period. The paper [4] considers the indicators necessary for a comprehensive assessment of the performance of higher educational institutions and provides an analysis of these indicators. The work [5] provides an overview of the features of methods for evaluating the results of activities, in particular scientific ones, of higher education institutions of the Republic of Kazakhstan.

The performance of scientific-research activities of scientists or scientific subjects can be assessed based on citation rates of publications published by these subjects of scientific activity. In work [6], a review of scientometric bases and methods for obtaining the main citation indicators was made. The most common bibliometric indicator, now, is the Hirsch index. The principle of its construction is described in the paper [7]. The Hirsch index is calculated as follows: a scientist receives an index h if the scientist has published at least h articles, each of which is cited at least h times. It is proposed to use the so-called g-index. This index is the largest number g that corresponds to the number of articles cited at least g2 times. In paper [8], the fundamental shortcomings of h- and g-indices are indicated, which consist in the loss of information about the citation of the most popular publications of the author, and the use of the e-index is proposed to eliminate these shortcomings. In the paper [9], several modifications of the h-index calculation are proposed, including those considering self-quoting.

The task of assessment of the results of searching for information has a number of common characteristics with the task of evaluating the results of scientific-research activities of scientists. These common characteristics are that between pages on the Internet, there is a connection through hyperlinks, and between scientific publications - through citation. For the task of evaluating the results of information search on the Internet, the so-called PR index is used, which is described in paper [10]. The work [11] describes the application of the

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Monte Carlo method to speed up the calculation of the PR index. The paper [12] considers a modification of the Monte Carlo method for finding the PR index in a dynamic network whose structure is constantly changing.

When constructing methods in this study, the approach of finding proximity between multidimensional vectors is used. The work [13] describes formulas for finding metric distances in various ways, as well as a method for indexing vectors based on K-nearest neighbors.

The aim of the study is to construct methods for assessing the productivity of research activities of scientists based on the analysis of citations of publications that are published by scientists.

To ensure the effective functioning of organizations of the educational sector in modern conditions, it is necessary, first, to improve a system of managing these organizations. These improvements relate to using modern management methodologies to implement all types of activities: scientific, educational, organizational, etc.

Most scientists believe that the higher education system must be self-managing and self-regulating. Self-managing of the higher education system is to minimize all types of centralized administrative influence of the state on the activities of universities, the development of competitive bases in the field of higher education, that is, the transition to selective priority funding of the university, depending on the rating.

Well-known methods for assessing the performance of subjects of scientific activity have several disadvantages. In particular, the convolution method requires the correct selection of weight coefficients, which can be a difficult task. After all, each subject of scientific activity a priori understands the areas in which there are positive results and will insist on taking these areas into account in the convolution with the maximum coefficient. That is, to choose such an assessment system, it is necessary to reach a consensus of all subjects of scientific activity on the choice of weight coefficients. The ideal point method requires constant refinement of the ideal point and the use of expert assessment, which is associated with the manifestation of the subjective factor in a comprehensive assessment.

Relevant is the development of a new comprehensive method for assessing the performance of subjects of scientific activity, which can serve as an effective tool for managing higher education institutions and their structural divisions: departments, faculties, and institutes. An important feature of this method should be the possibility of automation for use in the management systems of higher education institutions.

Well-known performance evaluation methods of subjects of scientific-research activity require constant intervention in calculating the subjective factor, agreeing on expert opinions, and changing the system of coefficients when changing assessment priorities, which is difficult to automate. The advantage of the study is the development of a method for assessing the performance of subjects of scientific activity, which is easily automated, does not require the involvement of experts, the selection of weight coefficients, the ideal point and the solution of additional tasks when constructing a comprehensive assessment.

Let's consider methods for assessing the performance of subjects of scientific activity as organizations. There are several global methods for evaluating the performance of higher education institutions. The most popular among them are the World University Rankings, described in the paper [14]. This rating is generated by Quacquarelli Symonds (also known as QS rating). However, the QS methodology may well be applied within the same country. QS rating provides a diverse assessment of the results of various activities of higher education institutions. Most of the indicators considered when calculating the rating are objective and can be obtained from open sources. Some of the indicators are subjective the reputation index. To obtain indicators, it is necessary to conduct a survey of a sufficient number of qualified experts, which is a difficult task.

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Another ranking is the Academic Ranking of World Universities or Shanghai Ranking, which is described in [15], and published by Shanghai Jiao Tong University. The Shanghai ranking focuses primarily on the results of scientific activities of higher education institutions. The Shanghai ranking only includes institutions of higher education whose graduates are Nobel or Fields Prize winners. There are a limited number of such educational institutions, which makes it impossible to use the Shanghai ranking methodology for a comprehensive assessment of all higher educational institutions. However, the method can be effectively used to evaluate research institutions.

The aspect of representation of higher education institutions in the WEB space is evaluated using the Ranking WEB of Universities methodology [16]. Each technique takes into account the calculation of the rating indicators that are characteristic only for it. For example, when compiling the QS rating, the academic reputation of higher education institutions and the reputation of university graduates among employers are considered. The indicators considered when determining the respective rating and their relative importance are shown in Tables 1 and 2.

Ranking Web or Webometrics has the widest coverage of universities. The goal is to construct a ranking for all universities in the world, and not just for hundreds or thousands of the most developed. The rating has been compiled by the Cybermetrics Lab (Spanish National Research Council, CSIC) since 2004 twice a year. The ranking is based on the web presence and influence of the university [4]. The ranking does not just evaluate the university website, its design or user-friendliness, but also the number of visits or unique visitors. Web metrics are considered as a proxy for assessing the global performance of the university and their impact. The Webometrics assessment methodology is constantly evolving and improving. This rating differs significantly from other ratings focused on the assessment of bibliometric indicators and giving preference to the scientific component of the university's activities. Webometrics focuses on the economic value of technology transfer to industry, community involvement (social, cultural, and environmental components of the university), and even its political impact.

Table 1. QS rating indicators

Type of Activity	Indicators	Relative Weight, %
Academic community	- academic reputation - H index - faculty quotation - academic staff with scientific degrees	40
Employers	- employer reputation - presence of employers on campus - employment rate of graduates - results of graduates	20
Learning	- the number of scientific and pedagogical workers relative to the number of students - student exchange	30
International activities	the percentage of tutors from other countries	10

Webometrics believes that link analysis for quality evaluation allows for a wide coverage of university activities than citation analysis or expert surveys. This rating motivates scientists and universities to increase and improve their presence on the Internet. This contributes to the dissemination of knowledge and a more objective assessment of the results of activities through their public discussion. Webometrics uses an a priori model to find the overall score. This methodology considers the power law distribution of the data. All indicators are divided into two groups: activity/presence and visibility/impact. Each of these groups is equivalent and, as a result, gives half of the overall assessment of the university.

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Table 2. Indicators on the Shanghai rating

Type of Activity	Indicators	Relative Weight, %
Quality of instruction	- graduates of the institution who received Nobel and Fields Prizes	10
Quality of faculty	- graduates of the institution who received Nobel and Fields Prizes	20
	- citing publications of faculty members	20
Result of researching	- Scientific publications, which are published in Nature and scientific journals indexed in Science	20
	- Citation Index-Expanded and Social Science Citation Index	20
Effectiveness	- Learning outcomes per unit of students	10

The insignificant representation of the university of the Republic of Kazakhstan in international rankings shows the need to develop its own methods for evaluating the university, which would be based on the same indicators. Such methods encourage the university to develop and improve the relevant indicators.

The paper [17] shows that the above methodologies have in common the determination of the performance results of subjects of scientific activity and, in particular, higher educational institutions based on several groups of indicators. Notably, each of reviewed ratings considers such groups of indicators as:

- the number of scientific publications of employees of higher educational institutions indexed in scientometric databases (Scopus, Nature, Science, etc.);
- citation indicators (SCIE – Science Citation Index-Expanded, SSCI-Social Science Citation Index, etc.);
- the qualitative composition of employees of higher educational institutions, in particular the number of professors, and prize winners, attracted foreign tutors and scientists.

This paper [18] describes a combined forecasting methods that take into account selective comparisons with a sample, that is, a fixed position of the time series. In contrast to the method described in this work [19], this method is less sensitive to the choice of parameters, but it needs to be adapted to the mechanism that generates a time series of potentials for the development of scientific areas. The paper [20] proposes adaptive combined forecasting models for time series, considering the results of identifying similarities in the retrospection of these time series. In this paper [21], a method for constructing unclear expert assessments is considered, which can be used to predict the potential for the development of scientific areas. However, a separate challenge in this method is the selection of experts. The paper [22] proposes a method for identifying areas of scientific research by scientists based on a cluster analysis of scientific publications, which is a preparatory stage for the task.

Also, to evaluate the efficiency of scientific-research activity can apply of forecasting methods of performance indicators. The paper [18] describes combined forecasting method considering the selective comparisons with a sample that is a fixed position of the time series. In contrast to the method described in this paper [19], this method is less sensitive to the choice of parameters, but it needs to be adapted to the mechanism that generates a time series of potentials for the development of scientific areas. The paper [20] proposes adaptive combined forecasting models for time series are proposed, taking into account the results of identifying similarities in the retrospection of these time series. In this paper [21], a method for constructing unclear expert assessments is considered, which can be used to predict the potential for the development of scientific areas. However, a separate challenge in this method is the selection of experts. The paper [22] proposes a method for identifying areas of scientific

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research by scientists based on cluster analysis of scientific publications, which is a preparatory stage for the problem of predicting the development of the potential of scientific areas.

The main disadvantage of traditional methods for assessing the performance of subjects of scientific activity and, in particular, institutions of higher education is the burden of a large number of questionnaires, formulas, rating lists, and etc. In particular, [1] it is indicated that the traditional methods of evaluating higher education institutions are a separate cumbersome activity. In addition, the methods discussed above are primarily aimed at evaluating the results of scientific activity, but it is no less important to take into account the complex other characteristics of the activities of higher educational institutions: educational, organizational, international, and the like. It is important that these characteristics can be assessed on the basis of data that is objective and, where possible, can be obtained from open sources. This will automate the evaluation of higher education institutions and reduce the need to involve experts.

The purpose of this study is to develop an efficient and flexible method for the comprehensive assessment of the performance of higher education institutions.

To achieve the goal, the following tasks have been formulated:

– to develop a method for a comprehensive assessment of the performance of higher education institutions based on the calculation of the volume of m-simplexes, using selected indicators that reflect the main aspects of the activities of higher education institutions.

– to study the developed method for sensitivity to changes in the overall assessments of the categories of indicators and the evolution of integrated assessment.

Basic material

Let $K_0, K_1, \ldots K_m$ be categories that reflect various aspects of the activities of subjects of scientific activity S, in particular, institutions of higher education. Each category of indicators determines the defined criterion for evaluating results of the activities of the subjects of scientific activity.

Let us denote by $P_1, P_2, \ldots, P_{k1}$ – the indicators belonging to the K_i, $i = \overline{0,m}$, where $(m+1)$ is the number of categories, and k_i – the number of indicators belonging to the category K_i.

The stages of building a comprehensive assessment of the performance of subjects if scientific activity.

1. Identifying indicators $P_1, P_2, \ldots, P_{k1}$, belonging to the corresponding category K_i, $i = \overline{0,m}$. This information is determined from open sources that are represented on the Internet.

2. Finding the productivity of the subject of scientific activity S for the period of time $T=[t_0, t_1)$, where t_0 is the initial moment of time, t_1 is the final moment of time. To do this, we will find the numerical values of the subject's indicators for the corresponding period.

Denoted by $\Pi_j^T(S)$ – the numerical value of the indicator Π_j of the subject S for the period T.

Indicators $\Pi_j^T(S)$ can be both absolute and relative. Which of the indicators, in particular the number of faculty awards, should be normalized in accordance with the number of all full-time teachers of an institution of higher education. Some of the indicators should be normalised according to the number of students in higher educational institutions. In general, it is a separate research problem and is not considered in this paper.

3. Construction of performance estimates of the subject S according to the criteria K_i, over a period of time $T=[t_0, t_1)$. Denote їх by $Q_i^T(S)$ – performance evaluation of the subject's scientific activity S, according to the criteria K_i, $i = \overline{0,m}$, for a period of time T. The value of the assessments of the results of the activity of the subject S according to the criteria K_i are calculated in different ways, depending on the method that is taken as the basis. For instance,

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in the method of weighted estimation, weighting factors are considered $\omega_0, \omega_1, \ldots, \omega_{k_i}$, such that $\omega_j \in \mathbf{R}$, $j = \overline{0, k_i}$, $\mathbf{R}$ – the set of real numbers.

Coefficients ω_j, $j = \overline{0, k_i}$ reflect the importance of the indicator Pj in assessing the performance of subjects of scientific activity for which the condition is fulfilled $\sum_{j=0}^{k_i} \omega_j = 1$. The assessment of performance of subject of scientific activity is founded by formula [23]:

$$Q_i^T(S) = \sum_{j=0}^{k_i} \omega_j \Pi_j^T(S), \quad (1)$$

where $Q_i^T(S)$ – The assessment of performance of subject of scientific activity S, founded by criteria K_i, $i = \overline{0, m}$, for a period of time $T=[t_0, t_1)$.

In the ideal point method based on indicators $\Pi_j^T(S)$, $j = \overline{0, k_i}$ construct a point $F^T(S) \in \mathbf{R}^{k_i}$ y (k_i+1) – measurable space, the number of dimensions of which is determined by the number of indicators, $i = \overline{0, m}$

It will be an ideal point

$$F^* = \left(\Pi_0^*, \Pi_1^*, \ldots, \Pi_{k_i}^*\right)$$

$(ki+1)$– measurable space for which for any subject S from the totality of all assessed subjects and an arbitrary period of time T, the following condition is satisfied:

$$\Pi_b^* \geq \Pi_b^T(S), \; b = \overline{0, k_i}$$

To evaluate the performance of the subjects of scientific activity S, it is necessary to find the distance between the point FT and the ideal point F*. The degree of proximity between two points is determined based on some metric distance:

$$Q_i^T(S) = \rho\left(F^T(S), F^*\right),$$

where $\rho\left(F^T(S), F^*\right)$ – Euclidean distance, Minkowski distance, etc.

4. Calculation of a comprehensive assessment of the performance of subjects of scientific activity S for the period $T=[t_0, t_1)$. In the method of weighted assessment and the ideal point, a comprehensive assessment of the performance of subjects of scientific activity S is determined by the formula:

$$Q^T(S) = \sum_{i=0}^{m} w_i Q_i^T(S),$$

where $Q^T(S)$ – a comprehensive assessment of the results of the activity of the subject S for the period $T=[t_0, t_1)$,

w_i, $i = \overline{0, m}$ – cofficients of the importance of the category K_i, $\sum_{i=0}^{m} w_i = 1$.

The difficulty in applying the methods of weighted estimation and the ideal point lies in the need to involve experts to determine the coefficients ω_j, w_i $j = \overline{0, k_i}$, $i = \overline{0, m}$, as well as choosing an ideal point and choosing a formula for finding the distance. In this study, a method is constructed that does not have these shortcomings and does not depend on the subjective opinion of the persons conducting the assessment.

5. Analysis and use of performance estimates.

To assess the performance of subjects of scientific activity, the assessment for each category can be considered as a point in the $(m+1)$ – measurable space. Consider the points v_i, $i = \overline{0, m}$, which are vertices of some m-simplex.

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m-simplex with vertices at points $\nu_i \in \mathbf{R}^{m+1}$ is some m-measurable polytope that is the convex hull of its $m+1$ vertices. That is, the m-simplex is the set of points $\Delta^m \in \mathbf{R}^{m+1}$, for which the condition is satisfied:

$$\Delta^m = \left\{ \theta_0\nu_0 + \theta_1\nu_1 + \ldots + \theta_m\nu_m \left| \left(\sum_{i=0}^{m} \theta_i = 1 \right) \wedge \left(\theta_i \geq 0, i = \overline{0,m} \right) \right. \right\},$$

where θ_i – some real numbers, $\theta_i \in \mathbf{R}$.

Namely Δ^0 (0-симплекс) – this is a point in $\mathbf{R}$, Δ^1 (1- simplex) – this is a segment in $\mathbf{R}^2$, Δ^2 (2- simplex) – this is a triangle in $\mathbf{R}^3$, Δ^3 (3- simplex) – this is a tetrahedron in $\mathbf{R}^4$, Δ^4 (4-simplex) – this is pentachloro in $\mathbf{R}^5$ and etc.

Each m-simplex can be assigned a numerical characteristic that determines the capacity of the part of the space that is limited by this m-simplex. This characteristic will be called the generalized volume of the m-simplex and denoted by $V(\Delta^m)$. For example, the generalized volume of a 0-simplex is zero, $V(\Delta^m) = 0$, the generalized volume of the 1-simplex is equal to the length of the segment $[\nu_0,\nu_1]$, $V\left(\Delta^1\right) = \sqrt{\nu_0^2 + \nu_1^2}$. The generalized volume of the 2-simplex is the area of the triangle with vertices at the points v_0, v_1, v_2 y R^3, which can be found by Heron's formula.

To find the generalized volume of an m-simplex for an arbitrary number of points m, one can use the Cayley-Menger formula. Details about the Kelly-Menger formula are described in paper [24].

Consider the value of performance estimates of the subjects of scientific activity at the moment of time T. in each category K_i, $i = \overline{0,m}$ is assigned a point in $(m+1)$ – measurable space v_i according to the rule:

$$\begin{aligned} \nu_0 &= \left(Q_0^T(S), 0, 0, \ldots, 0\right) \\ \nu_1 &= \left(0, Q_1^T(S), 0, \ldots, 0\right) \\ &\vdots \\ \nu_m &= \left(0, 0, \ldots, 0, Q_m^T(S)\right) \end{aligned},$$

where $Q_i^T(S)$ – assessment of the performance of the subjects of scientific activity S, found by the criterion K_i, $i = \overline{0,m}$, for a period of time $T=[t_0, t_1)$.

According to the method of constructing the points, it is obvious that the system of vectors that start at the origin and end at vi, ϵ orthogonal and linearly independent. Such a system will define a Euclidean space.

If the category in which the performance assessment of the subjects of scientific activity is set is one, then as a result we will have a 0-simplex in the form of a point on the coordinate axis (Fig. 1). If there are two categories, then a 1-simplex is constructed as a segment between two points; the 1-simplex is shown in Fig. 2. If there are three categories, then a 2-simplex is constructed (Fig. 3); if there are four categories, then a 3-simplex (Fig. 4); if there are five, then a 4-simplex (Fig. 5); the volumes of these m-simplices: for 1-simplex – this will be the length of the segment, for 2-simplex – the area of the triangle, for 3-simplex – the volume of the tetrahedron, for > 3 – some hypervolume [23].

Figure 1. Image Δ^0 or 0-simplex (point b $\mathbf{R}$)

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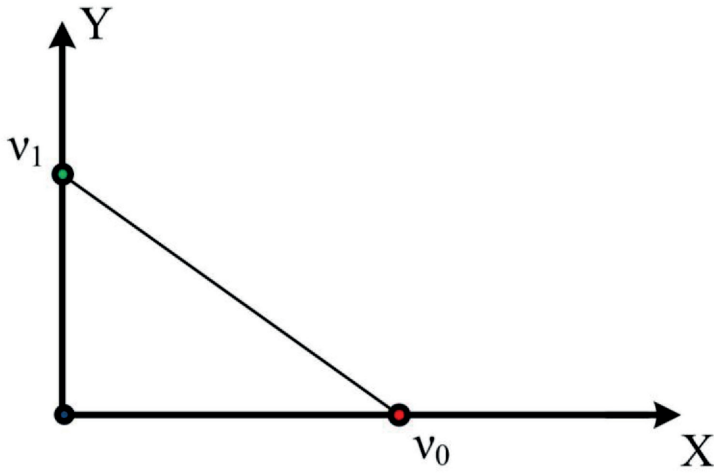

Figure 2. Image Δ^1 or 1-simplex (point b $\mathbf{R}^2$)

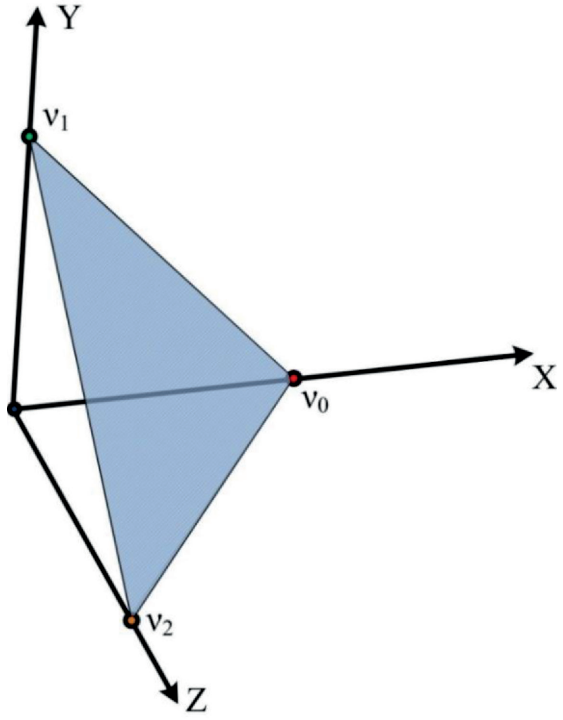

Figure 3. Image Δ^2 or 2-simplex (triangle $\mathbf{R}^3$)

Construct an m-simplex with vertices at the points νi, $i = \overline{0,m}$ and find its generalized volume using the Cayley-Menger formula. And let

$$\Psi = \begin{pmatrix} 0 & 1 & 1 & 1 & \cdots & 1 \\ 1 & 0 & d_{01}^2 & d_{02}^2 & \cdots & d_{0m}^2 \\ 1 & d_{10}^2 & 0 & d_{12}^2 & \cdots & d_{1m}^2 \\ 1 & d_{20}^2 & d_{21}^2 & 0 & \cdots & d_{2m}^2 \\ \vdots & \vdots & \vdots & \vdots & \ddots & \vdots \\ 1 & d_{m0}^2 & d_{m1}^2 & d_{m2}^2 & \cdots & 0 \end{pmatrix}$$

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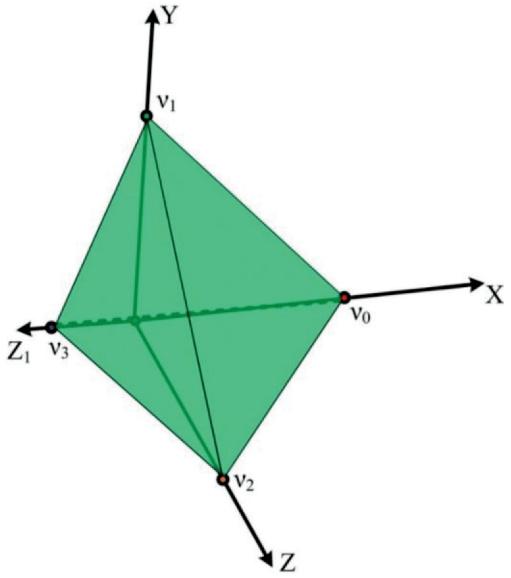

Figure 4. Image Δ^3 or 3-simplex (tetrahedron $\mathbf{R}^4$)

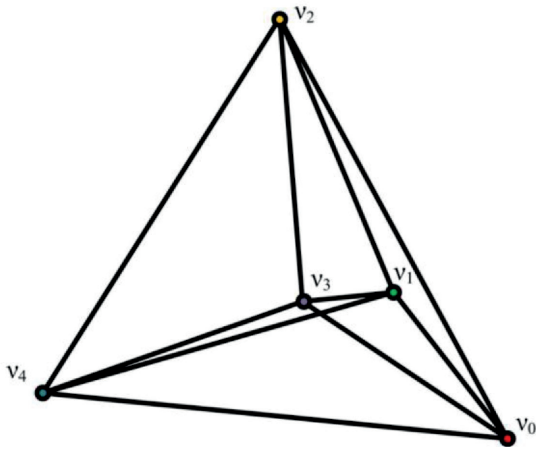

Figure 5. Image Δ^4 or 4-simplex (pentachlor in $\mathbf{R}^5$) then
the generalized volume of the m-simplex is:

$$V\left(\Delta^m\right)=\sqrt{\frac{\left|\Psi\right|\cdot\left(-1\right)^{m-1}}{2^m\left(m!\right)^2}}, \tag{2}$$

where d_{ij} – distance between ν_j, $i,j=\overline{0,m}$, $d_{ij}^2=\nu_i^2+\nu_j^2$, $\left|\Psi\right|$ – matrix determinant Ψ.

Comprehensive assessment $Q^T(S)$ activity of the subject S for a period of time T can find by the formula:

$$Q^T(S)=V\left(\Delta^m\right),$$

where $V\left(\Delta^m\right)$ – the generalized volume of the m-simplex.

We study the dynamics of changes in the comprehensive assessment of the performance of the subjects of scientific activity. To do this, we find the derivative of the generalized volume of the m-simplex with respect to time:

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$$\frac{dQ^T(S)}{dT}=\frac{dV\left(\Delta^m\right)}{dT}=\sqrt{\frac{(-1)^{m-1}}{2^m(m!)^2}}\cdot tr\left(|\Psi|\cdot\Psi^{-1}\cdot\frac{d\Psi}{dT}\right)$$

$$\frac{d\Psi}{dT}=2\cdot\begin{pmatrix}0&0&0&0&\cdots&0\\0&0&d_{01}d'_{01}&d_{02}d'_{02}&\cdots&d_{0m}d'_{0m}\\0&d_{10}d'_{10}&0&d_{12}d'_{12}&\cdots&d_{1m}d'_{1m}\\0&d_{20}d'_{20}&d_{21}d'_{21}&0&\cdots&d_{2m}d'_{2m}\\\vdots&\vdots&\vdots&\vdots&\ddots&\vdots\\0&d_{m0}d'_{m0}&d_{m1}d'_{m1}&d_{m2}d'_{m2}&\cdots&0\end{pmatrix},$$

where $d'_{ij}=\frac{\nu_i\nu'_i+\nu_j\nu'_j}{\sqrt{\nu_i^2+\nu_j^2}}$, $\nu'_i=\left(0,0,\ldots,0,\frac{dQ_i^T(S)}{dT},0,\ldots,0\right)$, $\frac{dQ_i^T(S)}{dT}$, $i=\overline{0,m}$,

are known and characterize the rate of change in performance estimates of the subjects of scientific activity of the corresponding category K_i.

$$\text{If } \frac{dV\left(\Delta^m\right)}{dT}>0,$$

then over time, a comprehensive assessment $Q^T(S)$ grows, and the larger the value of the derivative, the faster the growth occurs. This means that the performance of the subject of scientific activity S has a positive development trend.

$$\text{If } \frac{dV\left(\Delta^m\right)}{dT}<0,$$

then the complex estimate declines $Q^T(S)$, and the smaller the value of the derivative, the faster the decrease. In this case, the productivity of the subjects of scientific activity S requires adjustment, since it is determined by the negative development trend.

T Ψ is inherently definite, hence non-degenerate, i.e., which means that the inverse matrix in the formula exists.

The matrix Ψ Ψ is inherently definite, hence non-degenerate, i.e. $|\Psi|\neq 0$, which means that the inverse matrix Ψ^{-1} in the formula exists.

Let us estimate the sensitivity of the method of complex evaluation of the performance of subjects of scientific activity based on the calculation of the volumes of m-simplexes to a change in the performance estimates of the subject S according to the criterion $Ki-Q_i^T(S)$, $i=\overline{0,m}$. To do this, consider the change of the estimate $Q_i^T(S)$ category K_i by some infinitesimal amount $\varepsilon>0$:

$$\tilde{Q}_i^T(S)=Q_i^T(S)+\varepsilon,$$

where $\tilde{Q}_i^T(S)$ – modified estimates by magnitude $\varepsilon>0$.

Evaluation $\tilde{Q}_i^T(S)$ corresponds to the point

$$\tilde{v}_i=\left(0,0,\ldots,0,\tilde{Q}_i^T(S),0,\ldots,0\right).$$

Let us find the distance between the points v_i and v_j, and consider the point v_i taking into account the change in the estimate $\tilde{Q}_i^T(S)$ by the formula [23]:

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$$d_{ij} = \sqrt{\tilde{v}_i^2 + v_j^2} = \sqrt{\left(Q_i^T(S)\right)^2 + \left(Q_j^T(S)\right)^2},$$

$$\tilde{d}_{ij} = \sqrt{\left(Q_i^T(S)\right)^2 + \left(Q_j^T(S)\right)^2 + 2 \cdot Q_i^T(S) \cdot \varepsilon + \varepsilon^2},$$

As long as $\varepsilon^2 = o(\varepsilon)$, $2 \cdot Q_i^T(S) \cdot \varepsilon = O(\varepsilon)$, namely $2 \cdot Q_i^T(S) \cdot \varepsilon + \varepsilon^2 = O(\varepsilon)$ we can replace and denote the left side of the equality through the infinitesimal $\bar{\varepsilon} > 0$, then:

$$\tilde{d}_{ij} = \sqrt{\left(Q_i^T(S)\right)^2 + \left(Q_j^T(S)\right)^2 + \bar{\varepsilon}},$$

where $\tilde{d}_{ij}$ – distance, taking into account changes in performance estimates of the subject of scientific activity S.

Accordingly, the modulus of the difference of the squared distances $\tilde{d}_{ij}$ and d_{ij} define as:

$$\left|\tilde{d}_{ij}^2 - d_{ij}^2\right| = \left|\left(Q_i^T(S)\right)^2 + \left(Q_j^T(S)\right)^2 + \bar{\varepsilon} - \left(\left(Q_i^T(S)\right)^2 + \left(Q_j^T(S)\right)^2\right)\right| = \bar{\varepsilon}.$$

Let us find the determinant of the matrix Ψ, taking into account the change in the estimates of the performance of the subject of scientific activity S. Denote the matrix $\bar{\Psi}$:

$$\left|\bar{\Psi}\right| = \begin{vmatrix} 0 & 1 & 1 & \cdots & 1 & \cdots & 1 \\ 1 & 0 & d_{01}^2 & \cdots & \tilde{d}_{0i}^2 & \cdots & d_{0m}^2 \\ 1 & d_{10}^2 & 0 & \cdots & \tilde{d}_{1i}^2 & \cdots & d_{1m}^2 \\ \vdots & \vdots & \vdots & \ddots & \vdots & \ddots & \vdots \\ 1 & \tilde{d}_{i0}^2 & \tilde{d}_{i1}^2 & \cdots & 0 & \cdots & \tilde{d}_{im}^2 \\ \vdots & \vdots & \vdots & \ddots & \vdots & \ddots & \vdots \\ 1 & d_{m0}^2 & d_{m1}^2 & \cdots & \tilde{d}_{mi}^2 & \cdots & 0 \end{vmatrix},$$

where $\left|\bar{\Psi}\right|$ – matrix determinant $\bar{\Psi}$.

Let's find the layout of this determinant over the elements of the i-th row:

$$\left|\bar{\Psi}\right| = (-1)^i \cdot \begin{vmatrix} 1 & 1 & \cdots & 1 & \cdots & 1 \\ 0 & d_{01}^2 & \cdots & \tilde{d}_{0i}^2 & \cdots & d_{0m}^2 \\ d_{10}^2 & 0 & \cdots & \tilde{d}_{1i}^2 & \cdots & d_{1m}^2 \\ \vdots & \vdots & \ddots & \vdots & \ddots & \vdots \\ d_{(i-1)0}^2 & d_{(i-1)1}^2 & \cdots & \tilde{d}_{(i-1)i}^2 & \cdots & d_{(i-1)m}^2 \\ d_{(i+1)0}^2 & d_{(i+1)1}^2 & \cdots & \tilde{d}_{(i+1)i}^2 & \cdots & d_{(i+1)m}^2 \\ \vdots & \vdots & \ddots & \vdots & \ddots & \vdots \\ d_{m0}^2 & d_{m1}^2 & \cdots & \tilde{d}_{mi}^2 & \cdots & 0 \end{vmatrix} +$$

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$$+(-1)^{i+1}\tilde{d}^2_{i0}\cdot\begin{vmatrix} 0 & 1 & \cdots & 1 & \cdots & 1 \\ 1 & d^2_{01} & \cdots & \tilde{d}^2_{0i} & \cdots & d^2_{0m} \\ 1 & 0 & \cdots & \tilde{d}^2_{1i} & \cdots & d^2_{1m} \\ \vdots & \vdots & \ddots & \vdots & \ddots & \vdots \\ 1 & d^2_{(i-1)1} & \cdots & \tilde{d}^2_{(i-1)i} & \cdots & d^2_{(i-1)m} \\ 1 & d^2_{(i+1)1} & \cdots & \tilde{d}^2_{(i+1)i} & \cdots & d^2_{(i+1)m} \\ \vdots & \vdots & \ddots & \vdots & \ddots & \vdots \\ 1 & d^2_{m1} & \cdots & \tilde{d}^2_{mi} & \cdots & 0 \end{vmatrix}+$$

$$+(-1)^{i+m}\tilde{d}^2_{i(m-1)}\cdot\begin{vmatrix} 0 & 1 & \cdots & 1 & \cdots & 1 \\ 1 & d^2_{01} & \cdots & \tilde{d}^2_{0i} & \cdots & d^2_{0m-1} \\ 1 & 0 & \cdots & \tilde{d}^2_{1i} & \cdots & d^2_{1m-1} \\ \vdots & \vdots & \ddots & \vdots & \ddots & \vdots \\ 1 & d^2_{(i-1)1} & \cdots & \tilde{d}^2_{(i-1)i} & \cdots & d^2_{(i-1)(m-1)} \\ 1 & d^2_{(i+1)1} & \cdots & \tilde{d}^2_{(i+1)i} & \cdots & d^2_{(i+1)(m-1)} \\ \vdots & \vdots & \ddots & \vdots & \ddots & \vdots \\ 1 & d^2_{m1} & \cdots & \tilde{d}^2_{mi} & \cdots & d^2_{m(m-1)} \end{vmatrix}+$$

$$+\ldots+(-1)^{i+m+1}\tilde{d}^2_{im}\cdot\begin{vmatrix} 0 & 1 & \cdots & 1 & \cdots & 1 \\ 1 & d^2_{01} & \cdots & \tilde{d}^2_{0i} & \cdots & d^2_{0m-1} \\ 1 & 0 & \cdots & \tilde{d}^2_{1i} & \cdots & d^2_{1m-1} \\ \vdots & \vdots & \ddots & \vdots & \ddots & \vdots \\ 1 & d^2_{(i-1)1} & \cdots & \tilde{d}^2_{(i-1)i} & \cdots & d^2_{(i-1)(m-1)} \\ 1 & d^2_{(i+1)1} & \cdots & \tilde{d}^2_{(i+1)i} & \cdots & d^2_{(i+1)(m-1)} \\ \vdots & \vdots & \ddots & \vdots & \ddots & \vdots \\ 1 & d^2_{m1} & \cdots & \tilde{d}^2_{mi} & \cdots & d^2_{m(m-1)} \end{vmatrix}.$$

The determinant in each of the terms of the resulting sum is expanded in the i-th column:

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$$
\begin{aligned}
\left|\bar{\Psi}\right| = (-1)^{i} \cdot \Bigg[(-1)^{i} \cdot \begin{vmatrix}
0 & d_{01}^2 & \cdots & d_{0(i-1)}^2 & d_{1(i+1)}^2 & \cdots & d_{0m}^2 \\
d_{10}^2 & 0 & \cdots & d_{1(i-1)}^2 & d_{1(i+1)}^2 & \cdots & d_{1m}^2 \\
\vdots & \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\
d_{(i-1)0}^2 & d_{(i-1)1}^2 & \cdots & 0 & d_{(i-1)(i+1)}^2 & \cdots & d_{(i-1)m}^2 \\
d_{(i+1)0}^2 & d_{(i+1)1}^2 & \cdots & d_{(i+1)(i-1)}^2 & 0 & \cdots & d_{(i+1)m}^2 \\
\vdots & \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\
d_{m0}^2 & d_{m1}^2 & \cdots & d_{m(i-1)}^2 & d_{m(i+1)}^2 & \cdots & 0
\end{vmatrix} + \\
+ (-1)^{i+m} \cdot \tilde{d}_{(m-1)i}^2 \cdot \begin{vmatrix}
1 & 1 & \cdots & 1 & 1 & \cdots & 1 \\
0 & d_{01}^2 & \cdots & d_{0(i-1)}^2 & d_{0(i+1)}^2 & \cdots & d_{0m}^2 \\
\vdots & \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\
d_{(i-1)0}^2 & d_{(i-1)1}^2 & \cdots & 0 & d_{(i-1)(i+1)}^2 & \cdots & d_{(i-1)m}^2 \\
d_{(i+1)0}^2 & d_{(i+1)1}^2 & \cdots & d_{(i+1)(i-1)}^2 & 0 & \cdots & d_{(i+1)m}^2 \\
\vdots & \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\
d_{(m-1)0}^2 & d_{(m-1)1}^2 & \cdots & d_{(m-1)(i-1)}^2 & d_{(m-1)(i+1)}^2 & \cdots & d_{(m-1)m}^2
\end{vmatrix} + \\
+ \ldots + (-1)^{i+m+1} \cdot \tilde{d}_{mi}^2 \cdot \Bigg| \begin{vmatrix}
1 & 1 & \cdots & 1 & 1 & \cdots & 1 \\
0 & d_{01}^2 & \cdots & d_{0(i-1)}^2 & d_{0(i+1)}^2 & \cdots & d_{0m}^2 \\
\vdots & \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\
d_{(i-1)0}^2 & d_{(i-1)1}^2 & \cdots & 0 & d_{(i-1)(i+1)}^2 & \cdots & d_{(i-1)m}^2 \\
d_{(i+1)0}^2 & d_{(i+1)1}^2 & \cdots & d_{(i+1)(i-1)}^2 & 0 & \cdots & d_{(i+1)m}^2 \\
\vdots & \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\
d_{(m-1)0}^2 & d_{(m-1)1}^2 & \cdots & d_{(m-1)(i-1)}^2 & d_{(m-1)(i+1)}^2 & \cdots & d_{(m-1)m}^2
\end{vmatrix} \Bigg| + \\
+ (-1)^{i+1} \tilde{d}_{i0}^2 \cdot \Bigg[(-1)^{i} \cdot \begin{vmatrix}
0 & d_{01}^2 & \cdots & d_{0(i-1)}^2 & d_{1(i+1)}^2 & \cdots & d_{0m}^2 \\
d_{10}^2 & 0 & \cdots & d_{1(i-1)}^2 & d_{1(i+1)}^2 & \cdots & d_{1m}^2 \\
\vdots & \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\
d_{(i-1)0}^2 & d_{(i-1)1}^2 & \cdots & 0 & d_{(i-1)(i+1)}^2 & \cdots & d_{(i-1)m}^2 \\
d_{(i+1)0}^2 & d_{(i+1)1}^2 & \cdots & d_{(i+1)(i-1)}^2 & 0 & \cdots & d_{(i+1)m}^2 \\
\vdots & \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\
d_{m0}^2 & d_{m1}^2 & \cdots & d_{m(i-1)}^2 & d_{m(i+1)}^2 & \cdots & 0
\end{vmatrix} +
\end{aligned}
$$

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$$+(-1)^{i+m}\cdot\tilde{d}^2_{(m-1)i}\cdot\begin{vmatrix} 1 & 1 & \cdots & 1 & 1 & \cdots & 1 \\ 0 & d^2_{01} & \cdots & d^2_{0(i-1)} & d^2_{0(i+1)} & \cdots & d^2_{0m} \\ \vdots & \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ d^2_{(i-1)0} & d^2_{(i-1)1} & \cdots & 0 & d^2_{(i-1)(i+1)} & \cdots & d^2_{(i-1)m} \\ d^2_{(i+1)0} & d^2_{(i+1)1} & \cdots & d^2_{(i+1)(i-1)} & 0 & \cdots & d^2_{(i+1)m} \\ \vdots & \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ d^2_{(m-1)0} & d^2_{(m-1)1} & \cdots & d^2_{(m-1)(i-1)} & d^2_{(m-1)(i+1)} & \cdots & d^2_{(m-1)m} \end{vmatrix}+$$

$$+\ldots+(-1)^{i+m+1}\cdot\tilde{d}^2_{mi}\cdot\begin{vmatrix} 1 & 1 & \cdots & 1 & 1 & \cdots & 1 \\ 0 & d^2_{01} & \cdots & d^2_{0(i-1)} & d^2_{0(i+1)} & \cdots & d^2_{0m} \\ \vdots & \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ d^2_{(i-1)0} & d^2_{(i-1)1} & \cdots & 0 & d^2_{(i-1)(i+1)} & \cdots & d^2_{(i-1)m} \\ d^2_{(i+1)0} & d^2_{(i+1)1} & \cdots & d^2_{(i+1)(i-1)} & 0 & \cdots & d^2_{(i+1)m} \\ \vdots & \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ d^2_{(m-1)0} & d^2_{(m-1)1} & \cdots & d^2_{(m-1)(i-1)} & d^2_{(m-1)(i+1)} & \cdots & d^2_{(m-1)m} \end{vmatrix}+$$

$$+\ldots+(-1)^{i+m+1}\cdot\tilde{d}^2_{im}\cdot\left[(-1)^{i}\cdot\begin{vmatrix} 1 & 0 & d^2_{01} & \cdots & d^2_{0(i-1)} & d^2_{0(i+1)} & \cdots & d^2_{1(m-1)} \\ 1 & d^2_{10} & 0 & \cdots & d^2_{1(i-1)} & d^2_{1(i+1)} & \cdots & d^2_{1(m-1)} \\ \vdots & \vdots & \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ 1 & d^2_{(i-1)0} & d^2_{(i-1)1} & \cdots & 0 & d^2_{(i-1)(i+1)} & \cdots & d^2_{(i-1)(m-1)} \\ 1 & d^2_{(i+1)0} & d^2_{(i+1)1} & \cdots & d^2_{(i+1)(i-1)} & 0 & \cdots & d^2_{(i+1)(m-1)} \\ \vdots & \vdots & \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ 1 & d^2_{m0} & d^2_{m1} & \cdots & d^2_{m(i-1)} & d^2_{m(i+1)} & \cdots & d^2_{m(m-1)} \end{vmatrix}+\right.$$

$$\left.+\ldots+(-1)^{i+m+1}\cdot\tilde{d}^2_{mi}\cdot\begin{vmatrix} 0 & 1 & 1 & \cdots & 1 & 1 & \cdots & 1 \\ 1 & 0 & d^2_{01} & \cdots & d^2_{0(i-1)} & d^2_{0(i+1)} & \cdots & d^2_{0(m-1)} \\ \vdots & \vdots & \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ 1 & d^2_{(i-1)0} & d^2_{(i-1)1} & \cdots & 0 & d^2_{(i-1)(i+1)} & \cdots & d^2_{(i-1)(m-1)} \\ 1 & d^2_{(i+1)0} & d^2_{(i+1)1} & \cdots & d^2_{(i+1)(i-1)} & 0 & \cdots & d^2_{(i+1)(m-1)} \\ \vdots & \vdots & \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ 1 & d^2_{(m-1)0} & d^2_{(m-1)1} & \cdots & d^2_{(m-1)(i-1)} & d^2_{(m-1)(i+1)} & \cdots & 0 \end{vmatrix}\right]$$

Similarly, we expand the determinant $|\overline{\Psi}|$ and find the difference of the determinants $|\overline{\Psi}|-|\Psi|$. To do this, we group similar terms, and take into account equality (2), then:

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$$\left|\bar{\Psi}\right|-\left|\Psi\right|=\left(-1\right)^{i}\cdot\left[0+\left(-1\right)^{i+1}\cdot\bar{\varepsilon}\cdot\begin{vmatrix}1 & 1 & \cdots & 1 & 1 & \cdots & 1\\ d_{10}^{2} & 0 & \cdots & d_{1(i-1)}^{2} & d_{1(i+1)}^{2} & \cdots & d_{1m}^{2}\\ \vdots & \vdots & \ddots & \vdots & \vdots & \ddots & \vdots\\ d_{(i-1)0}^{2} & d_{(i-1)1}^{2} & \cdots & 0 & d_{(i-1)(i+1)}^{2} & \cdots & d_{(i-1)m}^{2}\\ d_{(i+1)0}^{2} & d_{(i+1)1}^{2} & \cdots & d_{(i+1)(i-1)}^{2} & 0 & \cdots & d_{(i+1)m}^{2}\\ \vdots & \vdots & \ddots & \vdots & \vdots & \ddots & \vdots\\ d_{m0}^{2} & d_{m1}^{2} & \cdots & d_{m(i-1)}^{2} & d_{m(i+1)}^{2} & \cdots & 0\end{vmatrix}+$$

$$+\ldots+\left(-1\right)^{i+m+1}\cdot\bar{\varepsilon}\cdot\left|\begin{vmatrix}1 & 1 & \cdots & 1 & 1 & \cdots & 1\\ 0 & d_{01}^{2} & \cdots & d_{0(i-1)}^{2} & d_{0(i+1)}^{2} & \cdots & d_{0m}^{2}\\ \vdots & \vdots & \ddots & \vdots & \vdots & \ddots & \vdots\\ d_{(i-1)0}^{2} & d_{(i-1)1}^{2} & \cdots & 0 & d_{(i-1)(i+1)}^{2} & \cdots & d_{(i-1)m}^{2}\\ d_{(i+1)0}^{2} & d_{(i+1)1}^{2} & \cdots & d_{(i+1)(i-1)}^{2} & 0 & \cdots & d_{(i+1)m}^{2}\\ \vdots & \vdots & \ddots & \vdots & \vdots & \ddots & \vdots\\ d_{(m-1)0}^{2} & d_{(m-1)1}^{2} & \cdots & d_{(m-1)(i-1)}^{2} & d_{(m-1)(i+1)}^{2} & \cdots & d_{(m-1)m}^{2}\end{vmatrix}\right|+\ldots+$$

$$+2\cdot\left(-1\right)^{i+m+1}\cdot d_{im}^{2}\cdot\left[\left(-1\right)^{i+1}\cdot\bar{\varepsilon}\cdot\begin{vmatrix}0 & 1 & \cdots & 1 & 1 & \cdots & 1\\ 1 & d_{10}^{2} & \cdots & d_{1(i-1)}^{2} & d_{1(i+1)}^{2} & \cdots & d_{1(m-1)}^{2}\\ 1 & \vdots & \ddots & \vdots & \vdots & \ddots & \vdots\\ 1 & d_{(i-1)0}^{2} & \cdots & 0 & d_{(i-1)(i+1)}^{2} & \cdots & d_{(i-1)(m-1)}^{2}\\ 1 & d_{(i+1)0}^{2} & \cdots & d_{(i+1)(i-1)}^{2} & 0 & \cdots & d_{(i+1)(m-1)}^{2}\\ 1 & \vdots & \ddots & \vdots & \vdots & \ddots & \vdots\\ 1 & d_{m0}^{2} & \cdots & d_{m(i-1)}^{2} & d_{m(i+1)}^{2} & \cdots & d_{m(m-1)}^{2}\end{vmatrix}+$$

$$+\ldots+\left(-1\right)^{i+m+1}\cdot\bar{\varepsilon}\cdot\left|\begin{vmatrix}0 & 1 & 1 & \cdots & 1 & 1 & \cdots & 1\\ 1 & 0 & d_{01}^{2} & \cdots & d_{0(i-1)}^{2} & d_{0(i+1)}^{2} & \cdots & d_{0(m-1)}^{2}\\ \vdots & \vdots & \vdots & \ddots & \vdots & \vdots & \ddots & \vdots\\ 1 & d_{(i-1)0}^{2} & d_{(i-1)1}^{2} & \cdots & 0 & d_{(i-1)(i+1)}^{2} & \cdots & d_{(i-1)(m-1)}^{2}\\ 1 & d_{(i+1)0}^{2} & d_{(i+1)1}^{2} & \cdots & d_{(i+1)(i-1)}^{2} & 0 & \cdots & d_{(i+1)(m-1)}^{2}\\ \vdots & \vdots & \vdots & \ddots & \vdots & \vdots & \ddots & \vdots\\ 1 & d_{(m-1)0}^{2} & d_{(m-1)1}^{2} & \cdots & d_{(m-1)(i-1)}^{2} & d_{(m-1)(i+1)}^{2} & \cdots & 0\end{vmatrix}\right|+$$

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$$+(-1)^{i+m+1}\cdot\bar{\varepsilon}\cdot\left[(-1)^{i+1}\cdot\bar{\varepsilon}\cdot\begin{vmatrix} 0 & 1 & 1 & \cdots & 1 & 1 & \cdots & 1 \\ 1 & d^2_{10} & 0 & \cdots & d^2_{1(i-1)} & d^2_{1(i+1)} & \cdots & d^2_{1(m-1)} \\ 1 & \vdots & \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ 1 & d^2_{(i-1)0} & d^2_{(i-1)1} & \cdots & 0 & d^2_{(i-1)(i+1)} & \cdots & d^2_{(i-1)(m-1)} \\ 1 & d^2_{(i+1)0} & d^2_{(i+1)1} & \cdots & d^2_{(i+1)(i-1)} & 0 & \cdots & d^2_{(i+1)(m-1)} \\ 1 & \vdots & \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ 1 & d^2_{m0} & d^2_{m1} & \cdots & d^2_{m(i-1)} & d^2_{m(i+1)} & \cdots & d^2_{m(m-1)} \end{vmatrix}+$$

$$+\ldots+(-1)^{i+m+1}\cdot\bar{\varepsilon}\cdot\begin{vmatrix} 0 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 1 & 0 & d^2_{01} & \cdots & d^2_{0(i-1)} & d^2_{0(i+1)} & \cdots & d^2_{0(m-1)} \\ \vdots & \vdots & \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ 1 & d^2_{(i-1)0} & d^2_{(i-1)1} & \cdots & 0 & d^2_{(i-1)(i+1)} & \cdots & d^2_{(i-1)(m-1)} \\ 1 & d^2_{(i+1)0} & d^2_{(i+1)1} & \cdots & d^2_{(i+1)(i-1)} & 0 & \cdots & d^2_{(i+1)(m-1)} \\ \vdots & \vdots & \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ 1 & d^2_{(m-1)0} & d^2_{(m-1)1} & \cdots & d^2_{(m-1)(i-1)} & d^2_{(m-1)(i+1)} & \cdots & 0 \end{vmatrix}\Bigg]$$

Considering that all determinants do not contain $\tilde{d}_{ij}$, i.e. they are constant. Therefore, in our case, all terms in square brackets are $O(\varepsilon)$ quantities. Since the number of terms in brackets is finite, the sum is also an $O(\varepsilon)$ quantity. Namely, the difference $|\bar{\Psi}|-|\Psi|$ contains $2m+3$ terms, of which $m+2$ are $O(\varepsilon)$ values, and m+1 are $O(\varepsilon 2)$ values. Accordingly, the entire sum is the quantity $O(\varepsilon)$. This means that small changes in the assessments of individual categories correspond to proportional changes in the complex assessment.

Consider numerical methods for calculating the generalized volume of an m-simplex. To calculate the determinant $D=|\Psi|$ numerically, you can choose the Gauss method with the choice of the main element, since zeros are placed on the diagonal of the matrix. Since the matrix is symmetric and inherently defined, one can use the Cholesky LDL decomposition for $m>1$ to calculate the determinant D. In this case, it will be necessary to spend 2 times less calculations than in the case of applying the Gauss method (Gauss).

If

$$\Psi=\begin{pmatrix} \delta_{00} & \delta_{01} & \cdots & \delta_{0m} \\ \delta_{10} & \delta_{11} & \cdots & \delta_{1m} \\ \vdots & \vdots & \ddots & \vdots \\ \delta_{1m} & \delta_{2m} & \cdots & \delta_{mm} \end{pmatrix},$$

then the determinant of the matrix Ψ will be calculated by the formulas:

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$$|\Psi| = \prod_{i=0}^{m} L_{ii},$$

$$L_{ii} = \sqrt{\delta_{ii} - \sum_{k=1}^{i-1} L_{ik}^2},$$

$$L_{ij} = \frac{1}{L_{jj}}\left(\delta_{ij} - \sum_{k=1}^{j-1} L_{ik} L_{jk}\right),\ j < i,\ i, j = \overline{0, m}$$

where $\left(L_{ij}\right)_{i,j=0}^{m}$ – a lower triangular matrix with positive elements on the diagonal, δ_{ij} – matrix coefficients Ψ.

If the estimates of the performance of the subject of scientific activity related to different categories are equal, then to find the volume of the m-simplex $V\left(\Delta^m\right)$, you can use the formula described in [23, 25]:

$$V\left(\Delta^m\right) = \frac{a^{2(m-1)}}{2^{m-1}\left((m-1)!\right)^2}\left[\frac{2}{a^4}\sum_{i=0}^{m-1}\sum_{j=i+1}^{m-1} d_{im}^2 d_{jm}^2 + \frac{2}{a^2}\sum_{i=0}^{m-1} d_{im}^2 - \frac{m}{a^4}\sum_{i=0}^{m-1} d_{im}^4 - m\right], \quad (3)$$

where a – are the values of exponents that are equal to each other or the distance from the vertices of the m-simplex to the origin, d_{ij} are the distances between the vertices v_i and v_j of the m-simplex.

The development of Architecture and software selection for information system development

The information system for evaluating scientific work of scientists, universities and scientific institutions was developed based on this method.

The functional-modular approach to the design of information technologies is generally accepted and has shown its effectiveness in practice. A model of information technology for evaluating the results of scientific activity is proposed and consists of four modules:

– information collection module;
– information storage module;
– analytical module;
– module for user interaction and data visualization.

The modular structure of the technology will allow expanding and modifying the capabilities of each of the modules regardless of the others, as well as increasing the stability and flexibility of the technology.

The structural model of the functioning of the information collection module (Figure 6) is responsible for receiving input data and their primary processing. Two sources for obtaining information are considered: manual user input and automatic collection of open information.

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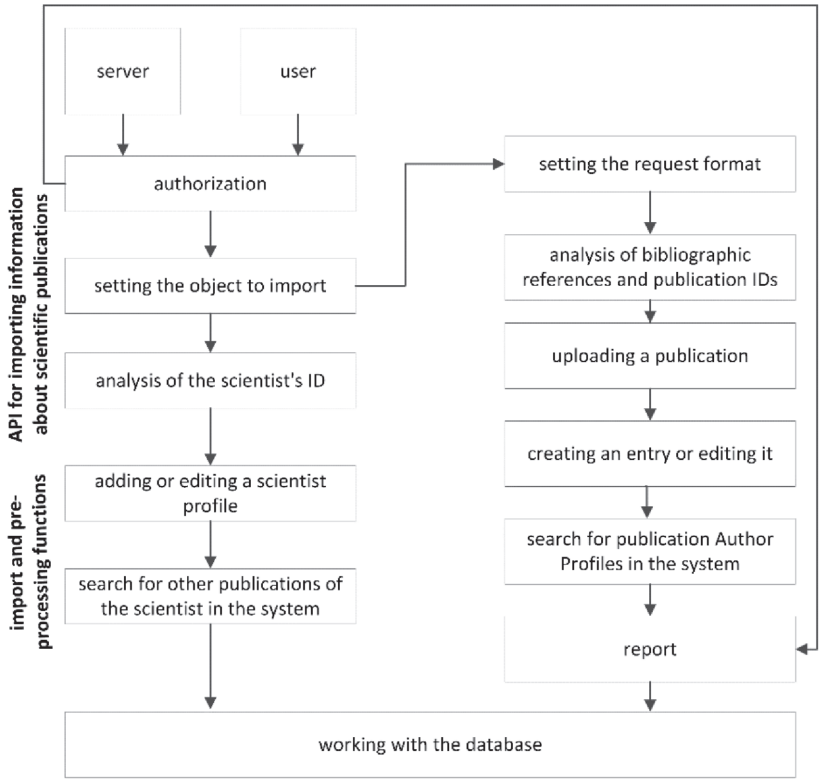

Figure 6. Structural model of the functioning of the information collection module

Open information is information obtained from open sources.

Open-source information is a source that the majority of citizens can access without any restrictions by legislative or other norms. Particularly, it can be printed and electronic media, television, radio, etc. In addition, open primary information includes information that is not intended for wide distribution («grey literature» – materials of various conferences, reference books, lists of addresses of enterprises). Scientometric databases are the best open sources of information which is necessary for evaluating the results of scientific work.

The scientometric database is a bibliographic and abstract database with tools for tracking the citation of articles published in scientific publications. The most important properties of information that are necessary for the correct functioning of the technology are reliability and completeness. Assessing the reliability of information is a difficult task. One of the principles is that information is considered reliable until a contradiction is revealed. Another principle states that any information that has not been verified cannot be reliable.

Contradictory information is information about the state of an object or phenomenon at a certain point in time, obtained from different sources that differ significantly. Verification is the process of confirming its authenticity. The main verification method is to obtain information from a reliable source.

Structured information is information about a certain object or phenomenon presented as a set of pairs (feature, value).

Structuring is the process of converting unstructured information into structured information. Open information is mostly available in an unstructured form. For storage and subsequent processing, information must be structured. Structured and reliable information is transmitted to the storage module.

The main task of the storage module is to store the information received by the information collection module. It also provides data sampling according to the requests of the analytical

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module. The data collection module contains a database that is located locally relative to other modules.

The analytical module solves the main tasks of information technology for evaluating the results of scientific activity: determining the assessments of scientific activity and forecasting the prospects for the development of scientific and pedagogical workers, institutions of higher education and their structural units, as well as establishing the directions of scientific activity. If we consider the structural subdivision of the university as a set of individual subjects of scientific activity, then the assessment of its scientific activity can be obtained as a vector or scalar convolution of estimates of the results of scientific activity of its employees.

The key concept in the implementation of the system for evaluating the productivity of scientific activity was to ensure maximum openness and accessibility for the academic community. Another important regulation was the use of only reliable, verified sources of information that do not include subjective assessments, but only fixed on the results of the real work of the subjects of scientific activity. To ensure these regulations, a system architecture was created in which the system interacts with users via the Internet.

The conceptual model of the information system for evaluating the productivity of scientific activity (Fig. 7) includes an information collection module, an information processing module, a database, and a web server. The target audience of users of the system are responsible individuals of the Ministry of Education and Science of the Republic of Kazakhstan, the management staff of institutions of higher education and individual scientists.

The architecture of the information system should be represented by blocks that include separate microservices for the implementation of such tasks:

- a complex for collecting, processing, storing information about the productivity of subjects of scientific activity;
- methods of formation of subject scientific spaces;
- methods of evaluating the productivity of subjects of scientific activity;
- methods of formation of organizational and functional structure of subjects of scientific activity.

The functional model of the information system for assessing the productivity of the subjects of scientific activity of the Republic of Kazakhstan consists of five main modules:

1. A manager that is intended to perform tasks and interact between other services of the system.
2. An information collection service that ensures the receipt of data from open sources and their preliminary study.
3. A data storage service that includes a database and methods of working with data.
4. Data analysis service, which includes methods for the formation of subject scientific spaces, methods for evaluating the performance of subjects of scientific activity; generating reports.
5. Visualization service, provides interaction with users through the WEB interface.

The info-communication system for evaluating the productivity of scientific activity is a combination of:

- web applications that search, store and process significant amounts of information on the publication activity of scientists from the Internet;
- methods of information processing (clustering methods for dividing scientists with relevant scientific directions, methods for constructing scalar and vector estimates of the results of research activities, methods for predicting the potential of directions, etc.);
- sources of information (information about quoting scientists from scientometric databases);
- consumers of information (institutions of higher education, research institutes, private companies, authorities responsible for scientific policy).

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The peculiarity of the implementation of services is that each of them is executed on a separate virtual server, and the interaction between the services is implemented using the corresponding APIs. The exchange of information and requests between the services takes place via local networks, as well as via the Internet. Data transmission is carried out over the https protocol, by sending POST requests in the appropriate format.

Open data about scientists and their scientific publications are mostly available in unstructured or weakly structured forms. In order to store and use them, it is necessary to perform structuring and primary processing. Further, after structuring, the information is placed in the database.

The system can work both on one server and be divided into several different ones to optimize the load. If the system components are located on different servers, it is necessary to provide communication between them using a local network or the global Internet. Each component has its own API for exchanging tasks between services and the results of their execution, regardless of their physical location.

The visualization module provides user interaction. Its architecture is typical for modern web applications: it consists of several applications created in Python using the Django framework, which functions on the Nginx web server. Eventually, in response to his request, the user receives an HTML document from the server. Bootstrap, jQuery and Highcharts frameworks are used to stylize the display of elements.

The virtual environment is used to isolate packages on the server and avoid version conflicts. The Supervisord program monitors the functioning of the modules. It is automatically restarted in case of an emergency termination of any of the processes.

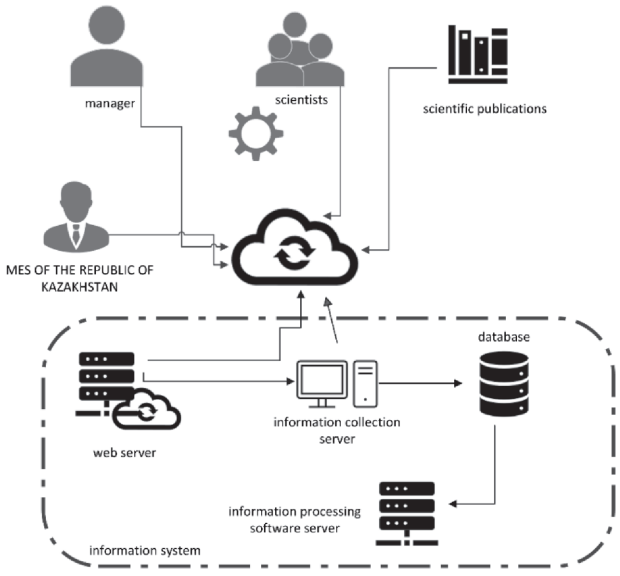

Figure 7. Conceptual model of the information system

All information is stored in a relational database. This database has a physical implementation in the Postgres DBMS, but the database is managed by interacting with ORM Django.

ORM is a programming technology that connects databases with the concepts of object-oriented programming languages, creating a «virtual object database».

This approach makes it possible to abstract from the physical implementation of the database and easily transfer it to another server.

The main models in the database are:

1. User (contains information such as username, password, email address of the user and his rights);

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2. Scientist (contains information about the employee: surname, first name, patronymic in Russian and English, academic title and academic degree, information about the place of work by linking with the corresponding models, implements links with the user's publications and assessments of his scientific activity);

3. Publication (contains information about the publication: title, source, link to the file, communication with the authors and other publications for citation);

4. Citation (implementation of the link between publications, also contains additional information about the source from which information about the citation was obtained, bibliographic reference, etc.);

5. Higher education institution (information about universities: name, type, contact information, information about structural divisions, and also implements communication with users to identify responsible persons (administrators);

6. Structural unit (department or institute, implements cascade communication between universities and a researcher);

7. Evaluation of the results of scientific activity (the evaluation contains scientometric indicators found for the corresponding object and the date of their location).

The peculiarity of the database is that each time an assessment of the results of scientific activity is found, these results are stored in the database. In the system, the user sees the score value that was found last.

At the same time, if more than a certain period of time has passed after finding the values of the estimates (for example, 1 day), a request is formed to update them and can also view the history of finding the estimates.

A significant part of the functions that require a large amount of calculations and access to the database is placed in the calculation module. In particular, such functions include: calculating estimates of research results, searching the database and adding new information about citations and publications, determining research directions and sending emails. The Celery server is used to manage background computing tasks. Two task queues with different priorities are implemented on the server. Using two queues allows you to reduce delays in responding to user requests. Moreover, to reduce the computational load on the server, the management of the calculation results is used. For example, if less than a day has passed since the calculation of the results of the user's research activity, the last result found will be returned to the user and no new calculations will be performed.

This module consists of spiders for scraping information from the international scientometric databases Scopus and Google Scholar, as well as the EBSCO website and the websites of scientific periodicals of the Republic of Kazakhstan. The spiders are written using the Scrapy framework and function on the Scrapyd virtual server. The module's capabilities can be easily expanded by writing new spiders. Standard Scrapyd capabilities are used to manage information collection tasks. To save the results, the system's API is used to add new objects.

Let us consider in detail the principles of organization and interaction of the constituent systems of the subjective information environment on the example of the developed system. Only registered users (created by the system administrator) have access to the system, login or email can be used to log in (if the user entered the email address in the profile settings).

One of the components of the evaluation of the activities of universities around the world is the determination of a generalized indicator of the quality and results of scientific research of an individual scientist, department, faculty and university in general. In the modern world of information technology, a lot of publications that are available in the web space, allows you to assess the scientific level of research. For the developed system, the following open sources were identified for collecting information about the scientific and research activities of scientists, universities and research institutes, namely:

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- international scientometric databases: Scopus and Web of Science;
- Database of Committee for Quality Assurance in the Sphere of Education and Science of the Ministry of Education and Science of the Republic of Kazakhstan;
- National Educational Database of the Ministry of Education and Science of the Republic of Kazakhstan;
- database of the National Center for State Scientific and Technical Expertise.

Modules for collecting information about scientists' publications in Google Scholar, Scopus and Publons have been developed in the information system for evaluating the scientific activities of universities, research institutions and their departments.

By development of the information system (Figure 8), the Python programming language, the Laravel framework were used, as well as for the frontend – the HTML markup language, the Javascript programming language, the framework for jQuery Javascript, the CSS framework MaterializeCSS, the Twig template engine.

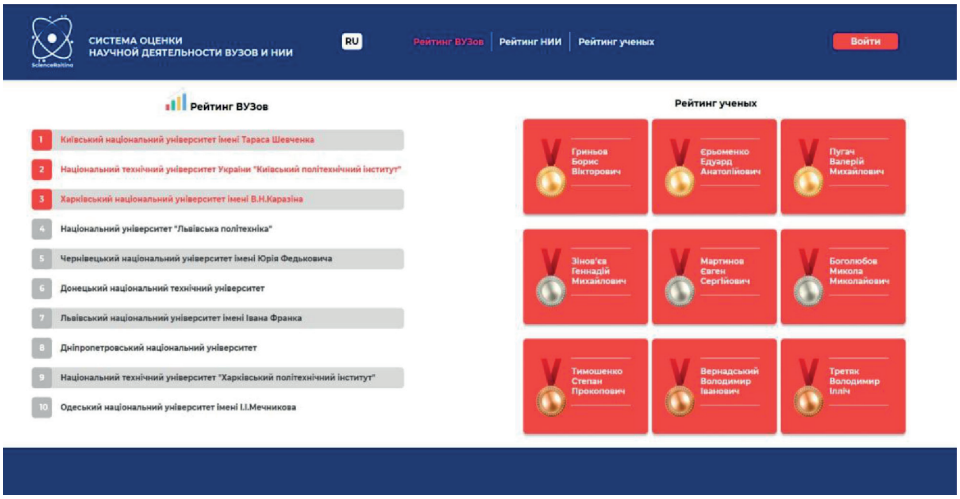

Figure 8. The welcome page of the information portal

The Laravel framework is designed for the development and the use of the MVC architectural model (Model – View – Controller) (Figure 9).

The main advantages of MVC are code reuse and task separation. The «Model» module based on a database (DBMS) implements an information model of the data that are located on the portal. The functions of the user interface are performed by the «View» module, and this module also provides the user with the database in the mode of viewing and displaying data.

The process of interaction of the above modules is executed by the Controller module, and also forms the final data structure for the user.

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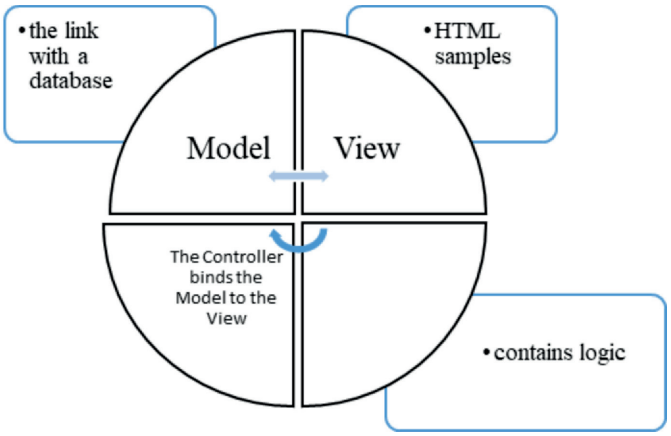

Figure 9. MVC architectural model

Authorization is registered in the file authcontroller.php . The postLogin function has been developed, which is responsible for logging in. If the login and password are entered correctly, the login occurs, and if the password or login does not match, an error message appears.

Based on the proposed architectural model, the architecture of the information system database is developed and classes and properties for the implementation of this model are defined.

The developed portal uses MySQL 8.0.23 as a DBMS, and the database that is stored in it contains 10 tables. Figure 10 shows a structural model of the data relationship scheme of tables by means of which during the selection of certain information, a rating of a university and a scientist is formed by means of queries using the python language.

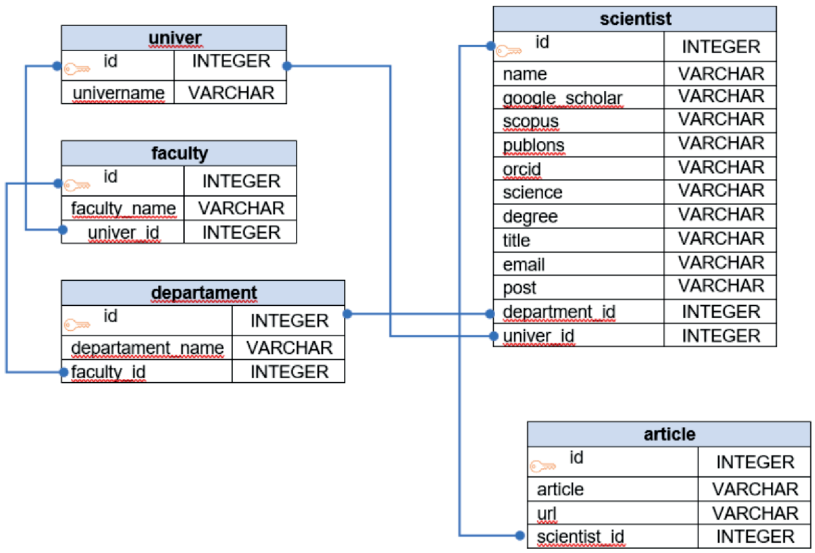

Figure 10. Structural model of the information system database

A module for automated collection of scientific publications of scientists of Kazakhstan from the database of journals included in the list of the Committee for Quality Assurance in Education and Science of the Ministry of Education and Science of the Republic of Kazakhstan was developed.

The program for collecting and systematizing information - the parser is written in Python, the “requests” library is used for queries (Figure 11), the SQLAlchemy library is used to work with the database.

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```
# Attempt to enable urllib3's fallback for SNI support
# if the standard library doesn't support SNI or the
# 'ssl' library isn't available.
try:
    try:
        import ssl
    except ImportError:
        ssl = None

    if not getattr(ssl, "HAS_SNI", False):
        from urllib3.contrib import pyopenssl
        pyopenssl.inject_into_urllib3()

        # Check cryptography version
        from cryptography import __version__ as cryptography_version
        _check_cryptography(cryptography_version)
except ImportError:
    pass

# urllib3's DependencyWarnings should be silenced.
from urllib3.exceptions import DependencyWarning
warnings.simplefilter('ignore', DependencyWarning)

from .__version__ import __title__, __description__, __url__, __version__
from .__version__ import __build__, __author__, __author_email__, __license__
from .__version__ import __copyright__, __cake__

from . import utils
from . import packages
from .models import Request, Response, PreparedRequest
from .api import request, get, head, post, patch, put, delete, options
from .sessions import session, Session
from .status_codes import codes
from .exceptions import (
    RequestException, Timeout, URLRequired,
    TooManyRedirects, HTTPError, ConnectionError,
    FileModeWarning, ConnectTimeout, ReadTimeout, JSONDecodeError
)

# Set default logging handler to avoid "No handler found" warnings.
import logging
from logging import NullHandler

logging.getLogger(__name__).addHandler(NullHandler())

# FileModeWarnings go off per the default.
warnings.simplefilter('default', FileModeWarning, append=True)
```

Figure 11. requests library

In the first stage, data is parsed from the official websites of universities, information about faculties, departments, departments and scientists of the current university is accumulated.

At the second stage, data is parsed from the EBSCO research database, information about scientists' publications is accumulated in scientometric databases (Scopus, Web of Science).

The received data is written to the database using SQLAlchemy (Figure 12).

```
from .types import NCHAR
from .types import NUMERIC
from .types import Numeric
from .types import NVARCHAR
from .types import PickleType
from .types import REAL
from .types import SMALLINT
from .types import SmallInteger
from .types import String
from .types import TEXT
from .types import Text
from .types import TIME
from .types import Time
from .types import TIMESTAMP
from .types import TupleType
from .types import TypeDecorator
from .types import Unicode
from .types import UnicodeText
from .types import VARBINARY
from .types import VARCHAR


__version__ = "1.4.32"


def __go(lcls):
    global __all__

    from . import events
    from . import util as _sa_util

    import inspect as _inspect

    __all__ = sorted(
        name
        for name, obj in lcls.items()
        if not (name.startswith("_") or _inspect.ismodule(obj))
    )

    _sa_util.preloaded.import_prefix("sqlalchemy")

    from . import exc

    exc._version_token = "".join(__version__.split(".")[0:2])


__go(locals())
```

Figure 12. Writing to the database via a parser

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In total, more than 15,000 articles from 44 journals were added to the database to determine the citation rating and popularity of Kazakhstani authors (Figure 13-14).

The obtained results allow us to apply the above methodology to evaluate the research work of universities.

26012	Distributed Optimization of Classifier Committee Hyperparameters.	https://doi.org/10.5220/0006884101710179
26013	Automatic Document Summarization based on Statistical Information.	https://doi.org/10.5220/0006888400710076
26014	New Approach for Mobility Management in Openflow/Software-Defined Networks.	https://doi.org/10.5220/0006847800250033
26015	Context-Aware Middleware Architectural Framework for Intelligent Smart Grid Data Management.	https://doi.org/10.1109/CITS.2018.8440177
26016	Energy-Based Centroid Identification and Cluster Propagation with Noise Detection.	https://doi.org/10.1007/978-3-319-98443-8_48
26017	Agents Interaction and Queueing System Model of Real Time Control of Students Service Center Load Ba	https://doi.org/10.1007/978-3-319-98443-8_32
26018	Research of Optimal Structure for Autonomous Earthmoving and Construction Machines' Communication Sy	https://doi.org/10.1109/ICUFN.2018.8436649
26019	A Study on the Wi-Fi Radio Signal Attenuation in Various Construction Materials (Obstacles).	https://doi.org/10.1109/ICUFN.2018.8436785
26020	A Chain Topology for Efficient Monitoring of Food Grain Storage using Smart Sensors.	https://doi.org/10.5220/0006850602550264
26021	Energy Efficient Price Based Power Allocation in a Small Cell Network by Using a Stackelberg Game.	https://doi.org/10.1109/BlackSeaCom.2018.8433625
26022	Development of a Robot for Boiler Tube Inspection.	https://doi.org/10.5220/0006930205440551
26023	Development of a Network-based Autonomous Firefighting Robot.	https://doi.org/10.5220/0006928305350543
26024	Energy-efficient self-backhauling in heterogeneous wireless networks: A game-theoretic approach.	https://doi.org/10.1016/j.phycom.2018.05.002
26025	Neuro-Spike Communications With Multiple Synapses Under Inter-Neuron Interference.	https://doi.org/10.1109/ACCESS.2018.2854878
26026	Review of Chirped Fiber Bragg Grating (CFBG) Fiber-Optic Sensors and Their Applications.	https://doi.org/10.3390/s18072147
26027	Approximate Probabilistic Neural Networks with Gated Threshold Logic.	http://arxiv.org/abs/1808.00733
26028	A simple analysis of flying capacitor converter.	http://arxiv.org/abs/1808.02758
26029	Binary Weighted Memristive Analog Deep Neural Network for Near-Sensor Edge Processing.	http://arxiv.org/abs/1808.00737
26030	Memristor-based Synaptic Sampling Machines.	http://arxiv.org/abs/1808.00679
26031	Automatic Extraction of Synonymous Collocation Pairs from a Text Corpus.	https://doi.org/10.15439/2018F186
26032	Dynamic Learning for Distributed Power Control in Underlaid Cognitive Radio Networks.	https://doi.org/10.1109/IWCMC.2018.8450359
26033	Reliability analysis and functional design using Bayesian networks generated automatically by an "Id	https://doi.org/10.1016/j.ress.2018.07.020
26034	Diffusion sensitivity enhancement filter for raw DWIs.	https://doi.org/10.1049/iet-cvi.2018.5213
26035	Learning automaton-based self-protection algorithm for wireless sensor networks.	https://doi.org/10.1049/iet-net.2018.0005
26036	FPGA Dynamic and Partial Reconfiguration: A Survey of Architectures, Methods, and Applications.	http://doi.acm.org/10.1145/3193827
26037	Learning in Memristive Neural Network Architectures using Analog Backpropagation Circuits.	http://arxiv.org/abs/1808.10631
26038	Adopting and managing open data: Stakeholder perspectives, challenges and policy recommendations.	https://doi.org/10.1108/AJIM-11-2017-0250
26039	Concurrently controlled grammars.	https://doi.org/10.14736/kyb-2018-4-0748
26040	Fast and backward stable computation of eigenvalues and eigenvectors of matrix polynomials.	https://doi.org/10.1090/mcom/3338
26041	Analytical Method for Determination of Internal Forces of Mechanisms and Manipulators.	https://doi.org/10.3390/robotics7030053
26042	Impact of Integrated Circuit Packaging on Synaptic Dynamics of Memristive Devices.	http://arxiv.org/abs/1809.10434
26043	Memristive LSTM network hardware architecture for time-series predictive modeling problem.	http://arxiv.org/abs/1809.03119
26044	Speaker Recognition for Robotic Control via an IoT Device.	https://doi.org/10.23919/WAC.2018.8430295
26045	Application of Classification Algorithm Based on SVM for Determining the Effectiveness of Treatment	https://doi.org/10.1016/j.procs.2018.04.034
26046	Design and Modeling of a Lightweight and Low Power Consumption Full-Scale Biped Robot.	https://doi.org/10.1142/S0219843618500226

Figure 13. Database of scientific publications in world publications

id	article	url
380	Numerical study of supersonic turbulent free shear layer mixing and combustion	https://ijmph.kaznu.kz/index.php/kaznu/article/view/245
381	Asymptotic convergence of the solution of the initial value problem for singularly perturbed higher-	https://ijmph.kaznu.kz/index.php/kaznu/article/view/246
382	Heat and mass transfer processes at high-temperature media during combustion of low-grade pulverized	https://ijmph.kaznu.kz/index.php/kaznu/article/view/247
383	The nanodimension crystallite formation in steel surface after pulsed plasma flow action	https://ijmph.kaznu.kz/index.php/kaznu/article/view/248
384	Manipulation of the plasma-dust layer in high-frequency discharge with an additional alternative pha	https://ijmph.kaznu.kz/index.php/kaznu/article/view/249
385	Investigation of radio emission from cosmic rays at an altitude 3340 m asl.	https://ijmph.kaznu.kz/index.php/kaznu/article/view/250
386	Informational and entropic criteria of self-similarity of fractals and chaotic signals	https://ijmph.kaznu.kz/index.php/kaznu/article/view/251
387	Research with purpose of defining the lift and drag forces acting on hydro turbine blade with changi	https://ijmph.kaznu.kz/index.php/kaznu/article/view/252
388	Numerical aspects of the adaptive computational grid in solving the problems of electrical prospecti	https://ijmph.kaznu.kz/index.php/kaznu/article/view/259
389	Immersion principle for a variation calculus problem with boundary conditions	https://ijmph.kaznu.kz/index.php/kaznu/article/view/260
390	Complex Dynamics and Statistics in Hamiltonian 1-Dimensional Lattices	https://ijmph.kaznu.kz/index.php/kaznu/article/view/261
391	Critical exponents of Fujita type for certain time-fractional diffusion equations	https://ijmph.kaznu.kz/index.php/kaznu/article/view/262
392	On a boundedness result of non-toroidal pseudo-differential operators	https://ijmph.kaznu.kz/index.php/kaznu/article/view/263
393	Simulation of thermal flows by lattice Boltzmann method on the CUDA computational platform	https://ijmph.kaznu.kz/index.php/kaznu/article/view/253
394	Computational study of temperature stratification effect on harmful gases expansion in the atmospher	https://ijmph.kaznu.kz/index.php/kaznu/article/view/235
395	Influence of slit sizes on the interaction structure of supersonic turbulent air flow with a multi-c	https://ijmph.kaznu.kz/index.php/kaznu/article/view/264
396	Evaluation of wind power potential in shelek corridor (Kazakhstan) using weibull distribution functi	https://ijmph.kaznu.kz/index.php/kaznu/article/view/265
397	Influence of background gas and external magnetic field on the localization of particles in two dime	https://ijmph.kaznu.kz/index.php/kaznu/article/view/266
398	Application of electron-beam technology to reduce anthropogenic load of thermal power plants	https://ijmph.kaznu.kz/index.php/kaznu/article/view/267
399	Mössbauer research in zoloceramic materials	https://ijmph.kaznu.kz/index.php/kaznu/article/view/236
400	Soliton solutions of a generalized Klein–Gordon equation with power-law nonlinearity via the first i	https://ijmph.kaznu.kz/index.php/kaznu/article/view/268
401	Solvability of a two-point boundary value problem with phase and integral constraints	https://ijmph.kaznu.kz/index.php/kaznu/article/view/216
402	Numerical simulation of clouds formation based on the power of explosion estimated by the sizes of t	https://ijmph.kaznu.kz/index.php/kaznu/article/view/217
403	Formation of ZnSe nanoclusters in the layers of silicon dioxide by high-fluence ion implantation and	https://ijmph.kaznu.kz/index.php/kaznu/article/view/218
404	Optical properties of dense coulomb plasmas	https://ijmph.kaznu.kz/index.php/kaznu/article/view/219
405	Efficiency comparison of photovoltaic and photovoltaic-thermal solar panels	https://ijmph.kaznu.kz/index.php/kaznu/article/view/220
406	Strong form factor of delta (1232)	https://ijmph.kaznu.kz/index.php/kaznu/article/view/221
407	The three quark-current of delta-isobar	https://ijmph.kaznu.kz/index.php/kaznu/article/view/222
408	Dispersion of electromagnetic waves in layered graphene-dielectric metamaterials	https://ijmph.kaznu.kz/index.php/kaznu/article/view/223
409	The nonlocal nonlinear Schrödinger and Maxwell – Bloch equation	https://ijmph.kaznu.kz/index.php/kaznu/article/view/224
410	Investigation of technologies of processing of big data	https://ijmph.kaznu.kz/index.php/kaznu/article/view/225
411	Use of machine learning for early pre-clinical diagnostics of heart diseases	https://ijmph.kaznu.kz/index.php/kaznu/article/view/226
412	Mathematical modelling of radiation defect formation processes in the materials irradiated with prot	https://ijmph.kaznu.kz/index.php/kaznu/article/view/227
413	On numerical simulations of the 1d wave equation with a distributional coefficient and source term	https://ijmph.kaznu.kz/index.php/kaznu/article/view/228
414	Computer modelling of distributions processes on vacancy nanoclusters depth in the heavy targets irr	https://ijmph.kaznu.kz/index.php/kaznu/article/view/229
415	Optical properties of a-As2Se3 thin films	https://ijmph.kaznu.kz/index.php/kaznu/article/view/230
416	Applications of parallel computing technologies for modeling the mixed convection in backward-facing	https://ijmph.kaznu.kz/index.php/kaznu/article/view/231
417	Combustion processes in furnace chambers of Kazakhstan TPPs using high-ash coal	https://ijmph.kaznu.kz/index.php/kaznu/article/view/232
418	The study of the heat power effectiveness of a parabolic solar concentrator	https://ijmph.kaznu.kz/index.php/kaznu/article/view/233

Figure 14. Database of scientific publications in Kazakhstan

This developed system is organized in the form of a web application, so all the program code of the system and the database are on the server, the client part is a website that initiates requests to the server and displays the results of its work (because the «thin client» scheme is used).

Such a scheme has two key advantages:

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- low requirements for the client's hardware and the ability to access the system using a wide range of devices – PCs, tablets, smartphones;
- significantly simplified the deployment of the system for users and its subsequent update. All changes to the program code occur on the server, so the client part of the system (the site) always works with the newest, up-to-date version of the system.

During the development of the portal, the principles of web design of the user interface were observed, such as:

- study of users to create a website UI design;
- compliance with the visual hierarchy, that is, placing each element in a certain way to simplify understanding;
- providing feedback and protecting the user from accidental actions;
- using the F-pattern.

Login to User accounts is carried out using a login and password from the database.

The postReg function is responsible for user registration, Google captcha is used during registration. After entering the data and clicking the registration button, an email for account activation arrives at the specified email address.

The request to change the password is processed by the 'getpasswordchar' function, if the mail entered in the field matches the mail in the database, then an email with instructions on password recovery is sent to this mail.

The password change itself is handled by the following functions: 'get Password Change', 'post Password Change'.

This system is developed on the principles of modularity, single entry of information and differentiation of rights and responsibilities.

Based on the integral method of evaluating the results of scientists' activities, the university rating was calculated (Figure 15).

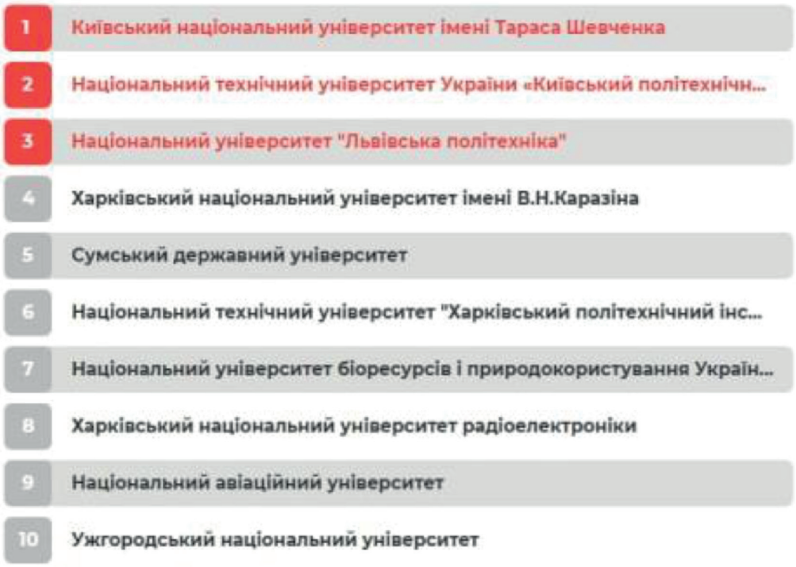

Figure 15. University ranking page

Conclusions and prospects for further studies

The article discusses the creation of the information-analytical system for evaluating the scientific performance of structural units of universities and research institutes based on the approach of constructing complex integral evaluation. A model of information technology for evaluating the results of scientific activity is proposed, consisting of four modules: an

information collection module; an information storage module; an analytical module; a module for user interaction and data visualization. The modular structure of the technology will allow expanding and modifying the capabilities of each of the modules independently of the others, as well as increasing the stability and flexibility of the technology. The implementation of this system is performed using microservices technology. A conceptual model of the information system and a structural model of the functioning of the information collection module, as well as a structural model of the information system database, are proposed.

The application of this method makes it possible to find the generalized volume of the m-simplex in O(m2) arithmetic operations, while the Cholesky method has a computational complexity of O(m3). With m=1000, the complexity of calculating the generalized volume of the m-simplex is 109 arithmetic operations, which are processed by modern computers in less than a second. The clock speed of modern processors is more than 1 GHz, which corresponds to 109 arithmetic operations that are performed by the processor per second. Since the number of categories m for calculating a comprehensive assessment of the performance of a subject of scientific activity, as a rule, does not exceed 10, the computational problem of finding the generalized volume of the m-simplex can be considered simple [23].

Most of the well-known indices for assessing the performance of scientific subjects, for example, h-index, g-index, e-index, I-10 index, etc., do not fully take into account citation information. Therefore, a method was proposed for calculating the evaluation of the research activity of scientists, which does not lose information about any citation of the author and about any publication. This method determines a scalar assessment of the results of scientific activity and is based on the determination of a number of coefficients. The coefficients determine the citation of one scientist in the publications of other scientists. As a result, estimates are found by solving a system of linear algebraic equations, which are built on the basis of the calculated coefficients.

There are a number of well-known indices for scalar evaluation of the performance of subjects of scientific activity. These indices generally give an answer to the question: how many citations of a particular author by other scientists took place over a fixed period. This allows you to determine the effectiveness of the activity of this author. However, most of the known evaluation approaches have their own calculation features and disadvantages, which are associated with the loss of part of the information. Therefore, it is not recommended to give preference to one of them. For the purposes of a comprehensive assessment of the productivity of research activities of scientists, a method of vector evaluation of the results and the construction of the so-called integral assessment was proposed. This method is based on the construction of vectors and scalar estimates for each scientist in a multidimensional metric space. The dimensionality of the space is determined by the number of calculated scalar estimates. Also, the method is based on the construction of an ideal point, which consists of scalar estimates, the best in terms of achieving maximum performance. The assessment of each subject of scientific activity is calculated as a metric distance from the ideal point to the vector of scalar estimates of this subject of scientific activity.

A method is presented for the comprehensive evaluation of the performance of the subject of scientific activity in the subject scientific space, including institutions of higher education, based on the calculation of the volume of the m-simplex using the Kylie-Menger formula. This method is a self-sufficient tool for a comprehensive assessment of the performance of the subject of scientific activity, because:

- in contrast to the ideal point method, the developed method does not need to select a point, the coordinates of which are the productivity of the subject of scientific activity, the best in terms of achieving maximum efficiency according to some criteria. If the coordinates of the point are chosen to be very small, then as a result of the estimation, a point with coordinates

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greater than that of the ideal point may appear. And this will contradict the definition of an ideal point. And if the coordinates of the ideal point are determined too large, then the distances between the points, which are estimates of the performance of the subject of scientific activity, will differ by an insignificant amount, which makes comparison difficult.

- in contrast to the method of weighted coefficients, it does not require the selection of these weight coefficients. The authors of Webometrics criticize other ratings for using the method of weighted coefficients [26]. Often there are situations when certain indicators are different from zero for only a few universities. This situation causes a distortion of the results of the final assessment of the university. It also opens up opportunities for speculation and tweaking of results. This problem is especially relevant for countries that do not yet have a strong academic tradition. It is shown that proportional changes in the complex assessment correspond to small changes in the estimates of individual categories. A method for establishing a trend in the development of the performance of the subject of scientific activity is given, by calculating the derivative of a comprehensive assessment with respect to time. Positive values of the time derivative correspond to positive development trends, and negative values correspond to negative ones.

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References

1. Biloshchytskyi, A., Kuchansky, A., Paliy, S., Biloshchytska, S., Bronin, S., Andrashko, Yu., Shabala, Ye., & Vatskel, V. (2018). Development of technical component of the methodology for project-vector management of educational environments. *Eastern-European Journal of Enterprise Technologies*, *2/2* (92), 4-13.
2. Otradskaya, T., Gogunskii, V., Antoschuk, S., & Kolesnikov, O. (2016). Development of parametric model of prediction and evaluation of the quality level of educational institutions. *EasternEuropean Journal of Enterprise Technologies*, 5, *3* (83), 12–21. doi:10.15587/1729-4061.2016.80790
3. Otradskaya, T., & Gogunskii, V. (2016). Development process models for evaluation of performance of the educational establishments. *Eastern-European Journal of Enterprise Technologies*, *3* (81), 12 – 21. doi:10.15587/1729-4061.2016.66562
4. Biloshchytskyi, A., Andrashko, Yu., Kuchansky, A., Biloshchytska, S., Kuzka, O., & Terentyev, O. (2017). Evaluation methods of the results of scientific research activity of scientists based on the analysis of publication citations. *Eastern-European Journal of Enterprise Technologies*, *3/2* (87), 4 – 10.
5. Biloshchytskyi, A., Myronov, V., Reznik, R., Kuchansky, A., Andrashko, Yu., Paliy, S., & Biloshchytska, S. A. (2017). Method to evaluate the scientific activity quality of HEIs based on a scientometric subjects presentation model. *Eastern-European Journal of Enterprise Technologies*, *6/2* (90), 16 – 22.
6. Biloshchytskyi, A., Kuchansky, A., Andrashko, Y., Mukhatayev, A., Toxanov, S., & Faizullin, A. (2020, November). Methods of Assessing the Scientific Activity of Scientists and Higher Education Institutions. In *2020 IEEE 2nd International Conference on Advanced Trends in Information Theory (ATIT)* (pp. 162-167). IEEE.
7. Hirsch, J.E. (2005). An index to quantify an individual's scientific research output. *PNAS*, *102* (46), 16569 – 16572. doi: 10.1073/pnas.0507655102
8. Egghe, L. (2006). Theory and practice of the g-index. *Scientometrics*, *69* (1), 131-152. doi:10.1007/s11192-006-0144-7
9. Hirsch, J. (2019). hα: An index to quantify an individual's scientific leadership. *Scientometrics*. https://doi.org/10.1007/s11192-018-2994-1.

10. Page, L., Brin, S., Motwani, R., & Winograd, T. (1998). The PageRank Citation Ranking: Bringing Order to the Web. *Proceedings of the 7th International World Wide Web Conference*, Brisbane, Australia, 161 – 172.
11. Avrachenkov, K., Litvak, N., Nemirovsky, D., & Osipova, N. (2007). Monte Carlo methods in PageRank computation: When one iteration is sufficient. *SIAM Journal on Numerical Analysis*, *45*(2), 890-904. doi:10.1137/050643799
12. Liao, Q., Jiang, S., Yu, M., Yang, Y., & Li, T. (2017, May). Monte Carlo based incremental PageRank on evolving graphs. In *Pacific-Asia Conference on Knowledge Discovery and Data Mining* (pp. 356-367). Springer, Cham. doi: 10.1007/978-3-319-57454-7_28
13. Kuchansky, A., Biloshchytskyi, A., Andrashko, Yu., Biloshchytska, S., Shabala, Ye., & Myronov, O. (2018). Development of adaptive combined models for predicting time series based on similarity identification. *Eastern-European Journal of Enterprise Technologies*, *1/4* (91), 25 – 28. doi: 10.15587/1729-4061.2018.121620
14. QS World Ratings. (2017). Retrieved January 26, 2018, from https://www.topuniversities.com/qs-world-university-rankings
15. Academic Ranking of World Universities. Retrieved January 26, 2018, from http://www.shanghairanking.com/ARWU2017.html
16. Ranking Web of Universities. (2017). Retrieved January 26, 2018, from http://www.webometrics.info/en/Europe/Ukraine
17. Sreeramana, A.P., & Kumar, P.M. (2016). ABC Model of Research Productivity and Higher Educational Institutional Ranking. *International Journal of Education and Management Engineering*, *6*, 74–84. doi: 10.5815/ijeme.2016.06.08
18. Michelucci, D., & Foufou, S. (2004). Using Cayley-Menger determinants for geometric constraint solving. *Proceedings of the 9nth ACM symposium on Solid modeling and applications*. Eurographics Association, 285–290.
19. Lizunov, P.P., Biloshchytskyi, A.O., Chala, L.E., Biloshchytska, S.V., & Kuchanskyi, O.Yu. (2016). Avtomaticheskij analiz shodstva shem i diagramm v jelektronnyh tekstovyh dokumentah. *Upravlenie razvitiem slozhnyh system* [Automatic analysis of similarities of schemes and diagrams in electronic text documents. *Management of complex systems development*], (28), 160-169.
20. Watkins, D.S. (2004). *Fundamentals of matrix computations*. John Wiley & Sons.
21. Thurau, C., Kersting, K., & Bauckhage, C. (2010, October). Yes we can: simplex volume maximization for descriptive web-scale matrix factorization. In *Proceedings of the 19th ACM international conference on information and knowledge management* (pp. 1785-1788).
22. Morozov, V., Kalnichenko, O., & Liubyma, I. (2017, July). Managing projects configuration in development distributed information systems. In *2017 2nd International Conference on Advanced Information and Communication Technologies (AICT)* (pp. 154-157). IEEE.. doi: 10.1109/aiact.2017.8020088
23. Kuchansky, A., Andrashko, Yu., Biloshchytskyi, A., Danchenko, O., Ilarionov, O., Vatskel, I., & Honcharenko, T. (2018). The method for evaluation of educational environment subjects' performance based on the calculation of volumes of m-simplexes. *Eastern-European Journal of Enterprise Technologies*, *2/4* (92), 15–25.
24. Kuchansky, A. (2020). Zadacha Identifikacii Predmetnyh Nauchnyh Prostranstv. *Upravlenie razvitiem slozhnyh system* [The problem of identification of subject scientific spaces. *Management of complex systems development*], (42), 70–78.
25. Biloshchitsky, A.A., Lizunov, P.P., Kuchinsky, A.Y., Andrushko, Y.V., & Beloshitskaya, S. (2017). Metodologicheskie osnovy sozdanija informacionnoj sredy upravlenija nauchnymi issledovanijami: monografija. [Methodological bases of creation of information environment of scientific research management: a monograph].
26. Andrashko, Y.V., Biloshchytskyi, A.O., & Kuchanskyi, O.Yu. (2017). Obzor metodov ocenki rezul'tatov dejatel'nosti nauchno-pedagogicheskih rabotnikov vysshih uchebnyh zavedenij. *Upravlenie razvitiem slozhnyh system*. [Review of methods for evaluating the performance of research and teaching staff and higher education institutions. *Management of complex systems development*], (29), 151-159.