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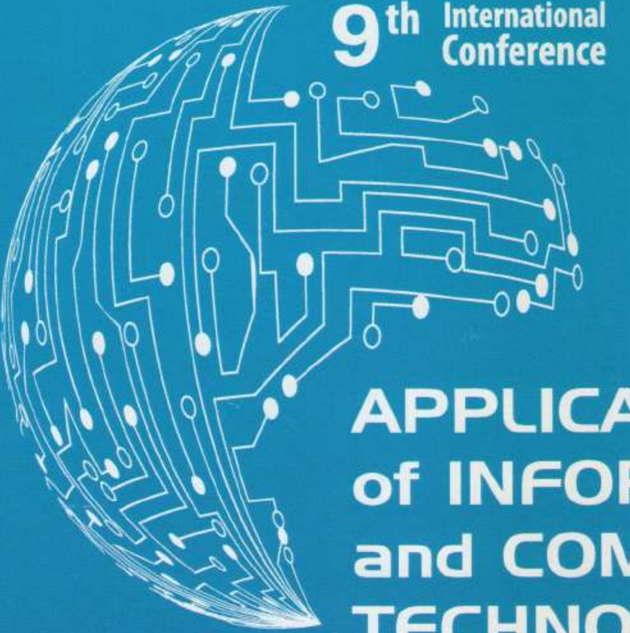

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Mathematical Basis and Information System Software for Educational Institutions Ranking

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This paper describes the development of information system software for educational institutions ranking. Analysis of the existing mathematical models of educational institutions ranking was conducted; the mathematical apparatus and ranking algorithm of educational institutions on the basis of an integral indicator of quality was proposed; an experimental study of the software was conducted; the architecture of a software implementation of information system was designed and described.

Key words: ranking algorithm, comparative assessment of an activity, information system of ranking, integral index, experimental research.

INTRODUCTION

One of the most important conditions for a real modernization of the educational system is the improvement of information support of the development and implementation of educational policy and managerial decisions [1]. One of the most effective and high demanded tools in this regard is the ranking system on the indicators of the educational development, which would allow, particularly, to provide an objective comparative assessment of the effectiveness of educational institutions activities.

The object of the study is a comparative assessment of educational institutions activities. The subject of the study is the information system of educational institutions ranking.

The goal of this study is to design information system software for educational institutions ranking.

To achieve the goal were identified the following objectives:

- to do the analysis of existing mathematical models of educational institutions ranking;
- to propose the mathematical apparatus of the educational institutions ranking based on the integral indicator of quality;
- to describe the ranking algorithm of objects of higher education system;
- to conduct an experimental research of the designed software;
- to develop and describe the architecture of the software implementation of the information system.

THE EXISTING MATHEMATICAL RANKING MODELS OF EDUCATION INSTITUTIONS

A. Kazakhstani ranking model of educational institutions

Today in the Republic of Kazakhstan the ranking of regions is conducted. It is necessary for analysis and estimation of the education systems. It is conducted according to the indicators of education quality on the region level. They are:

- education availability;
- the quality of financial as well as material and technical resources;
- the personnel quality;
- the results of education institutions activities [2].

Each of these indexes are determined by more significant indicators influencing the rating of regions. The rating scale is divided by expert estimation method into 44 grades according to the weight coefficients of indices significance.

More than 100 representatives of the educational system in different regions of the Republic of Kazakhstan took part in the poll concerned to the determination of the weighting coefficient and its significance. The weighting coefficient of each index is determined by two-grade scale. As a result the average weighting coefficients of significance of all indexes and indicators were determined.

The rating grade was calculated according to the following formula (1):

$$R_{result} = R_{ea} + R_{rq} + R_{pq} + R_{ar} \quad (1)$$

Here R_{result} is the rating result grade of the region; R_{ea} is the rating grade by education availability; R_{rq} is the quality of financial as well as material and technical resources; R_{pq} is the personnel quality; R_{ar} is the results of educational institutions activities.

The rating grade of education availability is calculated by the following formula (2):

$$\begin{cases} R_{ea} = \sum_{i=1}^{7} (K_i \times R_i); \\ R_{rq} = \sum_{i=1}^{9} (K_i \times R_i); \\ R_{pq} = \sum_{i=1}^{11} (K_i \times R_i); \\ R_{ar} = \sum_{i=1}^{17} (K_i \times R_i) \end{cases} \quad (2)$$

Here Ri is the rating grade of the region by i-indicator; Ki is the weighting coefficient of the significance of i-indicator determined by the expert poll. [3]

B. The Russian ranking method of educational institutions

The main task of ranking is a complex comparative assessment of regional educational systems, characterized by a number of different indicators. The most important is ensuring the completeness, uniformity and comparability of the used data.

The uniformity and comparability of data is achieved by the transition from the absolute values to the normalized values of the indicators.

In general, the normalized value of the index for each region is defined as the ratio of the absolute value of the index to a certain standard. As the standard can be used:

- Russian average value;
- the minimum possible value ("negative");
- the maximum possible value ("positive");
- standard value (norm adopted in the educational standard or established sanitary norms);
- arithmetic mean value [4].

In provided ratings the rate setting of the indicators was implemented based on the Russian average level for the purpose of correlation with the corresponding data in Russia.

The institutions ranking adequacy can be improved by applying the weighting coefficients that would determine the degree of indicator's influence on the formation of integrated rating assessment that reflects its purpose (thematic focus). In addition, the introduction of weighting coefficients allows to take into account the meaning content of the indicator and link its value, keeping in mind that in cases where certain indicators characterize the negative phenomena or processes, their higher values can negatively influence on the whole assessment. For such indicators the weighting coefficients with the sign "minus" is applied.

Thus, in points the weighting coefficients can possess both positive and negative values (for instance, in the range from -10 to 10, except 0). In fact, their values must be determined based on the opinions of recognized experts at the federal and regional levels.

As far as at the moment of preparation for this publication expert surveys have not been completed, during the ranking were used equal (modulo) values of the coefficient for all indicators ("+1" for positive and "-1" for negative parameters.)

The use of negative coefficient values leads to the fact that under certain circumstances the rating value can be negative. The situation, when the ratings of some regions are positive and ratings of other regions are negative, has the negative impact on the comfort of ratings perception and determination of the region's position. For solving this problem in the case of receiving the negative values in the calculation algorithm additionally was introduced a constant which is equal to the modulo of the minimum negative value of the rating, which is added to the values of the ratings in each region. That provides a positive absolute value of the rating for all the regions (and equal to 0 for the region, which had the minimum negative value).

As a result, a calculation algorithm of the rating may be represented by the following formula (3):

$$R_j = \sum_{i=1}^{n} k_i \times x'_i + C, \quad (3)$$

where

$$C = \begin{cases} 0, \ MIN(R_j) \geq 0 \\ |MIN(R_j)|, \ MIN(R_j) < 0 \\ 1 \leq j \leq r, \text{ number of the regions} \end{cases} \quad (4)$$

R_j – rating of j-*th* region;

k_i - weighting coefficient of the value of i-*th* indicator;

x'_i - normalized value of i-*th* indicator;

n – number of indicators.

Each of presented thematic ratings is determined on the base of referring to it a group of indicators (5):

$$RT_{absolut}(X_{t1}, X_{t2}, ..X_{tn}) = k_{t1} \times X'_{t1} + k_{t2} \times X'_{t2} + ... + k_{tn} \times X'_{tn} + C \quad (5)$$

For the demonstrativeness of the results during the comparison of the regions a relative rating is calculated for each region. This rating (6) is determined as the value of the absolute quantity of the rating in a percentage relatively to the value of the rating of the region which took the first place.

$$RT_{relative}(X_{t1}, X_{t2}, ..X_{tn}) = \frac{RT_{absolut}(X_{t1}, X_{t2}, ..X_{tn})}{RT^{max}_{absolut}(X_{t1}, X_{t2}, ..X_{tn})} \times 100 \quad (6)$$

As a result, each region in addition to its rank is characterized by two quantitative assessments: the absolute value of the rating and its correlation in a percentage relatively to the leader-region [5].

The Proposed Approach

For ranking the educational institutions is offered to introduce an integrated indicator of the quality of education institution. This integral indicator is integrated, because it is based on the objective significance of each factor.

The calculation of the integral index is conducted by the formula (7):

$$R(S_i) = \sum_{j=1}^{N} H_j \times k_{ij}, i = \overline{1, M}, \quad (7)$$

Where $R(S_i)$ is the integral quality of S_i objects; M is the number of objects; N is the number of attributes; H_j is the significance of the *j-th* attribute; k_{ij} is a qualitative assessment of the *j-th* attribute for the *i-th* object.

As a measure of the factor's significance is suggested to use feature entropy value (by K. Shannon [6]) as an objective measure of the uncertainty of feature values. In this case, the features with a higher degree of "spread" of values in the analyzable sample will be more important.

Formula (7) in this case changes to the following (8):

$$R(S_i)=\sum_{j=1}^{N}k_{ij}\left(-\sum_{t=1}^{K}p_{jt}\log_2 p_{jt}\right), i=\overline{1,M}, \quad (8)$$

where K is the system basis of quality; p_{jt} is the probability (frequency) of occurrence of qualitative assessment of $k_{ij}=t$ in the distribution of the values of j-th attribute.

Next, we will describe the institutions' ranking algorithm.

The first step is to choose a systemic base of the quality *K*.

At the second step the maximum and minimum values of each feature are calculated. Absolute and relative values can be used.

At the third step we transfer source data into high-quality analogues for the signs formation (9):

$$k_{ij}=1+round\left(\frac{(x_{ij}-x_{j\min})(K-1)}{x_{j\max}-x_{j\min}}\right), \quad (9)$$

Where x_{ij} is the initial quantitative value or qualitative value of the *j-th* factor for the i-th object; $x_{j\max}, x_{j\min}$ is the maximum and minimum values of the *j-th* attribute; K is a system base of quality; $round()$ is an operation of arithmetic rounding.

At the fourth and fifth steps the entropy H_j of each feature and integral quality of each object is calculated according to the formula (7).

At the sixth step it is necessary to distribute descending (or ascending) collection of objects found on the values of the integral quality.

At the seventh step, the results are analyzed and managerial decisions for correcting the condition and coordination of further development of the education institution are made.

If necessary, the last step is moving to a higher level. I.e. in the case of the macro object subsystems analysis, after calculating the performance of the integral quality data transmission to the macro level is conducted.

It should be noted that for an arbitrary number of N objects the maximum entropy is (10):

$$H_{\max}(N,K)=(N \bmod K)\times(N \operatorname{div} K+1)\times\log_2\frac{1}{N \operatorname{div} K+1}+ +(K-N \bmod K)\times(N \operatorname{div} K)\times\log_2\frac{1}{N \operatorname{div} K}, \quad (10)$$

where the operations *div* and *mod* are quotient and the remainder from the exact division respectively.

Thus the regulation of the integral quality of the object should be carried out on the value of (11):

$$R_{\text{norm}}=M\times K\times H_{\max}= =M\times K\times\left(\begin{array}{l}(N \bmod K)\times(N \operatorname{div} K+1)\times\log_2\frac{1}{N \operatorname{div} K+1}+\\ +(K-N \bmod K)\times(N \operatorname{div} K)\times\log_2\frac{1}{N \operatorname{div} K}\end{array}\right) \quad (11)$$

This algorithm is linear. Fig. 1 shows a scheme of generalized algorithm for ranking the higher education institutions.

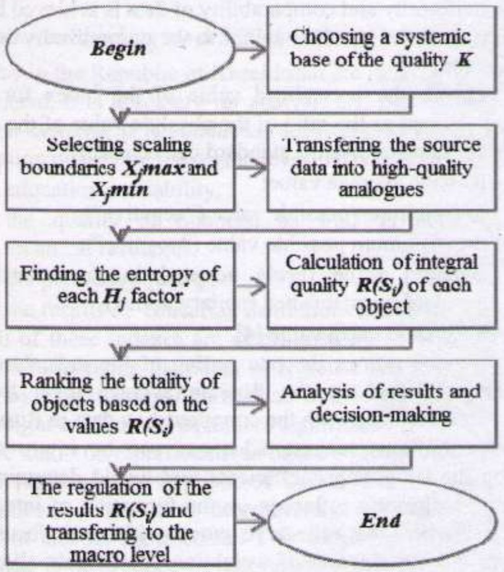

Fig. 1. The scheme of generalized algorithm for ranking higher education institutions

EXPERIMENTAL RESEARCH

A. General description of the experiment

As an experimental research the ranking of the real group of universities was made based on the following 8 factors [7]:

- the percentage of full-time teachers with academic degrees and academic ranks;
- the percentage of doctors and professors;
- participation of students in scientific work (the number per 100 students);
- publications (teaching aids and textbooks);

- the level of informatization of the university (the number of computing units per 100 students);
- the level of educational achievements of students in the control group on the 3 leading disciplines of the major.

B. Calculation of the integral index

The results of the first three steps of the algorithm are shown at Fig. 2.

Third step

Number	1	2	3	4	5	6	7	8	SUM
University 1	5	1	1	2	4	4	5	5	27
University 2	5	4	2	1	5	3	3	4	27
University 3	5	4	2	4	1	3	4	4	27
University 4	5	4	3	5	1	1	3	4	26
University 5	1	5	3	5	1	5	2	4	26
University 6	5	4	5	1	2	3	2	4	26
University 7	5	5	3	4	4	1	1	1	24

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Fig. 2. The program window with the results of the first three steps of the algorithm

It is required to find the integral data quality of educational institutions and rank them according to the given characteristic in common system of objects S(t).

When using regular approach with points (where the score is taken as a comprehensive quality) from the given table could seem that the 1st, 2nd and 3rd universities should be awarded the first place, 4th, 5th and 6th universities take the second place and 7th university takes the third place. But the systemic or integral quality is always greater than the sum of its constituent parts; Each integer detects a certain "integral effect".

Fig. 3 shows the program window with the results of the calculations of the entropy of each attribute as an expression of its value in a given situation.

The results of the calculations of the entropy

i	1	2	3	4	5	6	7	8
Hi	0,41	0,96	1,28	1,35	1,28	1,28	1,55	0,8

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Fig. 3. The program window with the results of the calculations of the entropy of each attribute

In terms of pedagogical hermeneutics, the difference in entropy can be interpreted as follows: the higher the attribute's entropy, the more it is disordered. This disorder brings disruption to the work of a single system of educational institutions and thereby hinders the achievement of the goals by a system. Consequently, the greater the value of the entropy of a particular educational factor, the more difficult it is to perform, and thus higher not it's subjective "weight", but its objective importance at this stage of the system operation. That means that to reduce the disorder more attention to it should be paid by the governing body. If the attribute's entropy is small, then this implies that its importance in the overall combination of attributes is negligible.

For example, for a given set of attributes in a given period of time the most significant attribute is the 7th attribute, and the least significant is the 1st attribute.

An important feature of this method is that the assessments of the significance of attributes are not permanent (as in the case of weighting coefficients), but dynamic over time and determined by the objective characteristics of the objects themselves.

Fig. 4 shows the program window with the calculations of values of the integral qualities of each object.

The calculations of values of the integral qualities of each object

R(Si)	=	Calculation	=	Result
R(S1)	=	5*0,41+1*0,96+1*1,28+2*1,35+4*1,28+4*1,28+5*1,55+5*0,8	=	28,98
R(S2)	=	5*0,41+4*0,96+2*1,28+1*1,35+5*1,28+3*1,28+3*1,55+4*0,8	=	27,89
R(S3)	=	5*0,41+4*0,96+2*1,28+4*1,35+1*1,28+3*1,28+4*1,55+4*0,8	=	28,37
R(S4)	=	5*0,41+4*0,96+3*1,28+5*1,35+1*1,28+1*1,28+3*1,55+4*0,8	=	26,89
R(S5)	=	1*0,41+5*0,96+3*1,28+5*1,35+1*1,28+5*1,28+2*1,55+4*0,8	=	29,78
R(S6)	=	5*0,41+4*0,96+5*1,28+1*1,35+2*1,28+3*1,28+2*1,55+4*0,8	=	26,34
R(S7)	=	5*0,41+5*0,96+3*1,28+4*1,35+4*1,28+1*1,28+1*1,55+1*0,8	=	24,84

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Fig. 4. The program window with the calculations of values of the integral qualities of each object

Thus, the resulting table looks like at the Fig. 5.

The results of the ranking

Institutions	Sum of qualities	Integral quality	Rank
S1	27	28,98	II
S2	27	27,89	IV
S3	27	28,37	III
S4	26	26,89	V
S5	26	29,78	I
S6	26	26,34	VI
S7	24	24,84	VII

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Fig. 5. The program window with the results of the ranking

It is easy to notice that in the first place according to the rating is the university which takes the places from 4th to 6th according to the method of score. This proves once again that any object is not just the sum of its parts, and the quality of the object is not the sum of its characteristic attributes.

The derived estimations are not static. If you change the values of the attributes, their significance also changes, and this in turn contributes to the dynamics of change as an integral quality of each object and the overall picture of the educational system.

Architecture Of Software Implementation

Developed information system has a client-server architecture, the essence of which is that the client (executable file) requests certain services in accordance with a specific protocol for data exchange. The server part consists of a database server (MS SQL Server 2012) and Web-based server (IIS service). The server processes the client's request and carrying out the necessary data manipulation, transfers the requested portion of data to the client. The developed system is based on technology of "thin client", using a powerful database server and stored procedures which allows performing calculations that implement basic logic of the data processing directly on the server. The client application, respectively, makes low demands on the hardware of workstation. The client part is implemented as a Windows-based applications (ASP.NET technology, built on the basis of the .NET Framework), performing the functions of input and correction of data. To access the data has been used technology - ADO.NET, which simplifies the reference to the information sources.

Fig. 6 shows the architecture of a software implementation of the information system.

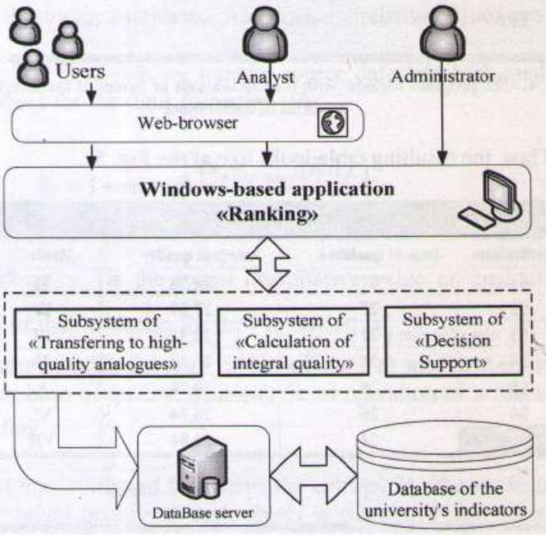

Fig. 6. Architecture of a software implementation of the information system

The basis of the information system are: relational database; software tools, providing data processing logic; user interface.

The main components of the system are presented by the following: data storage (DBMS MS SQL Server 2012), the organization of which satisfies to the ranking model; ASP.NET-application is a user interface of interaction of the user with the database; Windows-based application, which is a computational module.

Conclusion

For educational institutions ranking is offered to introduce an integral index of the quality of educational institution. This integral index is complex. As a measure of the factor significance is suggested to use the value of attribute's entropy.

Within this study was developed information system software for educational institutions ranking. Numerical characteristics that come out from the application of the proposed mathematical model may have information for making managerial decisions. Thus, the use of the information system can improve the efficiency of managerial decisions.

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