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Automation of multicriteria ranking of students using ePortfolio*

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Автоматизация процесса многокритериального ранжирования студентов с помощью электронного портфолио***

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Introduction. The paper considers improving the management quality of an educational organization through automating the personalized data collection, storage and ranking. The authors have developed a module of the university corporate system, an ePortfolio of students, which implements a multicriteria optimization method for calculating the students' rating on the basis of the collected and stored data.

The study object is multicriteria ranking methods. The subject of the study is the automated calculation of student's rating within the electronic portfolio. The study objective is to develop tools for collecting, storing and processing data on individual achievements of students and the implementation of the mathematical method of multicriteria optimization for ranking students on the basis of the portfolio data. Practical implications include development of a tool for an effective management of the educational process.

Materials and Methods. A prototype module of the university corporate system "ePortfolio" on the platform of 1C: Enterprise 8.3 is presented. To rank students, a special case of the alternative ranking method is implemented in the block of the data analysis module – pairwise comparison in order of their relative importance. At that, a unified scale of relations was used.

Research Results. The authors described the scheme of the information system (IS) operation "ePortfolio", presented a process interaction pattern for the portfolio formation, as well as a diagram of business processes under calculating an individual rating. A fragment of the sample is shown on which the performance of the multicriteria optimization block has been tested. The criteria of the calculations are described, as well as the rule of screening alternatives for solving for the optimum.

Введение. Работа посвящена повышению качества управления образовательной организацией за счет автоматизации персонифицированного сбора, хранения и ранжирования данных. Авторами разработан модуль корпоративной системы вуза — электронное портфолио студентов, в котором реализован метод многокритериальной оптимизации для расчета рейтинга обучающихся на основе собранных и хранящихся данных. Объектом исследования являются методы многокритериального ранжирования. Предметом исследования является автоматизированный расчет рейтинга студента в рамках электронного портфолио. Целью исследования является разработка инструментария для сбора, хранения и обработки данных об индивидуальных достижениях студентов и реализация математического метода многокритериальной оптимизации для ранжирования обучающихся на основе данных портфолио. Практическая значимость исследования — предоставить инструмент для эффективного управления учебным процессом.

Метод и инструментарий. Представлен прототип модуля корпоративной системы вуза «Электронное портфолио» на платформе «1С: Предприятие 8.3». Для ранжирования студентов в блоке модуля анализа данных реализован частный случай метода ранжирования альтернатив — попарное сравнение по степени их относительной важности. При этом использовалась унифицированная шкала отношений.

Результаты исследования. Авторы описали схему функционирования информационной системы (ИС) «Электронное портфолио», представили схему взаимодействия процессов по формированию портфолио, а также схему бизнес-процессов при расчете индивидуального рейтинга. Показан фрагмент выборки, на которой проводилась проверка работоспособности блока многокритериальной оптимизации. Описаны критерии, принимающие участие в расчетах, а также правило отбора альтернатив для нахождения оптимального решения.

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*** Работа выполнена в рамках инициативной НИР.

Discussion and Conclusion. The paper presents the results of the IS block operation on ranking a list of students. The calculation results coincide with the practical data.

Обсуждение и заключение. В работе приведены результаты работы блока ИС по ранжированию списка студентов. Результаты расчетов совпадают с практическими данными.

Keywords: multicriteria ranking, optimization, ePortfolio, "1C: Enterprise 8.3"

Ключевые слова: многокритериальное ранжирование, оптимизация, электронное портфолио, «1С: Предприятие 8.3».

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Introduction. Assessment of the educational process effectiveness is one of the most essential characteristics of the university's activity when calculating its rating [1]. To improve the competitiveness of an educational organization (EO) in the market of educational services, effective monitoring and objective assessment of the educational process results for each student are required [2]. The data is often stored separately or in general lists, which does not provide an identifying representation for a future employer. Educational organizations hold lots of events in which a large number of students participate. Individual achievements outside the university are also of interest, for example, volunteering, charity, work in summer youth camps, etc. Such information is rarely collected and stored properly. You can create a rating for each student based on the collected information. The ranking of students is one of the techniques for the effective management of the EO activities [3]. According to the new education standards and under the Federal Law 273 "On Education in the Russian Federation" [4], automated data collection, storage and processing are required. One of the solutions to this problem is an electronic portfolio, which will afford automated ranking of students.

Research Methods and Tools. The authors have worked out and implemented a module of the corporate system "Electronic Portfolio" on the platform "1C: Enterprise 8.3". It can also operate as an independent information system [5]. The IS stores information about students' achievements and, on the basis of this data, automatically arranges it in descending order. For ranking students, a vector optimization method is applied.

Research Objective is to develop a mathematical model that operates with a set of alternative solutions (alternatives) $F(X)$ (where X is a certain set of criteria), which will be further arranged in descending order of preference. The most preferable solution will be the first, next – the less preferable one, etc. The degree of preference is estimated by the value of the calculated rank for each alternative. The rank is calculated from the values of the criterion weights that are assigned by the decision maker (DM).

Let the function $F_i(X_j)$ form an evaluation vector of alternative solutions under the following conditions:

$$i = \overline{1,m}\,; j = \overline{1,n},$$

where m is the number of alternatives in the sample; n is the number of criteria involved in determining the student's rank.

Let $F_1(X_1)$ be the estimate of the solution X_1 by the first criterion; $F_2(X_1)$ be evaluation of the solution X_1 by the second criterion, etc.

Then the estimation vector for the first solution has the form:

$$F(X_1) = (F_1(X_1), F_2(X_1), F_m(X_1)).$$

A set of estimates Y_D belonging to the admissible region D determined on the basis of data stored in the ePortfolio database is identified as a region of a set of alternative estimates:

$$D = <C, F, X, G, P> [6],$$

where C is the goal, which is to rank the list of students in descending order of the calculated rating based on the ePortfolio data; F are alternatives, i.e. the names of students to be ordered; X are criteria, i.e., data on the students' achievements stored in the ePortfolio; P are preferences: $X_1 > X_n$. These are indicators that correspond to the educational process and are the basis for comparing alternatives and for making decisions; G are restrictions on the region of feasibility.

The alternative $F_i(X_j)$, in which the largest number of the studied criteria take the maximum value, can be found from the expression:

$$X_j \in D;\ F_i(X_j) \in Y_D.$$

Then the task of ordering (ranking) the alternatives $(F_i(X_j))$ on the criterion set D^m in descending order can be described by the expression:

$$Y_D = F_i(D) = \{Y \mid Y=F(X),\ X \in D^m\}.$$

To solve this problem, the authors applied a special case of the method of ranking alternatives — pairwise comparison according to the degree of their relative importance using a unified ratio scale [7]. For each DM function $F(X)$, the degree of preference $\mu_{Fi}(X_j)$, $j = \overline{1,n}$ was determined by the weight of each criterion.

Research Results. Automation of the multi-criteria ranking of students occurs in the information system module of their ePortfolio. The operation scheme of the prototype ePortfolio IS based on the developed configuration in "1C: Enterprise 8.3" [8] is shown in Fig. 1.

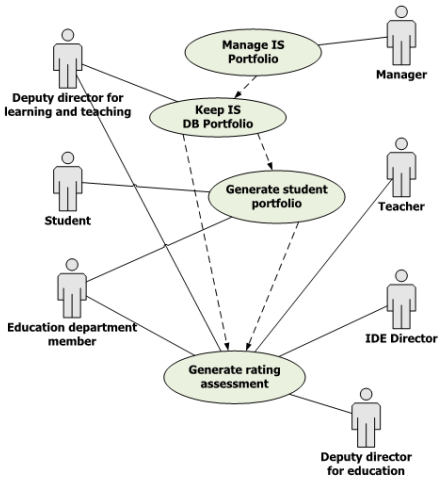

Fig. 1. ePortfolio operation scheme

To generate a student portfolio, it is provided:

- data input;
- data conversion to electronic format;
- data storage;
- submission of reports including the calculated students' ratings and ordered lists of departments, faculties, EO.

The process of generating a portfolio is presented in Fig. 2.

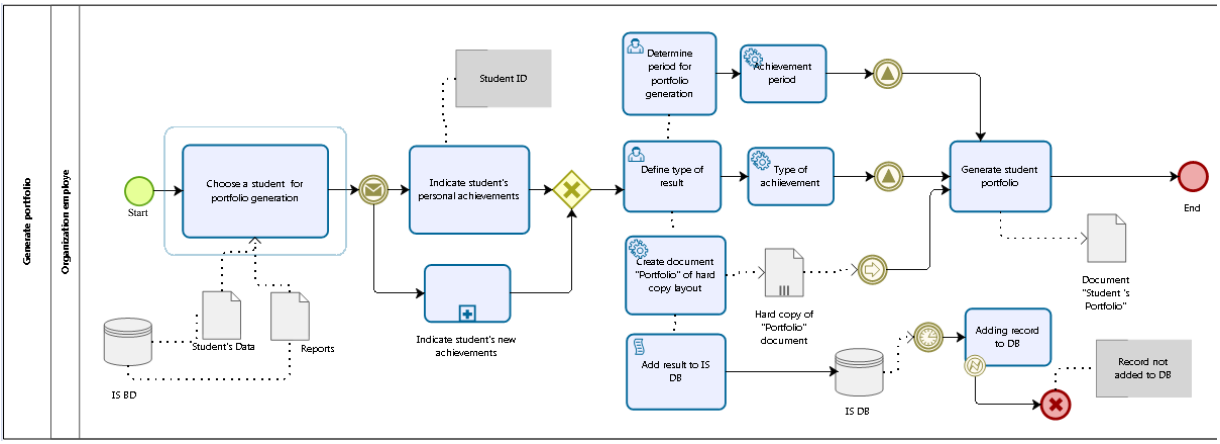

Fig. 2. Portfolio generation scheme

The database was designed for IS electronic portfolio [9], the transformation model of which is shown in Fig. 3.

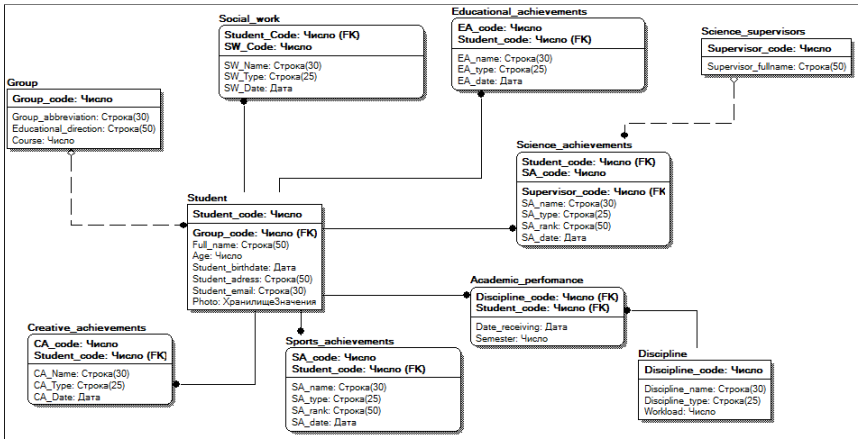

Fig. 3. ePortfolio database model

The interaction of information processes on the generation of an individual student's rating based on the information stored in the system database is shown in Fig. 4.

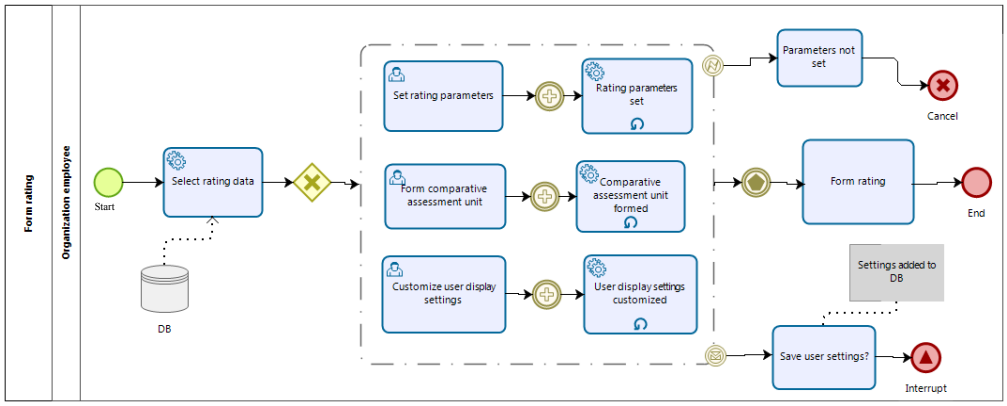

Fig. 4. Diagram of IS block operation on student's ranking score formation

The IS provides for the generation of various reports [10]. For example, a user can display comparative assessment blocks for educational, sports, social, creative, and scientific achievements. One of the report forms is presented in Fig. 5.

Student portfolio

Full name:	Aksanenko Svetlana Vladimirovna
Birthdate:	13.08.1994 0:00:00
Sex:	Female
Group:	MB-151mz
Address:	Moscow, ul. Grodnenskaya, 12, ap. 90
Telephone:	8-(916)-123-34-44
Email:	akssvet@gmail.com

Educational achievements:

Number	Achievement	Type	Rating
1	Mind games	Competition	1

Scientific achievements:

Number	Achievement	Organization	Type	Rating
1	Conference	SAEI HE MCU	Conference	1

Social activity:

Number	Achievement	Organization	Type	Rating
1	Blood donation	SAEI HE MCU	Donorship	1

Sports achievements:

Number	Achievement	Level	Type	Place	Rating
1	Wrestling	Institutional	Judo	Laureate	1

Creative achievements:

Number	Achievement	Type	Place	Rating
1	Quiz	"Quiz,please"	First	1
2	Tournament	Board games	Third	3

Fig. 5. Report in Portfolio form

The operation of the IS block, which is responsible for ranking students, was checked on a sample of 1000 people. The following rule was applied to the sampling:

$$F_i(X) \geq F_i(X^*),\ i = \overline{1,m},$$
$$i_0: F_{i0}(X) > F_{i0}(X^*),$$

where $F_{i0}(X^*)$ is Pareto-optimal solution.

After possible deletions implemented according to the rule, 250 mutually incomparable alternatives remained in the table, and only the best ones – from previously comparable ones. In this way, a sample was formed for further studies, a fragment of which is presented in Table 1.

Table 1

Sample Fragment for Ranking

No.	Full Name	Participation in Olympiad	Participation in sports competition	Union member	Increased scholarship	Scholarship	Publication of sci papers	Participation in sci conferences	Volunteer	Donor	Charity
1	Kolomoytseva Galina Yuryevna	x	x		x	x		x			
2	Martynenko Elena Anatolyevna	x		x		x	x				
3	Yurchenko Lyudmila Mikhaylovna			x					x		x
4	Konovodov Yury Nikolaevich		x			x				x	x
5	Alieva Antonina Leonidovna	x		x	x	x	x	x			
6	Baytsar Aleksandr Pavlovich	x							x		x
7	Smirnova Elena Vasilyevna			x		x		x			x

Optimization was carried out according to 13 criteria: participation in scientific conferences, availability of scholarships, participation in public organizations, etc. Further, a matrix of criteria was built, where weight was assigned to each criterion in accordance with the preferences of the DM (Table 2).

Table 2

Weighting Matrix

Criteria		X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	Gmean
Olympiad participant	X1	1.00	0.14	3.00	0.25	2.00	1.00	1.00	3.00	0.25	2.00	5.00	5.00	3.00	1.2773764
Participation in sports	X2	7.00	1.00	8.00	1.00	5.00	5.00	2.00	5.00	0.33	9.00	7.00	7.00	7.00	3.5535071
Union member	X3	0.33	0.13	1.00	0.14	0.33	0.20	3.00	0.14	0.20	0.50	3.00	1.00	1.00	0.4675483
Increased scholarship	X4	4.00	1.00	7.00	1.00	7.00	5.00	9.00	7.00	5.00	9.00	5.00	7.00	5.00	4.6581847
Scholarship	X5	0.50	0.20	3.00	0.14	1.00	0.33	0.33	0.33	0.14	0.20	3.00	0.14	1.00	0.434096
Sci papers publication	X6	1.00	0.20	5.00	0.20	3.00	1.00	7.00	5.00	5.00	7.00	7.00	0.33	5.00	2.007042
Participation in sci conf.	X7	1.00	0.50	0.33	0.11	3.00	0.14	1.00	0.33	0.20	1.00	3.00	0.33	0.33	0.5143549
Volunteering	X8	0.33	0.20	7.00	0.14	3.00	0.20	3.00	1.00	0.14	5.00	7.00	5.00	5.00	1.2315968
Donorship	X9	0.25	3.00	5.00	0.20	7.00	0.20	5.00	7.00	1.00	9.00	9.00	7.00	7.00	2.4958934
Charity	X10	0.50	0.11	2.00	0.11	5.00	0.14	1.00	0.20	0.11	1.00	5.00	0.20	0.20	0.4581585
Summer camps	X11	0.20	0.14	0.33	0.20	0.33	0.14	0.33	0.14	0.11	0.20	1.00	1.00	0.25	0.259332
Creativity competitions	X12	0.20	0.14	1.00	0.14	7.00	3.00	3.00	0.20	0.14	5.00	1.00	1.00	0.17	0.6757149
Member of social movement	X13	0.33	0.14	1.00	0.20	1.00	0.20	3.00	0.20	0.14	5.00	4.00	6.00	1.00	0.7389604
	Total	16.65	6.91	43.67	3.84	44.67	16.56	38.67	29.55	12.78	53.90	60.00	41.01	35.95	18.77

In Table 1, the "×" icon was replaced by the criterion weight. Then we conducted a pairwise comparison of students with respect to any criterion, for example, the first one. The comparison was carried out as follows: the highest advantage of one student over another is the value of the first criterion weight plus one. The unit is needed so that when dividing the unit by the weight of the criterion, a large number is not obtained. This number should be less than the maximum weight of the criterion. That is, the weight of the criterion is the maximum value in the table (highest priority). In the next steps of data processing, the system performs certain calculations [11]:

- it quantifies the inconsistency of comparisons;
- it calculates the degree of inaccuracy of comparisons;
- it defines a common criterion for each alternative;
- it finds the best solution;
- it checks the decision validity.

Results and Discussion. As a result of the operation of prototype IS ePortfolio block, which is responsible for calculating a student's rating and arranging a list of students provided in descending order, you can get the report presented in Table 3.

Table 3

Table Fragment with Student Ranking Results

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	Final values
	0.068048	0.189301	0.024907	0.248148	0.023125	0.106918	0.027400452	0.065609	0.132959973	0.024407	0.013815004	0.035996	0.039366	
F1	4.69	9.93	0	10.99	2.43	0	2.56	0	0	0	0	0	4.08	5.213001
F2	4.69	0	2.52	0	2.43	7.48	0	0	0	0	1.61	4.05	0	1.4058781
F3	0	0	2.52	0	0	0	0	6.14	0	3.16	0	0	4.08	0.7033417
F4	0	9.93	0	0	2.43	0	0	0	9.42	3.16	1.61	0	0	3.2877994
F5	4.69	0	2.52	10.99	2.43	7.48	2.56	0	0	0	0	4.05	0	4.1809328
F6	4.69	0	0	0		0	0	6.14	0	3.16	1.61	0	4.08	0.9819622
F7	0	0	2.52	0	2.43	0	2.56	0	0	3.16	0	4.05	0	0.412015
F8	4.69	9.93	0	0	0	0	0	0	0	0	0	0	0	2.1988993
F9	0	0	2.52	10.99	0	0	0	0	0	0	0	4.05	0	2.9357024
F10	0	9.93	0	10.99	0	7.48	0	6.14	0	0	1.61	0	4.08	5.9923473

In the table, F1 – F10 are the names of students; the top row shows the names of the criteria by which the rank of each object was calculated; the second row from the top is the criterion weight; other items are quantitative assessments of a student for participating in a particular activity. The DM gave highest preference to the criteria that were associated with the study (scholarship, increased scholarship, scientific activity, etc.). According to the calculation results, the first four places will be taken by students who receive increased scholarships. F10 student has the highest rating, he receives an increased scholarship, has scientific publications and is a participant in sports competitions. The IS provides for various different achievements of the same type (for example, a sports category, a winner or a participant in a competition) to be combined into one cluster; it affords making a general assessment of the cluster (to present as one criterion with a certain weight in calculations).

Conclusion. The authors propose a tool that provides the user with the opportunity to quantify the studied objects with a large amount of information about these objects. The electronic portfolio allows maximum consideration of various achievements of students not only within the walls of the university, it accommodates the data accessibility for the students themselves, and stores a large amount of information about the student. Calculation of individual rating, and ranking improve the educational process quality, which as a result will affect the overall rating of the university.

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