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Development of Ontology for Information System of Student's Academic Progress

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Abstract: In this study, a domain ontology for electronic registry of student's academic progress was developed. Considerable attention is paid to modeling and tuning of the electronic registry as a data structure that changes its state during the time. That provides round the clock operation of the subsystem in real time. Using the oracle database and oracle application express framework subsystem "Electronic Registry" was developed and put into operation at the National University of Radioelectronics.

Key words: Electronic registry, data center, operational analysis, ontology, mathematical model, national

INTRODUCTION

One of the main tasks of the educational activity of the university is the current control of the student's success. The frequency of such control can vary depending on the administrative tasks being solved. The analysis of the results of the current monitoring allows the average and top management of the university to perform operational management of the process of teaching students, the process of passing the semester control as well as to increase the motivation of students and as a consequence, the quality of education.

In order to monitor and subsequently analyze the current achievements of students in the university, it is possible to introduce an Electronic Registry (ER) of student's academic progress.

In most cases, the analysis of ongoing academic progress monitoring results requires significant time-consuming costs associated with the need to carefully organize the collection and processing of large volumes of operational information. Centralization of the process of taking into account the current student's academic progress (the filling of the ER with data) is a complex and time-consuming task. Its implementation requires processing of a number of primary documents, the management of which is carried out in material (study) form in accordance with the legislation of state like in Ukraine, Russian Federation, Iraq and many other countries.

The object of such an accounting can be both assessments for individual classes, types of occupations and integrated indicators for example, control points for subjects or indicators of student's readiness for the session (Kernosov *et al.*, 2013).

Research task: With the classical approach to solving the problems of accounting and analyzing the results of student's academic progress monitoring, the fulfillment of these tasks includes a considerable amount of manual labor. It includes processing the primary sources of current student's academic progress such as academic group registers and registers of teachers. The introduction of such a procedure requires stringent requirements for the timing and quality of filling in these documents and does not exclude the possibility of errors. Even with the centralized input of large volumes of data by a separate well-trained support unit of the university. In addition, this approach does not allow solving the accounting and analyzing tasks in the real time mode which reduces the quality of operational management of the educational process.

Therefore, the actual research task is to develop a new approach to the automation of current student's academic progress accounting and analysis. Such approach should reduces labor costs for conducting data accounting and analysis operations and relieves university staff from performing large amounts of routine operations that often lead to errors.

Knowledge-intensive tasks: At present, the automation of business processes of enterprises and organizations is becoming more and more an irresistible task. The development of modern information systems requires

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careful design, modeling and often requires the modification of existing business processes (Evlanov, 2016). The solution of the tasks set in this study requires the functioning of the subsystem “Electronic Registry” in real time which requires solving a number of scientific problems related to Domain Modeling (DM), the synthesis of data structures necessary for the operation of this web service and the provision of acceptable level of subsystem’s productivity.

Round-the-clock operation of the “Electronic Registry” subsystem in real time allows us to present the ER of current student’s academic progress as an object having many different states that change over time for both the ER as a whole and its individual elements. At the same time, the states of the ER elements define a set of accounting, control and analysis functional tasks available to different categories of the users at a particular moment in time. Proceeding from the foregoing, the task of this study is formulated as follows: development of the domain ontology for the “Electronic Registry” of student’s academic progress subsystem domain. This ontology should also include a set of mathematically formulated terms that allows determining the states of the ER and its elements as well as a list of its functions available to users at any moment of time. Centralized organization of data storage are the basic approaches of building such class of system as complex integrated systems.

Used approach: To solve this problem, the study proposes a web-based approach to automating the monitoring of student’s academic progress and the implementation of the ER in the form of a web-service as a part of the university’s information system. This approach is based on the idea of accounting decentralization of the current student’s academic progress: the transfer of this function to the university teachers who are responsible for the quality of the education and for the data entered.

The use of the web environment will allow the participants of this Business Process (BP) to perform their functions both in real time and any convenient time, adhering to the deadlines for submitting reports. Consequently, the tasks of a support unit of the university are the maintenance of informational system and its development in the event of new types of requests.

This will reduce the time for preparing analytical reports and the university’s management can conduct online monitoring of the work of employees which will improve the level of organization of this business process and the quality of maintaining an ER. Thus, the consequences of student’s academic progress accounting decentralization are: the ER is filled independently by the teachers responsible for the implementation of the student’s knowledge semester control.

The head of a university department appoints the persons responsible for maintaining the ER-the persons which duties include the training of the department staff, the organization and control of the ER keeping within the time limits regulated by the orders of the university administration. Maintenance of the information system and registration of users is carried out by a separate support unit of the university.

Integration of the ER web-service into the information system of the university allows it using the data of the module “Deanery” on the contingent of students and the list of subjects they study (including the subjects of the student’s choice). Also, integration with the “Schedule” module is possible which allows the recording of the current control results in relation to each training sessions according even individual students and teachers schedules.

In addition, this approach will make it possible to provide access to reporting documents to a wide range of users without mandatory registration and authorization in the system, i.e., the results of student’s academic progress will be able to be viewed not only by the teachers but also by the students themselves as well as by their parents.

At the same time, in order to comply with the law on personal data protection laws, it is also necessary to differentiate the rights of user access and it is possible to use “depersonalizing” indicators such as student’s readiness for the session (Kernosov *et al*., 2013).

Existing solutions: In analyzing the existing solutions, the following common implementations of the EW were considered:

- Program module “PS-Progress-Weblog” (ww.politek-soft.kiev.ua/index.php?do = newdevelopments& product = ps-gradebook-web)
- Web-service “Electronic Journal” of the automated management system of an educational institution (mkr.org.ua/portalinfos/index/1/21)
- Free Dean’s office (electronic dean’s office) is a module for the Moodle distance learning environment (www.deansoffice.ru)

Other implementations of the ER were also considered. They are closed and their authors do not provide detailed information in free access. The descriptions of the mentioned systems, like other sources, do not contain information on the modeling of the ER domain ontology the formal models underlying them are not available for analysis and research. As a consequence, they are not considered in this study.

In this study, we propose an ontology that allows us to formalize the BP related to the ER of the current student's academic progress maintenance and to the operational control of education quality. This makes it possible to formalize the ER setting for operating in real time. Simulation of ER allows effective implementation of the online monitoring of current student's academic progress as subsystem of educational information system and optimization of its productivity.

To model ontologies, CASE-tools are used OilEd, OntoEdit, Ontolingua, OntoSaurus, Protege, WebODE, WebOnto, etc. There are also ontology description languages: OWL, KIF, Common Logic (CL), CycL, DAML+OIL (FIPA), etc.

In this study, the ontology formalization approach based on set theory and mapping theory was used. This allows us to describe not only the information maintained by the "Electronic Registry" subsystem but also the knowledge of the rules and methods of its use. Finally, it gives the formal models, convenient for implementation in the software. Also, this mathematical model is less cumbersome than the graphical representation of ontologies in the form of a class diagram (UML) an Entity-Relationship Model (ER-diagram), sets of algorithms, etc.

MATERIALS AND METHODS

Domain of the information system of student's academic progress: Each semester the dates of the Control Points (CP), the dates of the ER filling completion and the ER results analysis finishing are specified. For example at the Kharkov National University of Radioelectronics usually it is done by issuing appropriate administrative documents. Control over the execu-tion of the order is assigned to the deans of the faculties (KNUR, 2013a, b, 2017).

After that, this data are entered into the "Electronic Registry" subsystem where a lot of subsystem properties and CP characteristics are automatically determined. Users of the subsystem "Electronic Registry" can be divided into 4 categories.

"View": To this group of users belong students, parents of students, curators of academic groups. These users do not have access to insert and edit student's academic progress indicators values and they do not have access to analytical reports.

"Control": To this group of users belong responsible for the departments for maintaining an ER and separate support unit of the university which maintenance the information system. These users provide the organization and control and maintenance of the electronic registry.

"Filling": To this group of users belong teachers who are responsible for estimation the knowledge of students. These users have access to editing and setting the values of student's scores and academic progress indicators.

"Monitoring": To this group of users belong: heads of departments, deputy deans, deans, management of the university. These users have access to analytical reports. Some employees in accordance with their duties can combine several roles at the same time. The "Electronic Registry" subsystem implementation although, needs the implementation BP by the university.

The deans of the faculties provide the filling of information system module "Deanery" with the records of the semester student's subject checklist according to curricula with mandatory input of data on teachers. They also provide data on the results of student's choice of alternative subjects in the "Deanery" module.

The persons responsible for the departments for maintaining an ER are checking the availability of ER user accounts from faculty members and ensuring that new employees are registered in the system as users. Teachers exercise ongoing monitoring of student's academic progress. Received data teachers contribute to the "Electronic Registry" subsystem.

Heads of profiling departments analyze student's academic progress, ensure the consideration of results at the meetings of the departments and take measures to increase it if necessary. The deaneries analyze the results of the current student's academic progress of the faculties and the quality of the ER maintenance by the teachers.

Using a web-based approach to automating student's academic progress accounting and control will allow users to independently generate analytical reports using a web browser. The routine operations for processing large amounts of data are automated and from the user's point of view, boil down to a simple click on a web link to the required report. At the same time, the ER is automatically filled with a part of the content using the data of other subsystems ("Deanery", "Curriculum", "Teacher's Load", "Schedule") and is controlled by special personnel which minimizes the probability of input errors.

RESULTS AND DISCUSSION

Development of domain ontology: To develop the ER, a thorough analysis of a complex subject area is necessary. The result of this analysis is the development of domain ontologies which includes specific terms of the subject area and their dependencies among themselves. At the same time, the specificity of the subject domain in question allows many of its terms to be formalized and described mathematically.

Consider the main terms of the subject area which are the basic characteristics of the state of the ER and its elements in time in the process of their operation and maintenance. The ER domain ontology will be synthesized taking into account the specificity of the Kharkov National University of Radioelectronics whose management decided to include to the ER indicators reflecting the percentage of student's readiness for the session (KNUR, 2013a, b).

Since, the names of individual characteristics of many terms can coincide in order to distinguish them in the mathematical expressions given in this study, upper indices will be used that reflect the affiliation of expressions to a specific term. For example, the characteristic t_s^s is the "start date" (start, subscript) of the "semester" (semester, superscript).

Term 1: The current date (t) is the present time (hereinafter we will assume that the present time is May 11, 2017). Since, the history of dynamically changing in time BP states should be reflected in the "Electronic Registry" subsystem, this term is one of the basic ones.

Term 2: A Semester (S) is an interval of time (which is characterized by start and end dates) during which time training and monitoring of student's academic progress takes place. The semester ends with the final control of student's academic progress. Formally, the semester can be described as follows:

$$S = <t_s^s, t_f^s> \quad (1)$$

Where:

t_s^s = The start date (start) of the semester

t_f^s = The end date of the semester

Term 3: The current Semester (S_c) is a semester to the time interval of which the current date t (the present moment of time) refers. That is, the following condition is fulfilled: the start date of the current semester t_s^s is less than the current date t and the end date of the semester t_f^s is greater than the current date. Formally, the current semester can be described as follows:

$$\forall S : (t_s^s < t) \wedge (t < t_f^s) => S = S_c \quad (2)$$

Term 4: Indicator of student's readiness for the session (M) is the percentage of done and submitted laboratory works, practical and seminar classes. This indicator takes into account laboratory works, performed with a positive evaluation, submitted reports, answers during practical and seminar classes, the implementation of calculations, calculation and graphic assignments, writing essays, etc. In other words, the indicator of student's readiness for the session takes into account the results of all types of activities provided by the work program for the subject.

In more detail the methodology of student's readiness for the session indicator calculation is described in order No. 27 P of 01.04.2013 on Kharkov National University of Radioelectronics (KNUR, 2013b).

The degree of the student's readiness for the examination session for the academic subject is considered 0% if the student has not completed all practical, seminar or laboratory classes.

The degree of the student's readiness for the examination session for academic subject is considered one hundred percent if the student has fully completed the training work which is indicated above.

Term 5: The Control Print (CP) is the time interval that is characterized by the beginning (the date of the CP, the point in time, according to the actual state for which student's readiness for the session indicators are calculated), the terms for filling in the ER and the terms for analyzing the obtained results (the end of the time interval) as is shown in Fig. 1.

Figure 1 shows the time diagram of the first CP of the Spring semester of 2017 year at the Kharkov National University of Radioelectronics which came on 17.04.2017 (KNUR., 2017). Formally, the control point can be described as follows:

$$CP = <id^{CP}, t_s^{CP}, C_{max}^{CP}, t_f^{CP}, t_{fs}^{CP}, R^{CP}> \quad (3)$$

Where:

id^{CP} = The CP identifier

t_s^{CP} = The date and time of the CP beginning (the time, according to the actual state for which student's readiness for the session indicators are calculated)

C_{max}^{CP} = Restriction on the maximum course of students. This parameter it is indicates, data on the students of which courses should be filled into the ER by teachers

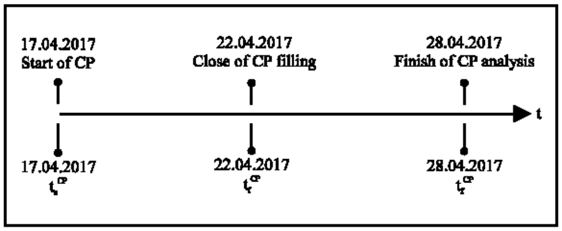


Fig. 1: Dates of CP in the timeline

t_f^{CP} = The date and time of closing (finish) filling ER with data about this CP
t_{fs}^{CP} = The date and time of this CP data analysis completion (finish statistic processing)
R^{CP} = Set of student's academic progress indicators related to this CP

Further in the research, we take the following notation the symbol => will denote a logical consequence and the symbol → will denote a mapping. The main characteristic of the CP is its date and time of the beginning t_s^{CP}. This characteristic allows us to assign CP to concrete Semester (S):

$$\forall CP: (t_s^s < t_s^{CP}) \wedge (T_s^{CP} < t_s^f) => CP \to S \quad (4)$$

Where:
t_s^{CP} = The date and time of the CP beginning
t_s^s = The start date of the semester
t_f^s = The end date of the semester

It should be noted that the control point is an subject area object, the state of which varies with time. A control point has a number of state characteristics and can be:

- Open or closed
- Active or inactive
- Shown or hidden
- Current and not current
- Analyzed or not analyzed

Control point state characteristic 1: A CP is considered to be open when the following condition is fulfilled:

$$\forall CP: t_f^{CP} < t => CP = CP^{op} \quad (5)$$

Where:
t_f^{CP} = The date and time of CP closure
t = Current time and date
CP^{op} = Open CP

In other words an open CP is CP the hour of closing which has not come yet. In the opposite case, CP is considered closed (closed):

$$\forall CP: t_f^{CP} < t => CP = CP^{cl} \quad (6)$$

Where:
t_f^{CP} = The date and time of CP closure
t = Current time and date
CP^{cl} = Closed CP

The openness of CP is a necessary but insufficient condition for the possibility of editing of ER indicators related to it. Unclosed points still be open but you can edit only those of them which is active. Closed CP is a CP that is closed for editing. Closure of CP is necessary and sufficient to block the editing of ER indicators related to it.

Control point state characteristic No. 2: A CP is considered to be active when the following condition is fulfilled:

$$\begin{aligned} &\forall CP: (CP = CP^{op}) \wedge (CP \to S_c) \wedge \\ &(t_s^{CP} = \min_{q=1,n} t_s^{CP_q}) \wedge (CP_q \to S_C) = CP = CP^{ac} \end{aligned} \quad (7)$$

Where:
CP^{op} = Open CP
S_c = Current Semester
n = Amount of CP in the current semester
q = 1, ..., n = Number of CP in the current semester
t_s^{CP} = The date and time of the CP beginning
$t_s^{CP_q}$ = The date and time of the qth CP beginning
CP^{ac} = Active CP

Thus, the active CP is CP which is not currently closed and is the closest to the present moment of time among of the still unclosed CP of the current semester. Active CP is a CP in which at the moment it is allowed to change the student's scores and academic progress indicators.

The activity of CP is a necessary and sufficient condition for the possibility of editing of ER indicators related to it. The CP is considered inactive (not active) Cp^{nac} when Eq. 7 is not satisfied.

Control point state characteristic No. 3: The CP is considered to be shown if it is a CP of the current semester and the following condition is fulfilled:

$$\begin{aligned} &\forall CP: (CP \to S_c) \wedge (\{CP_k^{op}\} = \varnothing) \wedge \\ &(t_s^{CP^{op}_k} < t_s^{CP}) => CP = CP^{sh} \end{aligned} \quad (8)$$

Where:
S_c = Current Semester
k = 1, 2, ... = Open CP number in the current semester
CP_k^{op} = Open CP of the current semester with the number k

$t_s^{CP^{op}_k}$ = The date and time of open CP with the number k (CP_k^{op}) beginning
Cp^{sh} = Shown CP

A CP is considered shown only when all previous CPs are closed. The shown CP can also be closed. This parameter is necessary for determining which CPs should be displayed when viewing and filling the ER. It is especially actual when there are no unclosed points in the semester (but they were), so that, the ER is not empty and the data of the last CP of the current semester should be available to users.

The shown CP is a CP that is shown in the user interface of the "Electronic Registry" web service. The shown CP may be inactive, open or closed. The shown CPs can be simultaneously several during the current semester. The CP is considered not shown (hidden) CP^{nsh} in the opposite case when Eq. 8 is not fulfilled.

Control point state characteristic No. 4: A CP is considered to be current if it is a CP of the current semester and the following condition is fulfilled: CP is either active at the moment or there is no active CP at the moment and the considered CP is the most recent of the already closed CPs:

$$\forall CP: \begin{cases} CP = CP^{c}, \text{if } \exists CP^{ac} \wedge (CP = CP^{ac}) \\ \text{else} CP = CP^{c}, \text{if } \neg\exists CP^{ac} \wedge \begin{pmatrix} (CP = CP^{cl}) \wedge CP \to S^{c}) \wedge \\ \wedge \left(t_s^{CP} = \max\limits_{z=1,\dots,m} t_s^{CP_z} \right) \wedge \\ (CP_z = CP^{sh}) \end{pmatrix} \end{cases} \quad (9)$$

Where:
Cp^{ac} = Active CP
Cp^{cl} = Closed CP
S_c = Current semester
t_s^{CP} = The date and time of the CP beginning
m = Amount of CP in the ER
Cp^{sh} = Shown CP
Cp^{c} = Current CP

This CP characteristic is necessary to determine what should be displayed to users of ER when the previous CP is already closed but its data are still be analyzed. In such a period of time, the data of the previous closed CP should be processed in the analysis of the ER. But when users are viewing and filling the ER, work is already performed with the data of the oncoming CP. When the analysis period of the previous CP is over, the current CP coincides with the analyzed CP and is one of the displayed CP. The CP is considered not the current CP^{nc} in the opposite case when Eq. 9 is not fulfilled.

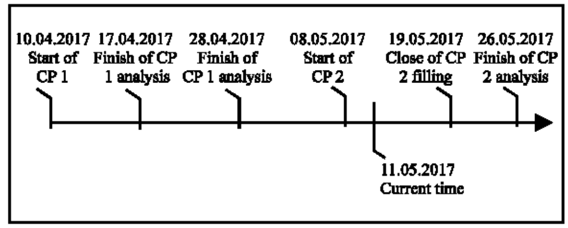


Fig. 2: Timeline of CPs

Control point state characteristic No. 5: A CP is considered to be analyzed if it is a CP of the current semester and the following condition is fulfilled: the CP's end date has already come but the end date of the CP's analysis has not come yet. Otherwise, the analyzed CP coincides with the current CP:

$$\forall CP: \begin{cases} CP = CP^{an}, \text{if } (CP \to S_c) \wedge (t_f^{CP} < t) \wedge (t < t_{fs}^{CP}) \\ \text{else } CP = CP^{al}, \text{if } CP = CP^{c} \end{cases} \quad (10)$$

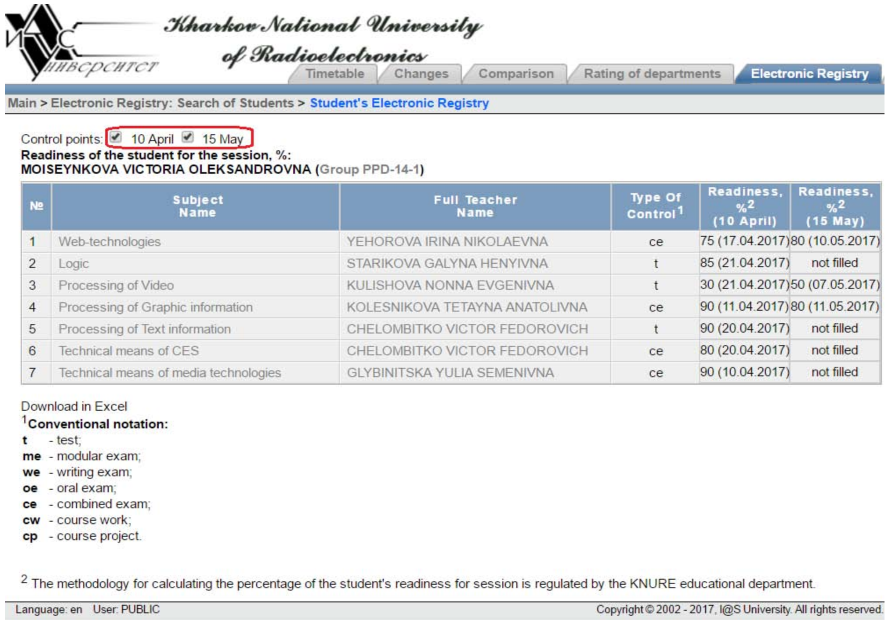
Where:
S_c = Current semester
t_f^{CP} = The date and time of CP closure
t_{fs}^{CP} = The date and time of CP data analysis completion
Cp^{c} = Current CP
Cp^{an} = Analyzed CP

This CP characteristic is necessary to determine what should be displayed for ER data analysis the when the previous CP is already closed but its data are still be analyzed. In such a period of time, the data of the previous closed CP should be processed in the analysis of the ER. But the data of the oncoming CP should be processed in viewing and filling the ER. When the analysis period of the previous CP is over, the current CP coincides with the analyzed CP and is one of the displayed CP. The CP is considered not analyzed (not analyzing) CP^{nan} in the opposite case when Eq. 10 is not fulfilled.

Let's consider an example on two Cps which are presented in Fig. 2. Imagine that the spring semester of 2017 year at the Kharkov National University of Radioelectronics has 2 CPs like it was in autumn 2013 (KNUR., 2013a, b).

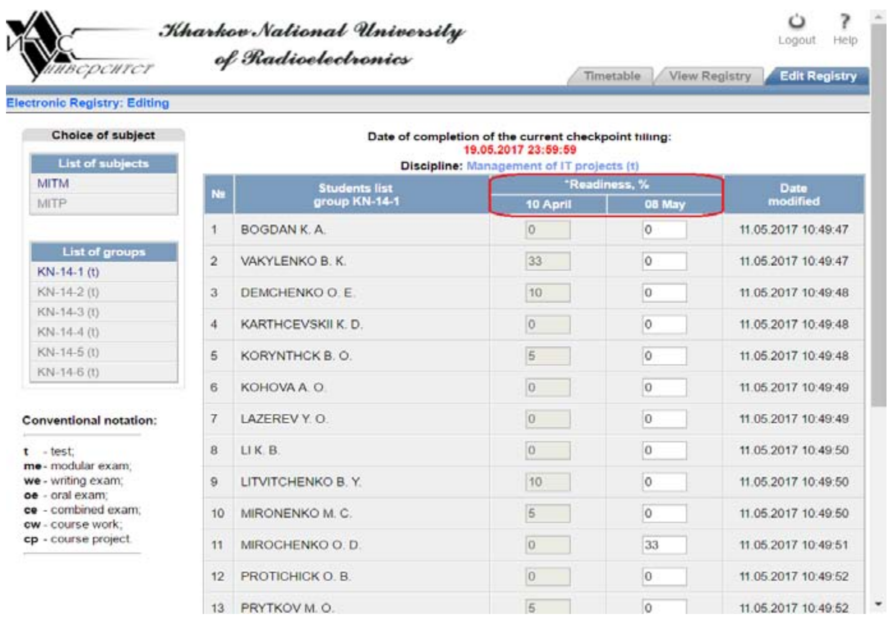
In this Fig. 2, we will look at the characteristics of the CP No. 1, applied to the current moment of time (May 11, 2017), taking into account that the current semester started on 01.02.2017 and includes two CPs. So, CP No. 1 is:

- Closed (from 01.02.2017 until 17.04.2017 23:59:59 was opened)



№	Subject Name	Full Teacher Name	Type Of Control[1]	Readiness, %[2] (10 April)	Readiness, %[2] (15 May)
1	Web-technologies	YEHOROVA IRINA NIKOLAEVNA	ce	75 (17.04.2017)	80 (10.05.2017)
2	Logic	STARIKOVA GALYNA HENYIVNA	t	85 (21.04.2017)	not filled
3	Processing of Video	KULISHOVA NONNA EVGENIVNA	t	30 (21.04.2017)	50 (07.05.2017)
4	Processing of Graphic information	KOLESNIKOVA TETAYNA ANATOLIVNA	ce	90 (11.04.2017)	80 (11.05.2017)
5	Processing of Text information	CHELOMBITKO VICTOR FEDOROVICH	t	90 (20.04.2017)	not filled
6	Technical means of CES	CHELOMBITKO VICTOR FEDOROVICH	ce	80 (20.04.2017)	not filled
7	Technical means of media technologies	GLYBINITSKA YULIA SEMENIVNA	ce	90 (10.04.2017)	not filled

Fig. 3: Student's card with indiactors of shown CPs



№	Students list group KN-14-1	*Readiness, % 10 April	08 May	Date modified
1	BOGDAN K. A.	0	0	11.05.2017 10:49:47
2	VAKYLENKO B. K.	33	0	11.05.2017 10:49:47
3	DEMCHENKO O. E.	10	0	11.05.2017 10:49:48
4	KARTHCEVSKII K. D.	0	0	11.05.2017 10:49:48
5	KORYNTHCK B. O.	5	0	11.05.2017 10:49:48
6	KOHOVA A. O.	0	0	11.05.2017 10:49:49
7	LAZEREV Y. O.	0	0	11.05.2017 10:49:49
8	LI K. B.	0	0	11.05.2017 10:49:50
9	LITVITCHENKO B. Y.	10	0	11.05.2017 10:49:50
10	MIRONENKO M. C.	5	0	11.05.2017 10:49:50
11	MIROCHENKO O. D.	0	33	11.05.2017 10:49:51
12	PROTICHICK O. B.	0	0	11.05.2017 10:49:52
13	PRYTKOV M. O.	5	0	11.05.2017 10:49:52

Fig. 4: The page for editing indicators by the teacher

- Inactive (from 01.02.2017 until 17.04.2017 23:59:59 was active)
- Displayed (until 01.02.2017 was not displayed)
- Not current (from 01.02.2017 until 17.04.2017 23:59:59 was current)
- Not analyzed (from 10.01.2017- 08.04.2017 23:59:59 was analyzed)

Consider the characteristics of CP No. 2. It is:

- Open (this CP became open from the beginning of the selected semester, if the selected time was after 19.05.2017 23:59:59, then this CP would be closed)
- Active (this CP became active, since, 18.04.2017 00:00:00 if the selected time was after 19.05.2017, then this CP would be inactive)
- Shown (CP became shown, since, 18.04.2017 00:00:00 if the selected time point was outside the selected semester, then this CP would be hidden)

- Current (CP became current, since, 18.04.2017 00:00:00 if the selected time was outside the selected semester, then this CP would not be current)
- Analyzed (CP became analyzed, since, 29.04.2017 00:00:00 if the selected time was outside the selected semester, then this CP would not be analyzed)

Consider the CP characteristics implementation in the web-service "Electronic Registry" of Kharkov National University of Radioelectronics. In Fig. 3, a CPs with the characteristic "visible" are highlighted. In Fig. 4, an inactive and inactive CPs are highlighted.

Term 6: With each semester, there are several control points in the ER. The filling of ER with indicators of student readiness for the session is made after the control point starts.

We will describe the Electronic Registry (ER) as a set of CPs grouped by semesters and ordered by time. Each CP is characterized by a set of indicators of student achievement:

$$EJ = \left\{ <CP_{11}>, ..., <CP_{is}>, ..., <CP_{n_{ks}n_s}> \right\} \quad (11)$$

Where:

ER	=	Electronic Registry of student's academic progress
CP	=	Control Point
s = 1, 2, ... ,	=	The semester in which the CP occurs
i = 1, 2, ... ,	=	The number of the CP in the semester

The given ontology for information system of student's academic progress includes elements which are the most essential for tuning of ER functioning in real time. The remaining elements of domain ontology for electronic registry of student's academic progress can be described by traditional methods for example in the form of a network of frames or as a set of relations of a relational database.

CONCLUSION

The proposed approach to the decentralization of the processes of maintaining the ER was implemented in practice. It was used by the Center of Information Systems and Technologies of the Kharkov National University of Radio.

The use of given approach and the development of the web-based subsystem "Electronic Registry" of higher education management information system made it possible to perform the functions of student's academic progress monitoring by all interested university staff at any time with using a set of automated analytical reports.

In the mathematical support of developed subsystem, the results of mathematical modeling of the ER were applied. The set of ER states is automatically calculated according to the current moment of time. Implementation of the developed domain ontology allows to realize the functioning of the subsystem "Electronic Registry" in real time and to organize effective monitoring of the student's academic progress. Now, the developed subsystem has 2.5 million visits per month. We think that given ontology can be easily implemented by higher education organizations of many countries.

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