Development of an automated information system to support computational procedures for scheduling

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Abstract. One of the most important problems of the high-quality organization of the educational process in a higher educational institution is the task of forming a high-quality educational timetable. This task is the main one in the activities of the dispatching service of the university. A well-designed timetable should ensure an even workload of student groups and faculty in the next semester. Therefore, much attention is paid to researching and analyzing the operation of existing alternative means, formalizing and solving problems of optimal scheduling. In this paper, it is assumed that the problem of drawing up an effective university schedule can be effectively solved within the framework of an automated information system. The tasks of optimizing the curriculum at the University are being solved, which will help to take into account the current sanitary and epidemiological rules and norms through the introduction of the information system "University Schedule". The paper presents diagrams of use cases and a diagram of the databases of the future system. The goal is to improve the level and quality of the preparation of the curriculum through the introduction of the system "University Schedule". The software tool created as a result of the project will be used directly by the teachers who are the people responsible for scheduling.

1. Introduction

Drawing up and promptly adjusting the class schedule is one of the difficult problems of managing the educational process of a large university. Significant difficulties arise in scheduling. First of all, this is due to the large dimension of the problem, which is characterized by the number of disciplines, rooms for classes, teachers and study groups, it is for these reasons that it is very difficult to draw up a schedule without using a computer.

The main requirements for scheduling include the following: conducting classes in accordance with the structural - logical scheme of disciplines; lack of "windows"; scheduling lectures for the first hours of classes (first, second and third lessons); alternation of disciplines from different cycles; taking into account the requirements of teachers for the rational use of working time.

The procedure for scheduling should not be considered only as a kind of program that implements the function of enumerating the distribution of classes before the start of the semester and its current adjustment, taking into account the requirements of the educational process. It is necessary to identify the normative models of the activities of students, teachers and staff, assess the preferences of departments and individual teachers, resolve contradictions, accumulate knowledge in the form of effective and unsuccessful schedules, keep records and analysis of mistakes, etc.

In other words, the task of drawing up an optimal timetable is only part of a complex set of tasks for managing the educational process.
At the moment, there are a number of similar automated information systems for creating an optimal schedule. For example, the automated system "1C: Automated scheduling" [1]. This system is designed to solve the problems of automated scheduling of educational schedules and operational management of premises in universities. With its help, you can create a schedule in automatic, manual and mixed modes, taking into account many restrictions and conditions. At the same time, you can build both a valid schedule and an optimized one, in which the number of windows or the number of rooms used is reduced.

Also on the market for these products there is such a system as "Galaxy" [2]. The system "Galaxy" offers a new look at the optimization of the resources of an educational institution and has a number of competitive advantages. Among the features that were absent in the analogue programs at the time of the appearance on the market of the system "Galaxy" is the automatic generation of the reference schedule, a high-tech user interface. The system "Galaxy" is addressed to universities and institutions of secondary vocational education.

Most of these automated systems have a large number of disadvantages:

- cost;
- implementation time is an important criterion, since project implementation time limited;
- hardware requirements - which is responsible for the conformity of the characteristics of the PC so that the embedded software can be used on it;
- difficulty in mastering the program - a criterion that should comply with the minimum efforts of users to prepare the initial information, use the software product and evaluate the results;

The main purpose of this work is the development of an automated information system for the formation of the educational schedule. This project will solve the problem of optimizing the educational schedule of an educational institution based on the use of information received from the teaching staff. Thus, the automation of the process of scheduling classes and the flexibility of the developed automated system gives advantages when using it in the education system, while improving the activities of personnel, and at the same time increasing the quality of the education provided by the university.

2. Methods

An automated information system (AIS) is a set of software and hardware intended for implementation at enterprises in order to automate activities related to the storage, transmission and processing of information [3].

The process of drawing up and tracking the school schedule lasts continuously throughout the school year. This process involves: the educational and methodological department, dean's offices, departments, the dispatch service of the university. The main responsibility for the formation of the curriculum lies with the workers of the dispatch service, which is part of the educational and methodological department.

Software products make it possible to quite successfully form a class schedule in an automatic mode, but at the same time, experience and a stable habitual schedule structure obtained during manual compilation are lost.

The order of formation of the training schedule is as follows.

On the basis of “State educational standards” approved by the Ministry of Education and Science of the Russian Federation, “Working curricula” are formed in areas and specialties. On the basis of "Working curricula" in the specialties in the departments of the faculties, before the beginning of each semester, "Teaching Reviews" are drawn up. Each line of the “Teaching Survey” is assigned to a department.
From the “Teaching Reviews” of all faculties, lists of disciplines are compiled for each department, which will be conducted by the teachers of this department. Such lists are usually called “extracts” for departments.

After solving these problems at the departments, "Applications for inclusion in the schedule" are drawn up and sent to the dispatching service. The compilation and operational monitoring of the status of these three journals is the essence of "manual" scheduling.

A diagram of the process of forming the curriculum at the university is shown in figure 1.

![Figure 1](image1.png)

**Figure 1.** Scheme of the process “Formation of the curriculum at the university”.

As can be seen from the diagram in figure 2, the ratio of the volume of input and output data is so great that there is an unreasonable loss of time arising from the preparation of a significant amount of input data only for scheduling. The possibility of using the database for solving other problems is absent.

![Figure 2](image2.png)

**Figure 2.** Data flows in a local approach.

To solve this problem, it is necessary to charge the input of each block of information to the appropriate services directly responsible for this data, which will control, maintain relevance and be responsible for the information entered. Information about teachers - HR department; curricula and disciplines - educational and methodological department; groups and students - dean's offices of faculties. In addition, it is necessary to interest these services in entering data into the information system, for example, the ability to automate their business processes, establish the search and elimination of critical errors, as well as the ability to form various samples using consolidated data from various blocks of information.
Thus, the data flow diagram will take the form shown in figure 3.

Figure 3. Data flows in a systems approach.

This is the schematic diagram of a systematic approach to automating the scheduling of a university, i.e. automation of all business processes related to the subject area of the schedule. It is this that will automate the process, and leave the final choice when making a decision to the user [4].

When forming the calendar curriculum, it is necessary to take into account the current sanitary and epidemiological rules and regulations [5], the division of student groups into subgroups, the presence of part-time teachers. When drawing up the schedule, the dispatcher must take into account the didactic requirements for the organization of the educational process, the instructions of the administration on the distribution of the classroom fund, as well as the personal wishes of teachers and student groups for drawing up a calendar training schedule.

Let us introduce the following notation:

- \( P \) - many teachers; \( \{p\} \) - many indexes to identify teachers, \( p = 1, 2, \cdots, P \);
- \( r_p \) - teacher rank \( p \), according to the unified tariff scale;
- \( G \) - many groups; \( \{g\} \) - set of indices to identify groups, \( g = 1, 2, \cdots, G \); \( s_g \) - number of students in a group \( g \);
- \( A \) - many audiences; \( \{a\} \) - many indexes for audience identification, \( a = 1, 2, \cdots, A \);
- \( k \) - many indexes for identifying enclosures, \( k = 1, 2, \cdots, K \);
- \( T \) - many working hours;
- \( D \) - many days of the week; \( \{d\} \) - many indices to identify the days of the week, \( d = 1, 2, \cdots, D \);
- \( L \) - many lesson; \( \{l\} \) - multiple indices to identify the lesson, \( l = 1, 2, \cdots, L \);
- \( Z \) - many academic disciplines; \( \{z\} \) - many indexes for identifying lessons (“Teaching Reviews” strings), \( z = 1, 2, \cdots, Z \);
- \( c_z \) - indicators of the complexity of mastering the discipline \( z \); \( z = 1, 2, \cdots, Z \);
\{v\} - many indices to identify occupations, \( v = 1,2,\ldots, V \);

\( b_{vc} \) - number of hours for each type \( v \) lessons of each subject \( z \) "Teaching Review"; \( v = 1,2,\ldots, V \);

\( z = 1,2,\ldots, \bar{Z} \);

\( \eta_d \) - the share of the weekly study load of the student group falling on the \( d \)-th day of the week, and

\[ \sum_{d=1}^{\bar{D}} \eta_d = 1. \]

Let’s introduce two groups of boolean numbers: \( x_{pdl} \) and \( x_{gdl} \) (\( p=1,2,\ldots,P; g=1,2,\ldots,G; d=1,2,\ldots,D; l=1,2,\ldots,L \))

\[ x_{pdl} = \begin{cases} 1, & \text{if teacher } p \text{ on day } d \text{ conducts classes } l-th \text{ class lesson,} \\ 0, & \text{otherwise}. \end{cases} \tag{1} \]

\[ x_{gdl} = \begin{cases} 1, & \text{if group } g \text{ on day } d \text{ is in class } l-th \text{ lesson,} \\ 0, & \text{otherwise}. \end{cases} \tag{2} \]

and a group of variables \( x_{gd} = \sum_{l=1}^{L} x_{gdl} \) (\( g = 1,2,\ldots,G, \ d = 1,2,\ldots, \bar{D} \)).

Let us introduce six groups of functions: \( \psi(x_{gd}), f_{kp}(x_{pdl}), f_{kg}(x_{gdl}), f_{vc}(x_{pdl}), \varphi_{pdl}, \Phi_{gdl} \) (\( p = 1,2,\ldots, P, \ g = 1,2,\ldots, G, \ d = 1,2,\ldots, \bar{D}, \ l = 1,2,\ldots, L, \ k = 1,2,\ldots, \bar{K} \)).

The function \( \psi(x_{gd}) \) - is a complex dependence, with the help of which the total difficulty of the educational load of the \( g \)-th group on the \( n \) \( d \)-th day is calculated.

The function \( f_{kp}(x_{pdl}) \) has a complex dependence that allows \( x_{pdl} \) using a pre-formed database to determine the number of the corpus in which teacher \( p \) on day \( d \) conducts a lesson with the \( l \)-th lesson.

The function \( f_{kg}(x_{gdl}) \) is a complex dependence, which allows for \( x_{gdl} \) using a pre-formed database to determine the number of the corpus in which the group \( g \) on day \( d \) is engaged in the \( l \)-th lesson.

The function \( f_{vc}(x_{pdl}) \) is a complex dependence that allows for \( x_{pdl} \) using a pre-formed database to determine the subject and type of classes (for example: physics, laboratory), which teacher \( p \) on day \( d \) conducts on the \( l \)-th lesson;

The arguments to the function \( \varphi_{pdl} \) are the values of the function \( f_k(x_{pdl}) \). The function \( \varphi_{pdl} \) can only take two values: 0 or 1.

\[ \varphi_{pdl} = \varphi(x_{pdl} - x_{pdl(-1)}) = \begin{cases} 1, & \text{if } f_k(x_{pdl}) \neq f_k(x_{pdl(-1)}) \\ 0, & \text{if } f_k(x_{pdl}) = f_k(x_{pdl(-1)}) \end{cases} \tag{3} \]

If the function \( \varphi_{pdl} \) takes on the value 0, it means that the teacher \( p \) on the day \( d \) \( l \)-th and \( l+1 \)-th lesson spends in the same building (no teacher’s transition from one building to another).

If the function \( \varphi_{pdl} \) takes the value 1, it means that the teacher \( p \) on the day \( d \) \( l \)-th and \( l+1 \)-th lesson spends in different corps (the presence of the teacher’s transition from corps to corps).
The arguments to the function $\varphi_{gdl}$ are the values of the function $f_k(x_{gdl})$. The function $\varphi_{gdl}$ can only take two values: 0 or 1.

$$\varphi_{gdl} = \varphi(x_{gdl} - x_{gdl(l-1)}) = \begin{cases} 1, & \text{if } f_k(x_{gdl}) \neq f_k(x_{gdl(l-1)}) \\ 0, & \text{if } f_k(x_{gdl}) = f_k(x_{gdl(l-1)}) \end{cases}$$ (4)

If the function $\varphi_{gdl}$ takes the value 0, it means that a group of students $g$ on the day $d$–th and $l+l$–th lesson is engaged in the same building (no transition of a group of students from building to building).

If the function $\varphi_{pdl}$ takes the value 1, it means that a group of students $g$ on the day $d$–th and $l+l$–th lesson is engaged in different buildings (there is a transition of a group of students from building to building).

The criterion - the minimum of "windows" for teachers, can be expressed by function (5).

$$\sum_{p=1}^{P} \sum_{d=1}^{D} \sum_{l=2}^{L} |x_{pdl} - x_{pdl(l-1)}| \Rightarrow \min$$ (5)

The criterion - the minimum of "windows" for groups, can be expressed by function (2.6).

$$\sum_{g=1}^{G} \sum_{d=1}^{D} \sum_{l=2}^{L} |x_{gdl} - x_{gdl(l-1)}| \Rightarrow \min$$ (6)

The criterion - the minimum losses from the transitions of teachers from corps to corps, can be expressed by function (7).

$$\sum_{p=1}^{P} r_p \sum_{d=1}^{D} \sum_{l=2}^{L} \varphi_{pdl} \Rightarrow \min$$ (7)

The criterion - the minimum losses from the transitions of students from corps to corps, can be expressed by function (2.8).

$$\sum_{g=1}^{G} s_g \sum_{d=1}^{D} \sum_{l=2}^{L} \varphi_{gdl} \Rightarrow \min$$ (8)

According to the recommendations of the Sanitary and Epidemiological Services (SES), the complexity of the study load should be minimal on Monday, increase by Wednesday, and decrease by the end of the school week.

In this case, the function $\beta(x_{gd})$ for the criterion for taking into account the load balance in the schedule of student groups is as follows.

$$\beta(x_{gd}) = \sum_{g=1}^{G} \sum_{d=1}^{D} |\psi(x_{rd}) - \eta_d \sum_{d=1}^{D} \psi(x_{gd})| \Rightarrow \min$$ (9)

Constraints (2.10) require that the hours of all disciplines and all types of classes planned by "Teaching Reviews" should be included in the class schedule [6].
The formation of the optimal training schedule is formulated as follows.

Find an optimal partition of the set of works planned by “Teaching Reviews” (by discipline and type of occupation) into \( p \times d \times l + g \times d \times l + a \times d \times l \) disjoint subsets, which would ensure that the minimum of function (5), the minimum function (6), minimum of function (7), minimum of function (8), minimum of function (9), under constraints (10). In this case, the required boolean variables \( x_{pdl} \) and \( x_{gdl} \) \( (p=1,2,\ldots,P; \ g=1,2,\ldots,G; \ d=1,2,\ldots,D; \ l=1,2,\ldots,L) \) are defined by relations (1) and (2), and the components of formulas (7) and (8) of the function are determined by relations (3) and (4), respectively.

Thus, the formalization and solution of this problem of forming the optimal timetable of the University will improve the level and quality of drawing up the educational timetable through the introduction of the system "University Schedule".

3. Results

In the course of the work performed, the UML diagram (figure 4) and the ER-diagram of the database (figure 5) of the future automated information system for the formation of the university curriculum [7] [8] were designed.

![UML diagram of use cases](image-url)
Figure 5. ER-diagram of the reference book of the "University Schedule" system.

The result of the design of the AIS "University Schedule" indicates that the prototype of such an information resource, implemented at the next stage, will automate the process of forming the class schedule.

4. Conclusion

The analysis of the existing procedure for the formation of the curriculum at the university is carried out. It has been established that the educational and methodological department, dean's offices, departments, the dispatch service of the university are involved in the process of drawing up and tracking the curriculum. The main responsibility for the formation of the curriculum lies with the workers of the dispatch service, which is part of the educational and methodological department.

For the purpose of the automated formation of the university curriculum, it is proposed to create an information system "University Schedule", which is one of the subsystems of the automated information system for organizing the educational process at the university.

A methodology for designing the information system "University Schedule" is proposed, the basis of which is a systematic approach, according to which any system is a set of interrelated objects (elements) that function together to achieve a common goal.

In the future, it is planned to create an application to solve this problem.

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