2020 Ural Symposium on Biomedical Engineering, Radioelectronics and Information Technology (USBEREIT)

Timetable Model for Individualization of Education Based on Multi-agent Approach

Alexey Syskov
Institute of Radioelectronics and Information Technology
Ural Federal University
Yekaterinburg, Russian Federation
am.syskov@gmail.com

Maria Rabovskaya
Ural Federal University
Yekaterinburg, Russian Federation
m.ya.rabovskaya@urfu.ru

Valentina Makhneva
Ural Federal University
Yekaterinburg, Russian Federation
v.v.gusarova@urfu.ru

***Abstract*—Scheduling is a well established process at universities. Each university has its own traditions and schedule quality parameters. The research about automated timetable are most common. Those researches uses a heuristic and meta heuristic approaches. There are many modifications of methods such local search methods, simulated annealing, adaptive memory programming, tabu searches and so on. But developing and implementation of IT services for Scheduling in university based on automated timetabling are well known problem. Last years the digital transformation of education is widely discussed topic. Key challenges are the radical individualization of education and lifelong education. And new models of educational process organization and resource use are under researcher's focus. Adaptive learning, traditional, MOOC (Massive Open Online Courses) and blended courses, inter-school and university shared courses are under point of view due those potential for individualization of education and lifelong education. The timetable model and real-world IT services are the basis for implementation such digital transformation in direction to increasing personalization and student motivation. The paper discusses the multi-agent scheduling model and the results of its implementation as services for interactive mode timetabling.**

Keywords—digital transformation, individualization of education, timetable, scheduling, multi-agent system, university, curriculum

I. Introduction

Traditionally, there are two tasks associated with scheduling at the university: 1) usually term period scheduling on the basis of the curriculum for teaching groups; 2) schedule adjustment after students select electives and in the learning process, this task is performed by dispatchers as requests for changes to the schedule are received.

Usually, the first task in research is associated with the problem of scheduling (timetabling): it is necessary to develop software that will automatically distribute training meetings of students and teachers, taking into account the existing limitations and quality criteria of the final schedule.

The most widely problem of automated timetabling is discussed at the conference Practice and Theory of Automated Timetabling (PATAT) and the EURO Working Group on Automated Timetabling [1]. An overview of the methods and models can be found in [2][3][4]. Integer linear programming methods are used to obtain the final distribution of training groups and teachers by class and time slots are most common, for example [5] [6] [7].

The work was supported by Act 211 Government of the Russian the student can request a guide on what to do next, relative to Federation, contract υ 02.A03.21.0006.

However, the actual implementation of Automated Timetabling services is extremely limited. This is due to the fact that the criteria for the quality of schedules and restrictions differ not only from university to university, but inside universities for schools, faculties, departments [5]. Increased requirements for the flexibility of the educational process are increasingly shared by Automated Timetabling solutions and real scheduling services [8]. Education leaders provide the student with new forms of educational activities that allow him to form the necessary competencies, for example, project-based learning [9].

In Russia, the availability of the Automated Timetabling service is declared for the Galaktika system, but examples of practical application of Automated Timetabling services are not given [10]. Galaktika is a leader in field of software development for university in Russia.

Limitations of the use of Automated Timetabling methods in practice can be offset by an expert service system to support interactive scheduling. Such services should use data from various educational process management systems and be based on the Timetabling model.

In this regard, there is a need to develop timetable models with the following characteristics: the ability to schedule in real time; transitions between automatic and interactive scheduling; using data from related information systems to control constraints.

Multi-agent systems view the resource planning process as a self-organizing system. Within the framework of the system, a search is made for the balance of opposing interests of the basic agents of needs and opportunities [11].

The multi-agent approach allows you to build schedule models in which order processing in real time is possible, along with a stream of other unforeseen events, for example, cancellation of orders, unavailability of resources, malfunctions or delays, etc.

The article discusses the multi-agent scheduling model and the results of its implementation as services on the example of the Ural Federal University in Russia.

II. Materials

The Ural Federal University has more than 35,000 students studying in 489 educational programs.

The schedule is compiled in the departments of 13 schools. For scheduling, an information system is used. As shown in fig. 1 schedule is formed on the basis of the curriculum for teaching groups.

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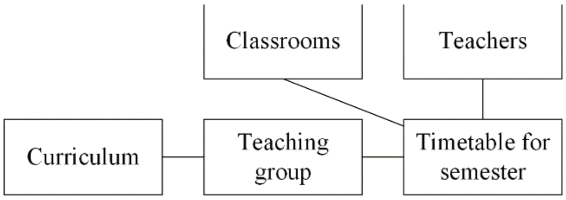

Fig. 1. Main stages of timetabling

Teaching groups are formed on the basis of the curriculum and student choice. Fig. 2 shows a use case diagram for student selection services.

The student chooses electives and technology based on the schedule. Thus, it is necessary to provide constrains for teaching groups in the schedule model, which will avoid conflicts in the student's calendar.

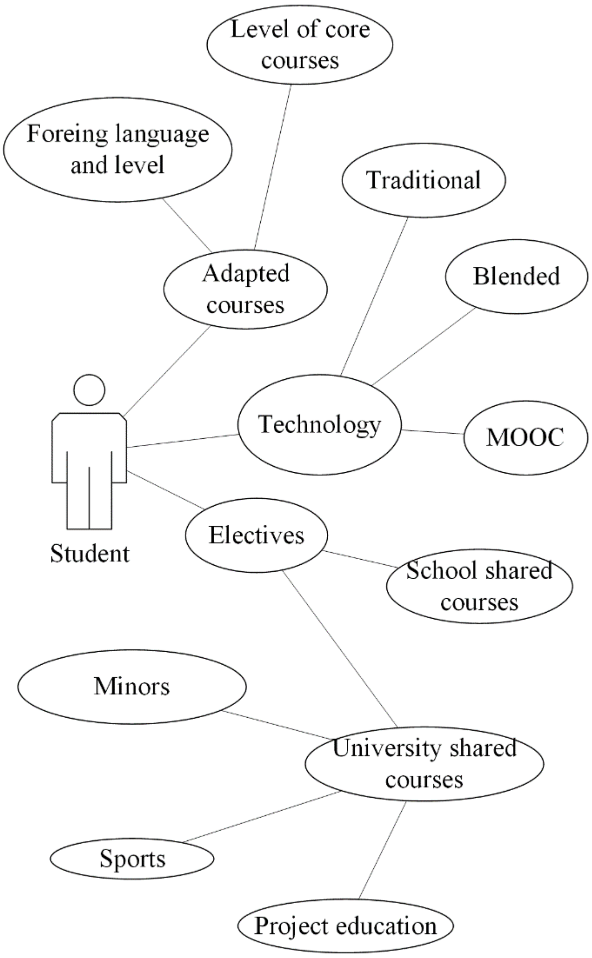

Fig. 2. Student course selection use case diagram

III. Model

A. Multi-agent model

Consider agents based on examples [11][12][13][14] Table 1.

TABLE I. SPECIFICATION OF AN AGENT'S BEHAVIOR

Agent	*Specification of an Agent's Behavior, Its Main Goals, and Tasks*	*Attributes*
Cource owner (COA)	Acceptance of orders for the implementation of the course. Formation of study groups. Assignment to teaching groups of teachers.	Course. Technology implementation of the course. Number of students per course.
Timetable (TA)	Develops a timetable for the school.	Courses. Shared courses. Curricula of educational programs. Training teams. The audience. Teachers.
Mediator (MA)	Provides temporary slots for courses common to several schools. Resolves conflicts using a common university auditorium.	Shared courses. University-wide classroom fund.
Student (StA)	Selects electives based on own calendar.	Student electives.
Lifelong learning program (LLPA)	Short education program for life learning.	Courses.
Educational programm (EPA)	The educational program, curriculum and application for courses in the term.	Curriculum.
Scene (SA)	Data loading and serving the resulting schedule	Calendar events, classrooms, teachers, teaching group.

The fig. 3 shows the interaction diagram of agents based on protocols.

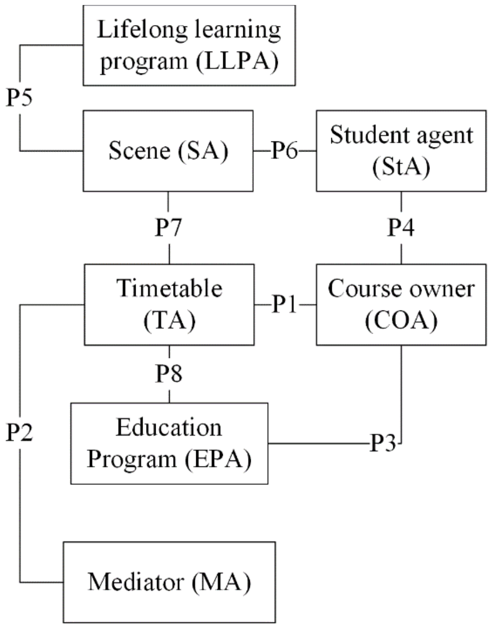

Fig. 3. Agents and protocols

The Table 2 describes the interaction of agents within the protocols (P1…P8).

TABLE II. SPECIFICATION OF AN AGENT'S PROTOCOLS

Protocol-Agent	*Receive message*
P1-TA	Teaching groups with teachers, preferences for time slots and classrooms. Changes in teachers.
P1-COA	Accessible classrooms.
P2-MA	Shared courses.

Protocol-Agent	*Receive message*
P2-TA	Classroom foundation for general courses. Temporary slots for general courses.
P3-COA	Orders for semester courses
P4-COA	Registration for electives.
P5-SA	Course Activities.
P6-StA	Date and time for electives.
P7-TA	Available resources: timeslots, rooms, teachers.
P8-TA	Curriculum.

B. *Agent Constraints*

Agents have their own goals, performance criteria and constrains Table 3.

TABLE III. AGENTS'S CONSTRAINS AND GOALS

Agent	*Constrains*	*Goals*
Cource owner (COA)	Technology implementation of the course. Resources: specialized classrooms; teachers.	Minimizing the use of resources.
Timetable (TA)	The absence of conflicts between students and teachers. Temporary slots.	Minimizing the gap between events.
Mediator (MA)	Conflicts in shared courses.	Minimizing resources for streaming lectures.
Student (StA)	Lack of intersection of courses.	-
Lifelong learning program (LLPA)	Technology implementation of the course. Resources: specialized audiences; teachers.	Minimizing the use of resources.
Educational programm (EPA)	Curriculum.	-

Consider the restriction of the absence of conflicts in the student schedule for TA. For electives, at the time of scheduling, there is no data on student group members. Suppose that SA on the basis of data in information systems in a certain way marks study groups. So that when adding a study group *i* TG_i^{ts} for the time slot *ts*, it is possible to identify the presence or absence of conflict among students. Function (1) is zero for no conflict case.

$$f(TG_i^{ts}) = \sum_{j=1..n} Ch(TG_i^{ts}, TG_j^{ts}) \qquad (1)$$

where Ch return 0 if for TGi and TGj there is no conflicting markers, 1 in other case, *n* – number of teaching groups it time slot *ts*.

The fig 4. shows the idea of such teaching group markup. We can put the yellow-red labeled group in slot 4. For other slots, conflicts are possible after students are enrolled in a groups.

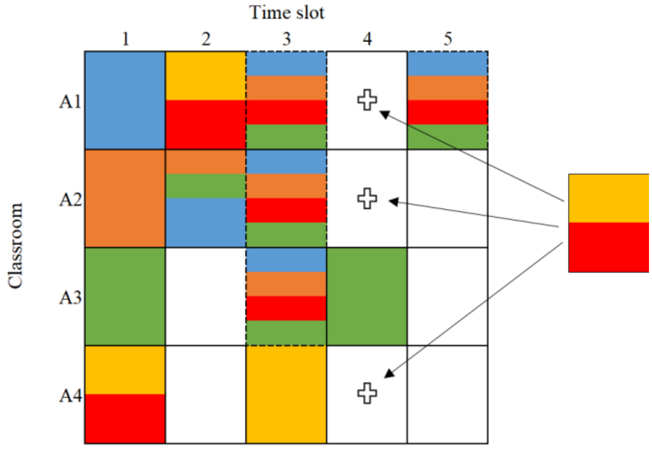

Fig. 4. Teachung group markup

IV. RESULTS

The integrated information system (IIS) for timetabling are used Fig. 5. There are processes for timetabling in IIS: curriculums; orders for resources; scheduler; student calendar.

Scheduler app for interactive timetabling are used. There are student's event in Calendar. Order for resources system are used for: teaching group management; assigning teachers to teaching group; enrolling students into teaching groups.

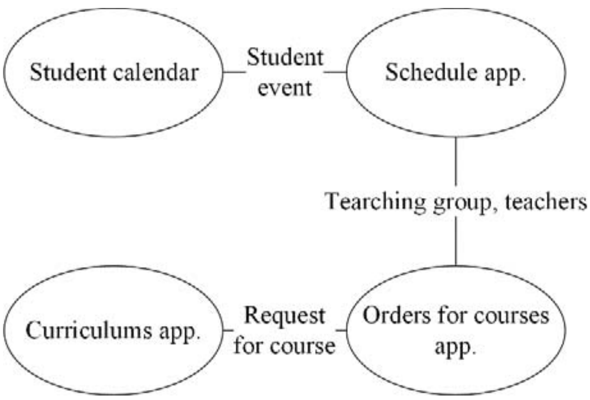

Fig. 5. Timetabling processes diagramm

Screen of scheduler app in interactive mode in fig. 6 are showed. For markup the teaching group the following data are used: shared courses in curriculums; student's traces in educational program.

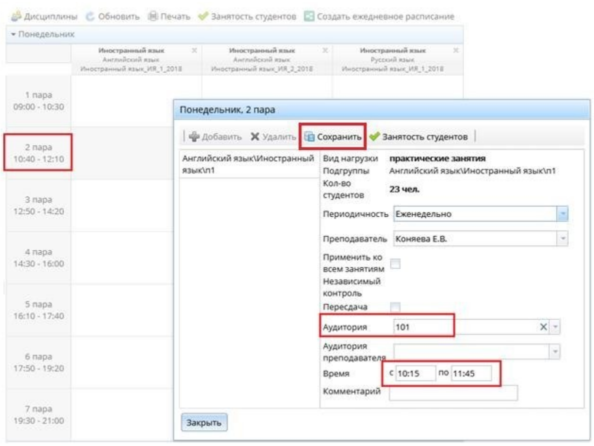

Fig. 6. Screen of scheduler user interface

V. CONCLUSIONS

The paper shows the possibilities modeling of timetabling system in university. A special attention is paid to individualization of education IT services support. IT services for interactive mode timetabling are developed.

In the introduction, the problem of implementing an automatic schedule was noted. Among the reasons: focus on the schedule generation stage to the prejudice of the other life circle stages; differences in scheduling approaches in different departments of the same university.

This article presents the results of the development of the timetable model using the multi-agent approach. The presented model can be used to develop timetabling methods and instructions for interactive and automatic modes.

A method for the interactive mode of operation of a multi-agent system is presented. The method is designed to search for conflicts when planning a schedule before enrolling students in training teams. The methodology was tested using the integrated information system.

The considered methodology is relevant when building a schedule in the context of individualization of the educational process. When traditionally, the schedule is compiled interactively. But there is a need to develop models for the transition to automatic scheduling.

The next steps will be the development, testing and implementation of a minimum viable product information system to creating automated timetable services based on multy-agent model. Those service will include Timetable agent (TA) and Mediator (MA) as autonomous programs.

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