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NEW APPROACHES TO THE SCHOOL SCHEDULING AUTOMATION

Zainab Saadi Hussein Al-Hilali, Volodymyr Shevchenko

***Abstract**: An innovative approach was applied to the scheduling problem. Scheduling is a resource-consuming task in any field. School Learning Management Systems lack this functionality for off-line classes. The solution could help to account the working time of the staff simpler and, primarily, to construct the weekly school classes schedule, which complies with the requirements and limitations of the school and teaching process, with less effort. In this paper, we adopted approaches from another area of workforce management to this significant task. We also developed the software solution, which solves this issue and implements the scheduling for classes in a school or university, considering requirements, limitations, and input wishes. The results quality was evaluated via experiments because of strong practical interest in the task and showed objective validity.*

The focus of this work is the scheduling task and innovative solution developed, which seems to be valuable for the community.

***Keywords**: e-learning, scheduling, learning management system, school management.*

***ITHEA Keywords**:* J.1 Computer Applications - ADMINISTRATIVE DATA PROCESSING - Education, K.3.1 Computing Milieux - COMPUTERS AND EDUCATION - Computer Uses in Education, I.2.8 Computing Methodologies - ARTIFICIAL INTELLIGENCE - Problem Solving, Control Methods, and Search - Scheduling, H.4.1 Information Systems - INFORMATION SYSTEMS APPLICATIONS - Office Automation - Time management (e.g., calendars, schedules), F.2.2 Theory of Computation - ANALYSIS OF ALGORITHMS AND PROBLEM COMPLEXITY - Nonnumerical Algorithms and Problems - Sequencing and scheduling

Introduction

Learning Management Systems (LMS) are very popular today, also known as e-Learning systems (like Moodle and others). They cover many functions concerning the study itself and the learning process organization:

- student progress tracking throughout the classes (disciplines) and the whole learning curve,
- communication with teachers,
- learning material arrangement,
- homework assignments to the students,
- additional functions.

The scheduling is a crucial and challenging task in many fields. Time-tables creation for workforce management in organizations is one of the vital stability factors for Contact Centers and other companies with shift-based work organization [Chernichenko, 2016; Lytvynenko, 2015; Panchenko, 2003; Panchenko2, 2003; Panchenko, 2004; Apex, 2008].

As to the schools and universities, the schedule of classes is one of the crucial documents, which directs the whole teaching process. We have the following inputs:

- requirements – the workload of each teacher (or professor), how many hours of which kind of classes he/she should deliver per week,
- wishes – which days and time are preferred by workers, or not possible at all for them because of another kind of business or activities,
- sites – classrooms of different types for each class,
- limitations – which classes could be sequent, which one should go first, next and last, the upper limit of classes per day, the limit of lectures per day.

Also, in the case of school or university schedule, a necessary additional requirement of interchangeability (or, a kind of flexibility in the sense of change

management) should be considered. We mean that changes should be possible to make on request without extra overhead for the scheduling manager (for example, to find another teacher or professor for the particular class or to move some class to another day of week and time – for one time or on a regular basis).

So, we consider the task of delivering the schedule, which meets all the requirements above. This functionality can be rarely found in systems aimed to support the learning process, namely LMS [Hilali, 2015; Hilali, 2016; Aggarwal, 2018; Nagar, 2018; Nawaz, 2012; Shariat, 2014; Eljinini, 2012; Maysam, 2012; Muhsen, 2013; Guangran, 2011; Pishva, 2013; Inayat, 2013; Dominic, 2014; Dominic, 2015; Dominic2, 2015; Kocaleva, 2015; Marikar, 2016; Dushyanthi, 2016; Shili, 2017; Okey, 2019; Dada, 2019; Adejo, 2018; Akinul, 2017; Deogratius, 2018; Robles, 2017]. It was out of the scope of these systems in most cases, because this kind of systems is more about on-line (instead of off-line, in-class) education. Even when this function exists, it is presented mostly as just a calendar (for flexible manual planning) or as a separate product. It requires much integration efforts for the next regular use. Manual schedule adjustment and tuning is a time-consuming process because it is hard to take into account all the limitations at once. If the process is not automatized, it requires much attention and iterations to comply with all the needs posted above. Nevertheless, this question is not well presented in recent papers concerning LMS and e-Learning [Hilali, 2015; Hilali, 2016; Aggarwal, 2018; Nagar, 2018; Nawaz, 2012; Shariat, 2014; Eljinini, 2012; Maysam, 2012; Muhsen, 2013; Guangran, 2011; Pishva, 2013; Inayat, 2013; Dominic, 2014; Dominic, 2015; Dominic2, 2015; Kocaleva, 2015; Marikar, 2016; Dushyanthi, 2016; Shili, 2017; Okey, 2019; Dada, 2019; Adejo, 2018; Akinul, 2017; Deogratius, 2018; Robles, 2017].

Scheduling automation will help to solve four sub-tasks at once:

- schedule generation itself,
- change management (with some additional effort),

- accurate accounting of staff working hours,
- reporting of the actual time spending, including shifted and interchanged classes and other cases, which have been fixed in the system during the changes.

Here we tried different new approaches (taken from other areas) to the scheduling task for schools and implemented it in the developed software. As this task is avoided mainly in existing LMS (scheduling automation), the design purpose is to automate this kind of activity to:

- create schedule fast and in accordance with the requirements and limitations set,
- provide an effective software user interface for the next changes management,
- minimize the integration and customization efforts for regular usage.

In this way, we cover the significant task of the LMS, the planning, and scheduling. The research objective of this paper is to check via the experiment if the schedule can be obtained in the suggested way and if that schedule is viable enough. The methodology is the feedback analysis after the experiment – namely, the implementation of the new approach proposed to the school scheduling. It shows the practical value of the proposed innovative approach.

In the next sections, we will overview the existing approaches, emphasizing the methods chosen for our task (namely, methods used for the workforce scheduling), giving more specifics on the proposed solution, and then discussing the outcomes and the future work.

Approaches to the Scheduling

There exist a number of approaches to schedule construction. The choice depends mostly on the filed specifics. So, for example, CPU scheduling differs a lot from WorkForce Management (WFM), which schedules shifts for the working staff of the organization. Markov processes, “brute force” algorithms, optimized search algorithms, genetic algorithms have been applied to generate the schedules as usual [Panchenko, 2003; Panchenko2, 2003; Panchenko, 2004; Apex, 2008]. Machine learning methods [Panchenko, 2003; Panchenko2, 2003;] and gradient descent methods also could be applied here, and we will try to improve the schedule flexibility by introducing an innovative method to the generation process.

“Brute force” algorithms were the most popular because of their simplicity, but they required much computation time. For the large inputs (more than 100 staff, many different activities – classes, non-unit assignment or correspondence matrix of classes – teachers/professors), the process can become incomputable in real-time without supercomputing power. Because of this fact, many optimization techniques and heuristics appear, which help to decrease the computation power required and to sort out just the right cases due to a set of predesigned heuristics. More of this, a kind of gradient descent optimizations were applied to decrease the “brute force” techniques even more. Nowadays, new technics appear like pervasive Artificial Neural Networks (ANN) and other machine learning methods.

The goal is to produce the schedule, which complies with the input requirements and limitations at most, and also is flexible enough for the next change management process. Of course, this kind of flexibility implies extra resources availability. We mean that we should have:

- extra teacher(s), who can provide the same specific class (say, mathematics for 5th-grade pupils) to support another teacher, who should deliver that particular class but cannot come for some reason,
- extra classrooms to make it possible to move classes in time,

The convenient visual tool to support such kind of changes, and to visualize the consequences of changes made, is also a must.

Scheduling Solution Proposed

We started our development on the fundament of the WFM system, which turned out to be similar to the required one. WFM Scheduling solves the task of putting workers (contact center operators) to the shifts, where the shift-based schedule is obtained from the previous stage of planning the resources and forecasting the quantity of the staff at every particular time of the week [Panchenko, 2003; Panchenko2, 2003; Panchenko, 2004; Apex, 2008]. (Time periods are usually hours, half-of-hours or quarter-of-hours.)

We used both “optimized brute force” (modeling a mass service) and “minimization of the energy” methods [Panchenko, 2003; Panchenko2, 2003; Panchenko, 2004]. Both methods are described in [Panchenko, 2003; Panchenko2, 2003; Panchenko, 2004], so we will not go into details here. The latter is based on the idea, which is widely used in many areas for modeling today and is rooted in physics. It is about the probability distribution of final positions of falling metal particles over the magnetic field. In scheduling, this tries to build the most appropriate schedule at first try, and then make improvements to comply with requirements denied in an iterative manner. The number of iterations can grow if the requirements are inconsistent or have a small intersection.

The input requirements and approaches to complete the schedule for two fields under consideration are much different at first glance but turned out to be very similar indeed.

This scheduler is used as a part of the LMS (which is under construction now), or as a separate part (with light integration via the proposed API to export the inputs for

the scheduler and to import the resulting schedule) as presented on **Fig. 1**. The API call takes input parameters for the schedule and returns the resulting completed schedule (now in XML and JSON formats).

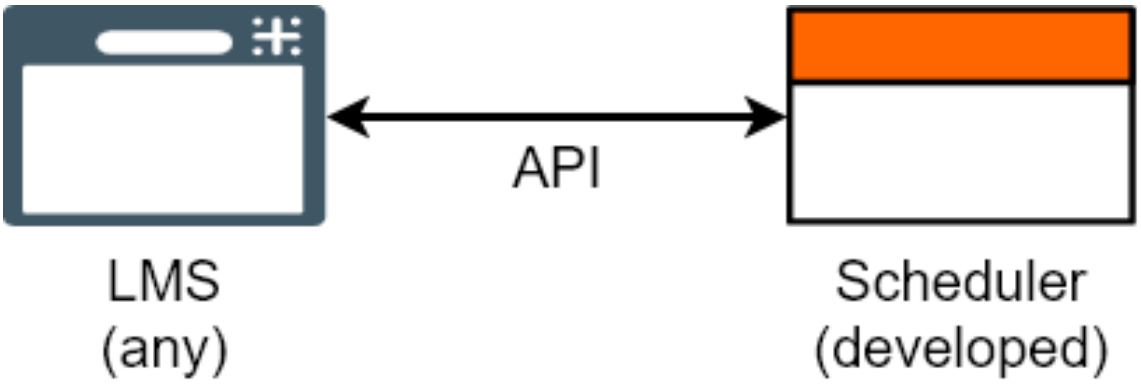

Fig. 1. Scheduler module integration with LMS via API

So, here we proposed to use WFM scheduling ideas for the school schedule completion. We summarize the results and discuss them in the next section.

Experiment Results and Discussion

We developed the new software on the principles of the scheduling for the workforce. For the development of MVP (minimum viable product), we used both variants of algorithms, and it seems that both gives acceptable results. This scheduler is a part of the LMS, which is under development now and is implemented in trial mode in 2 Iraq schools. Now we collect feedbacks to improve the system and move on to the development of the new planned features.

- The main modules of the developed system are:
- scheduler,
- schedule viewer for different roles: teacher, class timetable, classroom load,
- change management support subsystem,
- API for integration with external content management system (LMS),
- API for data exchange (inputs, outputs).

The first feedbacks for the system are positive, so we continue to develop it further.

We leave search optimizations of algorithms for future developments. Also, we are going to try current machine learning techniques, which are also promising for the scheduling task – namely, simple artificial neural nets (trained over the large schedule examples database, which should be collected first), transfer learning techniques, and probably more sophisticated methods subject to its adequacy. These methods are promising for increasing flexibility of the resulting schedule, to simplify the next changes management.

So, here we applied WFM scheduling methods [Panchenko, 2003; Panchenko2, 2003; Panchenko, 2004] to solve the school weekly class scheduling task. It is the main result of the paper. Furthermore, no mention could be found of a similar application in the literature.

Conclusion

In this paper, we investigated the problem of scheduling for the School Management System (or LMS) and proposed our solution to solve it. We articulated that change management is also an essential part of the system.

The main academic contribution of this work is WFM scheduling methods adaptation and application to the school weekly class scheduling task solution.

The innovation of the proposed approach is to use workforce scheduling methods (designed for WFM solutions) to the field of school/university scheduling, which was not evident for obtaining the fair result at first glance. There is no other mention of such methods applications in the literature.

The scheduling task is significant as it takes much time for manual work and has substantial practical importance. So, we are evaluating the results by experiments.

We developed the scheduling solution (based on the “optimized brute force” and “minimization of the energy” algorithms), which helps the managing staff to generate schedules accordingly to the input requirements, limitations, and wishes. Thus, a novel approach (previously used for the contact center scheduling in WFM systems) was applied to the class scheduling task for the school/university environment.

Now, this system is in use by two Iraq schools, and we are gathering feedbacks for the next development, optimization, and other improvements. This system is web-based and provides authorized access for members only according to the role granted. It is developed using modern Microsoft.Net technologies at the back-end and has a front-end client – browser with JavaScript.

The first feedbacks are positive enough and show us that this additional functionality is on demand by the users, giving us the background for the further development and improvement of the system because we solve the important task for users. So, we can conclude that the quality of the obtained results is expectedly high.

Plans include the implementation of more sophisticated approaches to deliver the schedule in a more optimal way (concerning resources required to complete the task). Also, we are going to adopt Artificial Intelligence and Machine Learning approaches mentioned in the paper to make results even better and, possibly, to decrease the time needed for this.

We would like to make the software more user-friendly and adaptive for the different types of limitations to the schedule. Also, the system needs to be more integrated

into the learning process, which implies APIs integration with existing external LMS(es) and open API improvement for external developers who will be interested in additional functionality and modules development.

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TABLE OF CONTENT