Design of an Exact Approach for Timetabling at Project-Oriented Schools

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1 Introduction

Automatic timetabling in an educational context is a complex planning task that can help to provide decision support for school administrations and replace manual planning through higher solution quality and speed. Depending on the application, a distinction can be made between the high school timetabling problem (HSTP) and the university course timetabling problem (UCTP) [1]. In the school context, planning is done for disjunct classes and an assignment to rooms, teachers and events is required that is free of conflicts [2]. This contrasts with scheduling at universities, where students often have a great freedom of choice, which is why it is more a matter of minimizing conflicts in timetabling approaches due to the many overlapping possibilities. A distinction is made in this class between curriculum-based course timetabling (CB-CTT) and post-enrolment course timetabling (PE-CTT). The CB-CTT formulation [3] takes into account a curriculum that reflects the courses to be fulfilled by the students and to which the constraints are oriented. In contrast, the PE-CTT formulation [4] requires students to enroll in courses before the actual timetabling is done. We want to focus on project-oriented schools that combine or recombine features from the context of classical school and university timetabling. The experimental school Universitätsschule Dresden (USD) serves as a real use case for such a school, which should be supported in the timetabling process. Since 2019, a learning concept has been tested there that focuses on project work and does not have a typical class structure. Students stay together in small project groups for a limited period of time and work on a specific topic. The planning horizon is much shorter than for regular schools, so one of the project cycles usually lasts six weeks and followed by a new planning iteration instead of one isolated timetabling procedure at the beginning of a school year. In principle, each student receives his or her individual timetable in the USD instead of a common timetable being generated for a whole class where everyone follows the same subject-related schedule. This distinction is shown again in Figure 1.

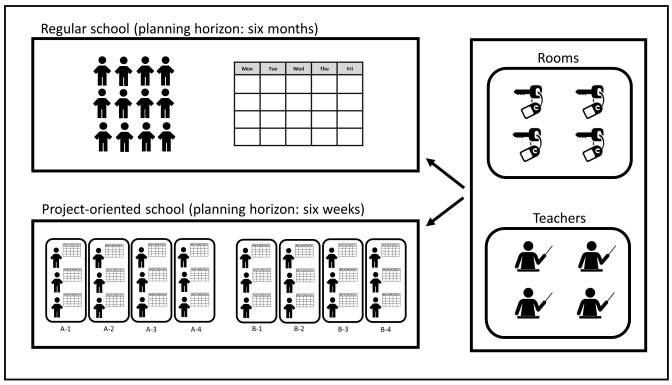

Fig. 1. Comparison between regular school and project-oriented school

2 Problem Description

At USD special restrictions apply that must be taken into account during the solution process. The projects have a certain capacity, so there can be four to six students in a project group. In addition, each student is expected to work on several projects from different categories within a cycle. There is also the possibility for students to come up with a topic on their own and form a fixed project group. At the school, a distinction is made between group rooms and special rooms that have also a specific capacity that needs to be respected. The special rooms are for example a science lab, a music/art room or a sports hall. For each project, it is determined before the cycle begins whether and how many appointments are to take place in these special rooms. Regarding teachers, their availability must be taken into account. In addition, it is important to have the appropriate professional qualifications for the supervision of the specialized rooms. Each project also has a teacher that is directly responsible. It is not necessary to be supervised by this teacher on all dates, but there must be a minimum number of meetings per week to be able to discuss the progess of the project. The generated timetables should not have any overlapping conflicts in relation to the students and teachers. Each student must therefore be assigned to exactly one project and one room at each time slot, and each teacher can only supervise one room at a time.

The objective criteria that play a role in the underlying problem are, on the one hand, the highest possible satisfaction of the students in the assignment to projects. For this purpose, preferences are requested from each student regarding the projects, which are then to be fulfilled as best as possible in the solution process. In addition, there should be a fair distribution of the teachers' workload and a roughly equal number of supervised rooms for each teacher. And the use of rooms should be efficient, so the goal is to have as few rooms in use as possible.

3 Methodical Approach and Preliminary Results

In order to solve the timetabling problem at USD, we will try to use an exact procedure. For this purpose, a mathematical optimization model is to be set up that represents the above-mentioned conditions. All hard constraints must be met in order to achieve a feasible solution. The three mentioned objective criteria are implemented as soft constraints and give through their optimization an indication of the quality of the generated timetables. This results in a multi-objective perspective, which will be treated with the approach of a lexicographic optimization. Most important in the solution process is the consideration of student preferences, prior to the fair distribution of the teacher's workload and the efficient use of space. The aim is to test variants in which not only a strict hiearchical optimization is used, but also a certain degradation is allowed in order to find other solutions in the efficient set and compare them with each other. First results are promising and give hope that the problem can be solved to optimality in an acceptable time with the help of a commercial solver such as Gurobi. A systematic computational study is to be performed, with randomly generated instances of different sizes, to analyze the impact on computation times and to determine the possible limitations of the approach. A sensitivity analysis is also conceivable in order to find out how the computing time reacts to different parameter constellations. In the end, the USD should be supported by a practicable approach to generate feasible and optimized timetables, which are necessary to successfully implement the developed concept of project work at the school.

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