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Rapid Development of University Course Timetables

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1 Introduction

Many universities continue to solve timetabling problems manually even though there are a variety of timetabling systems[1] applicable to these problems [3,1]. The often tedious process of initially setting up an automated system and making adjustments for the specific needs of an institution is one of the critical reasons for this. We will discuss an application of the comprehensive timetabling system UniTime[2][4] at a large college with 10,800 students. Here the generated timetables were published eight weeks after our first meeting with the schedule manager. Our goal is to describe how such a rapid implementation of an automated university course timetabling system can be achieved even for large problems.

2 Timetabling Process

The course timetabling problem for the Faculty of Arts at Masaryk University had been solved manually until the Fall 2010 semester. The initial process consisted of manual creation of departmental timetables by about 40 schedule deputies. These timetables, containing all time assignments and most room assignments for the department classes, provided the initial input for the central schedule manager. Unfortunately, even these partial timetables were inconsistent. They did not reflect the availability of shared resources (rooms) and substantial changes to the proposed assignments were necessary. The amount of changes required was estimated at 30-40 % by the central schedule manager who was responsible for creation of the complete timetable. Partial timetables

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[1] http://www.asap.cs.nott.ac.uk/watt/applications
[2] http://www.unitime.org

from each of the schedule deputies were submitted via MS Excel files containing tables with assignments. These tables were manually modified during the process. Finally a text form of the timetable was generated from Excel and imported into the Information System of Masaryk University (IS MU)[3].

Since the college has been renovating some of its facilities, it was necessary to create timetables for Spring 2011 such that the number of available classrooms decreased from 65 to 49. Such a substantial change was one of the main reasons for our attempt to generate timetables automatically even within such a limited time period. Since training 44 schedule deputies in the use of UniTime was not manageable within the required time frame, we decided to use their manually created timetables as the primary input for automated generation of the complete college timetable. The remaining input data were retrieved from the IS MU. The overall initial input[4] to the timetabling consists of the following data

- partial timetables created by individual schedule deputies: time assignments for all 1917 classes, partial room assignments (69 % of classes), class identifier (course identifier + optional section number), preferred room equipment (standard room, multi-media lab, computer lab), instructor name
- 49 rooms: identifier, building, capacity, equipment
- 584 instructors: identifier, name
- 1570 courses: identifier, name
- last-like semester enrollment to courses: course identifier, student (70689 records).

It is important to realize that each course may consist of several classes, i.e., one or more lectures and/or one or more seminars (note above that there are 1570 courses and 1917 classes). In most cases we identified the course structure automatically. The correct structure of the remaining courses was entered through the UniTime interface. Another important manual process was identifying courses having two or more identifiers (so called cross-listed courses). Many of these were identified automatically based on the assignment of multiple courses to the same time and room within a departmental timetable. The correct course structure is important to be able to schedule students meaningfully among lectures and seminars and to share resources among cross-listed courses if necessary [4]. After cross-listed courses and classes were identified, the number of courses and classes decreased to 1421 courses and 1746 classes. This means that there were 1746 entities requiring time and room assignments.

The goals of the timetabling problem in this instance are to assign times and rooms to all classes such that consistency of rooms and instructors is maintained, the number of student conflicts between classes are minimized, preferences on the room equipment are considered, and the assignments in the partial timetables are retained as much as possible. In addition, placement of classes to very early and very late times is discouraged — the college allowed extension of the time patterns from 7:30 am to 8:45 pm due to missing classrooms, but their use is certainly not perceived positively. Some other constraints were specified by the central schedule manager using the UniTime interface but the quantity of these was not significant.

The information contained in the partial manually created timetables was not complete. These timetables did not contain room assignment for 31 % of classes (often due to missing classrooms). Moreover, it was not possible to assign more than 48 %

[3] `http://is.muni.cz`

[4] After the first publication of the timetable, 7 rooms and 13 classes were added.

Table 1 Comparison of generated timetables.

Solution	Fully Automated	First Published	Finalized
Student conflicts	812	871	1,119
Time preferences (%)	92.34	92.53	89.20
Room preferences (%)	82.99	83.38	74.65
Selected time kept (%)	89.8	89.9	87.66
Selected room kept (%)	62.9	65.6	64.05
Broken hard constraints	0	10	71
Interactive time changes (%)	-	1.4	10.85
Interactive room changes (%)	-	6.7	20.95

of classes due to inconsistencies among hard constraints. The amount of preference data for creation of acceptable timetables was also very limited. At Purdue University, where UniTime is used for course timetabling [4], input data contain information about preferred times and rooms for each class. Here we only have information about one acceptable time and, for 69 % classes, about one acceptable room. In addition, we were able to ask for preferred room equipment for each class. For rooms, it was possible to add information about preferred building based on the building assigned in the partial timetables. The original room in a partial timetable was treated as a strongly preferred room. We also needed additional input for time preferences. Our decision was to assign a strong preference for the selected time in the partial timetable. A weaker preference was assigned to all time slots during the week falling one period before and one period after the selected time. This is very important since it gives some advice to the system when the original selected time cannot be used. Since there are 16 time slots each day, starting at 7:30 am and ending at 8:45 pm, this makes it possible to distinguish between instructors demanding early and late hours and choose a closely matching time at least. In addition, we generally discouraged placement to very early and late times.

To conclude, the strong preference for selected times and rooms allowed keeping the partial timetables as much as possible. Other added preferences were generated to create an acceptable solution for both time and room. The standard criteria for minimizing student conflicts maintained quality with respect to student programs.

3 Evaluation and Conclusion

The generated timetables are made available in the IS MU[5]. We would like to compare the quality of three following timetables: the first timetable generated automatically, the timetable published after the first set of interactive changes [2], and the finalized timetable. After the first publication of the timetable, four rooms were added to the available resources. This certainly lead to significant changes which are also clear when exploring the number of interactive changes in the finalized timetable.

Results are presented for all three timetables in Table 1. These include information about the number of student conflicts between classes and the percentage of satisfied time and room preferences related to standard optimization criteria. In addition, we

[5] `http://is.muni.cz/rozvrh/?obdobi=5026&fakulta=1421&lang=en`

present information about the percentage of time and room assignments we were able to retain from the manually created timetables. The number of broken hard constraints during interactive timetabling, when the user can allow such inconsistencies (e.g., use too small rooms or rooms without required equipment), are also presented[6]. The last two lines of the table show the percentage of interactive changes that were made to the first published and the finalized timetable in comparison to the fully automated timetable.

Generated solutions were very well accepted by the central schedule manager. Even given the reduced number of rooms, it allowed high satisfaction of all requested criteria. The current semi-automated approach allows much better consideration of student conflicts, which were originally considered only on the level of partial departmental timetables. Importantly, the central schedule manager evaluated the decrease in her workload to be 30 %, which is a significant improvement especially given this was the first use of the system. Certainly the quality of the final automated timetable depends greatly on the quality of manually generated partial timetables. Our experience also indicates that a fully automated solution may not be acceptable, even in the future, due to administrative and political reasons within the Faculty of Arts. In the following semesters, we would like to allow departmental schedule deputies to enter and modify their input data directly in the application. However, this may be a slow transition as the acceptance of a complex automated system may not be easy.

We would like to point out that no changes were necessary to the constraint solver of the UniTime system and only a couple of minor changes were necessary in its interface to make the data input easier. The only extensions consisted of the preparation of scripts to load the data in a proper format and to minimize manual input by automatically generating some constraints. This automated constraint generation allowed detection of the course structure, preparation of initial preferences, adjustments to the desired room capacity for classes, etc.

In the future, we plan to continue with further application of the system at Masaryk University. We have already started to work on the course timetabling problem for the Faculty of Education, where there is an intent to have the system used by all departmental schedule deputies right from the start.

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[6] For the finalized timetable, this number includes 17 unassigned classes. Their assignment was not included by the schedule manager due to complex modeling of the course structure.