University Timetable Quality Optimization Using Multi-Objective Integer Programming

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Abstract Studying real-life data of a large Danish university, we present an Integer Programming model which can be utilized to perform the complete room allocation for a semester. A course at this university has traditionally been fixed to a certain time slot, which does not facilitate the best utilization of rooms. The presented model can be used to simulate the rescheduling of courses to other time slots, further enhancing room utilization. The utilizing of multi-objective methods allows for finding solutions with different characteristics in a structured way, facilitating end-users to take more enlightened decisions.

Keywords University Timetabling · Multi-Objective · Integer Programming · Quality Optimization · Mathematical Programming

1 Introduction

Timetable planners at universities today face many demands from various stakeholders: Management, professors and students. Here we will briefly present

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a practical case-study where it is attempted to apply Integer Programming (IP) models to solve a practical case at the Technical University of Denmark (DTU). IP has previously been applied to university timetabling in [1], [2], [3], [4] and others, however the scientific area is still dominated by heuristic approaches.

At DTU, the amount of teaching rooms/auditoriums, compared to the number of courses, is decreasing. Furthermore, it is a tradition at DTU to have fixed time slots for the courses offered. This is increasingly leading to problems, when planning which courses should be taught in which rooms.

There are only two time slots per day at DTU, 8-12 and 13-17. A simple way to avoid building more auditoriums would be an extra time slot, but evening teaching is very unpopular both for the students and the professors. Hence to increase the utilization of rooms, a new tiled time slot is considered starting at 10:00 and ending at 15:00 (including lunch break from 12:00 until 13:00). This idea has potential as a typically course section will contain 2 hours of lecturing and 2 hours of exercises. This leads to large demand for auditoriums at 8-10 and at 13-15 and a large demand for exercise rooms at 10-12 and at 13-15. Hence, the new tiled time slot may enable better utilization.

Planning with the new time slot, is however hard, because of the many conflicts between the courses. Furthermore professors are not too kind-hearted regarding changes. They would like to keep the fixed teaching time slots and also have the requested rooms. This task is difficult for the DTU management. By applying Mathematical Programming approaches a number of scenarios can be considered, and this can help the university management to decide the number of courses that are allowed to be moved, the allowed moves etc.

2 Preliminary Model

In the following we present an IP model which has been tested on real-life data, and which has shown to be fast to solve with a commercial MIP solver. In our view, IP models has many advantages: 1) They clearly define the problem in well-defined terms. 2) They separate the problem and the solution method. 3) They provide easy access to generics solvers which can quickly be applied once the model is build. Therefore we have chosen to handle the problem by an IP approach.

The developed model is multi-objective, so instead of constructing a single objective function with weighted terms, the model contains multiple objectives. The utilizing of multi-objective methods allows for finding solutions with different characteristics in a structured way, facilitating end-users to take more enlightened decisions. For instance, solutions can be plotted in a Pareto-front which illustrates the relationship among objectives. Only little research has been performed within multi-objective models for timetabling problems, even though most timetabling problems are multi-objective in nature.

The data has been provided by DTU and represents the actual planning done for a complete semester.

Definition of sets and parameters:

C – Set of courses
Q – Set of curricula
R – Set of rooms
R_c – Set of possible rooms for course $c \in C$
T – Set of time slots
T_c – Set of possible time slots for course $c \in C$
T_t^O – Set of overlapping time slots for time slot $t \in T$

r_c^{req} – The requested room for course $c \in C$
t_c^{req} – The requested time slot for course $c \in C$

Let variable $x_{c,r,t}$ be 1 if course $c \in C$ is planned in room $r \in R$ at time slot $t \in T$, and 0 otherwise.

$$\max \quad \text{obj}_{\text{roomReq}} = \sum_{c \in C, t \in T_c} x_{c, r_c^{\text{req}}, t}$$
$$\min \quad \text{obj}_{\text{reschedule}} = \sum_{c \in C, r \in R_c, t \in T_c \setminus \{t_c^{\text{req}}\}} x_{c,r,t}$$

s.t.

$$\sum_{r \in R_c, t \in T_c} x_{c,r,t} = 1 \qquad \forall c \in C \qquad (1)$$
$$\sum_{c \in C, \hat{t} \in T_t^O} x_{c,r,\hat{t}} \leq 1 \qquad \forall r \in R, t \in T \qquad (2)$$
$$\sum_{c \in q, r \in R_c, \hat{t} \in T_t^O} x_{c,r,\hat{t}} \leq 1 \qquad \forall q \in Q, t \in T \qquad (3)$$

$$x_{c,r,t} \in \{0,1\} \qquad \forall c \in C, r \in R_c, t \in T_c$$

The objectives are defined as $\text{obj}_{\text{roomReq}}$ and $\text{obj}_{\text{reschedule}}$. We want to maximize the number of room requests met by $\text{obj}_{\text{roomReq}}$ and we want to minimize the number of courses moved by $\text{obj}_{\text{reschedule}}$. Constraint (1) defines the course allocation constraint, which states that each course must be allocated a room and a time slot. The room double booking constraint is defined by (2), which ensures that at most one course can take place in a room at a given time. Constraint (3) ensures that two courses from the same curriculum are not planned in overlapping time slots.

The objective denotes the sum of room assignments that are planned in the room requested by the teacher. Note that this is a simplified model of the real world.

3 Preliminary Results

The pareto front is shown on figure 1. Problem data was provided for the fall semester 2017. Figure 1 also shows the total number of room request (grey line).

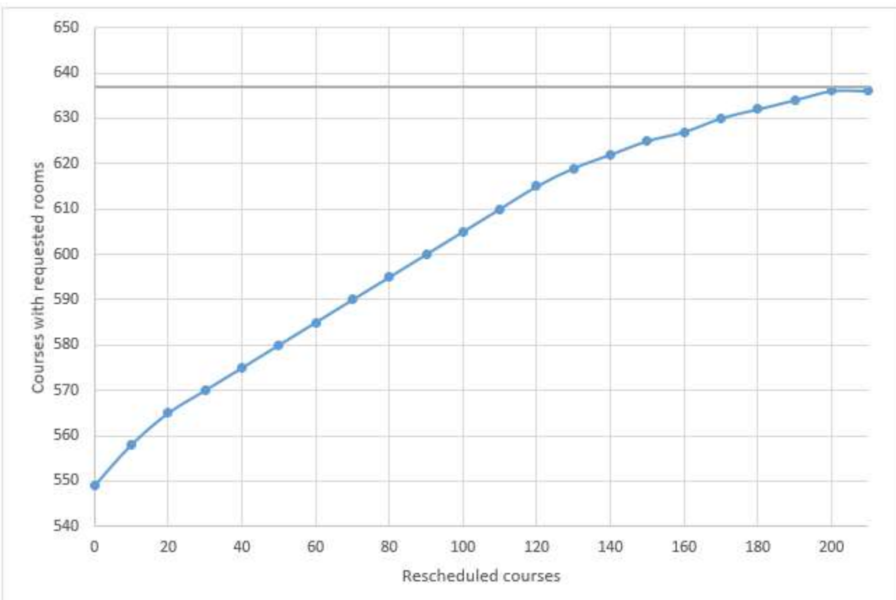

Fig. 1

4 Conclusion

DTU have provided problem data for the fall semester 2017. The model have been verified and the results are a quality increase of around 10% for room allocation alone. Considering the opening of the tiled time slots and allowing reschedule of courses to the tiled time slot; the expected results are a quality increase of around 20%.

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