Timetabling Problems at the TU Eindhoven

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Abstract. The students of the Industrial Design department at the TU Eindhoven are allowed to design part of their curriculum by selecting courses from a huge course pool. They do this by handing in ordered preference lists with their favorite courses for the forthcoming time period. Based on this information (and on many other constraints), the department then assigns courses to students. Until recently, the assignment was computed by human schedulers who used a quite straightforward greedy approach. In 2005, however, the number of students increased substantially, and as a consequence the greedy approach no longer yielded acceptable results.

This paper discusses the solution of this real-world timetabling problem. We present a complete mathematical formulation of it, and we explain all the constraints resulting from the situation in Eindhoven. We solve the problem using lexicographical optimization with four subproblems. For all four subproblems, an elegant integer linear programming model is given which easily can be put into CPLEX. Finally, we report on our computational experiments and results around the Eindhoven real-world data.

1 Introduction

In February 2005, outraged students of the Industrial Design department were protesting at the TU Eindhoven (The Netherlands). Uproar and revolt were in the air. What had happened? Here is the story. The academic year of the roughly 350 students of Industrial Design is split into a number of periods. In every period, every student must do a number of small *courses*. There is a pool of roughly 55 courses to choose from, and every student submits an ordered preference list with his/her 10 favorite courses to the department. Based on all the ordered preference lists, a *scheduler* at the department then assigns roughly four courses to every student. Until recently, the scheduler was a human decision-maker who essentially applied a hand-woven greedy assignment procedure.

In February 2005, the students were absolutely dissatisfied with the work of the human scheduler: many of them did not get the courses which they would have liked to get; many of them were assigned to courses which they really did not want to do; and more than 150 out of the 350 students received courses that were not listed on their preference list!

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The department of Industrial Design realized that they had a problem. They also realized that they did not know how to solve this problem. The number of students had increased substantially, and the timetabling problem had become much larger, much harder, and much more complex. Hence, the department contacted the local experts on the campus: us. They were hoping to find a somewhat better assignment through computer programs. They explained their problem to us (in a certain problem formulation No. 1), and we happily told them that we would be able to solve it: the problem (in formulation No. 1) could be modeled as a network flow problem, and hence is solvable in polynomial time. Unfortunately, it turned out that formulation No. 1 was not a complete formulation of the problem: they had forgotten to inform us about a number of additional restrictions that lead to a new, more difficult assignment problem (in formulation No. 2), which eventually turned out to be NP-hard.

This paper is a report on the course assignment problem of the Industrial Design department. We describe the assignment problem in its (incomplete) formulation No. 1 and in its (complete) formulation No. 2. We show that formulation No. 1 yields a tractable problem, whereas formulation No. 2 yields an intractable problem. Our main contribution is a careful case study of the complete problem formulation. We design an elegant integer linear programming model for it, with roughly 9000 variables and roughly 7000 constraints. Putting this ILP model into CPLEX yields excellent results within moderate computation times. We describe the ILP model in detail, and we report on our computational experiments with the real-world data of the Industrial Design department.

Structure of the paper. The rest of the paper is structured in the following way. In Section 2 we give a literature review of university and school timetabling. Section 3 contains a detailed description of the problem we solved for the department of Industrial Design. The problem is formulated as an integer linear program which is described in Section 4. Section 5 contains the computational results. Some conclusions are given in Section 6.

2 Literature Review

The literature contains a large number of variants of the timetabling problem. These variants differ from each other by the type of institution involved (university or high school) and by the type of constraints. The annotated bibliography of timetable construction by Schmidt and Ströhlein [22] lists many papers that appeared before 1980. Schaerf [21] gives a survey of the various formulations of timetabling problems and classifies the timetabling problem into the following three main classes: school timetabling, examination timetabling and course timetabling. Of course this classification is crude, and there are many real-world timetabling problems that fall in between two of these classes. For surveys of timetabling methods and applications see de Werra [11], Burke et al. [3], Carter and Laporte [8] and Burke and Petrovic [5].