Evaluation of the University Course Timetabling Problem with the Linear Numberings Method

Patrick De Causmaecker
Katholieke Universiteit Leuven
Campus Kortrijk
Computer Science and Information Technology
Etienne Sabbelaan 53, 8500 Kortrijk, Belgium
Patrick.DeCausmaeker@kuleuven-kortrijk.be

Peter Demeester and **Greet Vanden Berghe**
Katholieke Hogeschool Sint-Lieven
Departement Industrieel Ingenieur
Information Technology
Gebroeders Desmetstraat 1, 9000 Gent, Belgium
{Peter.Demeester,Greet.VandenBerghe}@kahosl.be

Introduction

The research reported in this abstract deals with the university course timetabling problem at the KaHo Sint-Lieven School of Engineering. At present we are able to automatically solve the problem taking only the hard constraints into account. Currently, we investigate the possibility of using the linear numberings method (Burke *et al.* 2001; De Causmaecker *et al.* 2005) to express and evaluate the soft constraints in the university course timetabling problem. This method has until now only been applied to employee timetabling.

University Course Timetabling

The university course timetabling problem is the process of assigning lectures, which are taught by lecturers and attended by students, into 'room-time' slots, taking into account hard and soft constraints. In the literature different reviews and problem descriptions with different kinds of constraints can be found (Burke & Petrovic 2002; Petrovic & Burke 2004; Schaerf 1999; McCollum 2006). We concentrate on the university course timetabling problem as it is perceived at the KaHo Sint-Lieven School of Engineering. The problem can be informally described as follows:

- each lecture has a pre-assigned lecturer/team of lecturers,
- each student group is assigned to a curriculum,
- and lectures need to be assigned to 'room - time' slots.

The following hard constraints hold:

HC1 Lecturers and students can only be in one place at the same time.

HC2 A room can hold at most one lecture at a time.

HC3 Class rooms have a limited capacity.

HC4 The number of class rooms is limited.

HC5 Feasible time slots are periods in weekdays that start after 8 am and end before 6 pm. Feasible slots range from 1 hour and 30 minutes up to 4 hours and 50 minutes. Due to the length variations, we have to deal with overlapping time slots.

HC6 The timetable period is one semester, which spans 12 weeks. Some of the lectures are organized every week; others are only organized a few times during the timetable period (e.g. 3, 4, 6 or 9 times).

The approach that we developed to solve the hard constrained problem is described in (Adriaen *et al.* 2006). Apart from the hard constraints we need to take soft constraints into consideration:

SC1 Lecturers express preferences for certain time slots.

SC2 Some student groups must have one day off per week.

SC3 Lectures should be scheduled in 2 or 3 consecutive time slots from a student point of view. Scheduling a single lecture on one of the teaching days is to be avoided.

SC4 Scheduling lectures in the last time slot of the day is to be avoided.

SC5 The number of lecturing hours per day should be spread evenly over the week for students.

SC6 Gaps between lectures are to be avoided.

We argue that the linear numberings method (Burke *et al.* 2001) can be used to express and evaluate the soft constraints in this university course timetabling problem.

Linear Numberings Method

A constraint in the linear numberings method is expressed as a 'numbering' which involves a template of numbers (see Table 1), a set of numbering constraints and their corresponding values. A numbering constraint is formulated as an equality. The left hand side is the condition that is checked against the value at the right hand side (rhs). When the condition is not satisfied, the constraint is violated and a cost will be generated. The left hand sides of the numbering constraints are grouped into 4 sets, each consisting of 2 members (minimum and maximum). The 4 sets are:

total which compares the minimum/maximum number of corresponding events against the value on the rhs.

pert which compares, for every number in the numbering, the (maximum/minimum) number of events against the value on the rhs.

consecutive which compares the (maximum/minimum) number of consecutive events against the value on the rhs.

between which compares the (maximum/minimum) gap between non-consecutive events against the rhs value.

Further details, examples, applications and a more formal description of the method can be found in (Burke *et al.* 2001; Vanden Berghe 2002; De Causmaecker *et al.* 2005).

Linear Numberings Method and University Course Timetabling

Until now the linear numberings method has only been applied to employee timetabling. Employee timetabling consists of assigning qualified personnel to time slots, such that the coverage in every time slot is fulfilled and that the personal preferences of the employees are taken into account. Typically resources are not part of the scheduling problem. In university course timetabling however, lecturers and students need to be assigned to 'room-time' slot combinations in such a way that none of the hard constraints is violated and that the soft constraints are taken into consideration as much as possible. We assign in this case the appropriate soft constraints to the lecturers (**SC1**, **SC4**) and student groups (**SC2**, **SC3**, **SC4**, **SC5**, **SC6**). If we draw the comparison with employee timetabling, the soft constraints can be considered as the work regulations of lecturers and student groups. The problem that needs to be solved can be reduced to an employee timetabling problem, where the employees are the student groups and the lecturers.

Numbering 1				
	T_1	T_2	T_3	T_4
D_1	U	U	U	0
D_2	U	U	U	0
D_3	U	U	U	0
D_4	U	U	U	0
D_5	U	U	U	0

Numbering 2				
	T_1	T_2	T_3	T_4
D_1	1	2	3	4
D_2	6	7	8	9
D_3	11	12	13	14
D_4	16	17	18	19
D_5	21	22	23	24

Table 1: *Numbering 1* allows to avoid lectures on the last time slot of the day. We assume that there are only 4 time slots per day. *Numbering 2* expresses that there should be at least two consecutive lectures for a particular student group. We assume for simplicity that there is no overlap.

Suppose we want to express soft constraint **SC4** in terms of the linear numbering method. The numbering corresponding to **SC4** (see Numbering 1 in Table 1) reveals that the constraint only addresses the last time slot of each day. The last time slot of each day gets a number and the other time slots get a *U*, which is short for *Undefined*. We decided to put the number 0 at every last time slot of the day. To express that no lectures are allowed on the last time slot of each day, we apply the following numbering constraint:

$$max\_total = 0$$

to this numbering. Table 2 presents a solution for a student group. The asterisks correspond with the lectures. The evaluation algorithm will now overlay Table 1 with Table 2 and count the number of lectures (asterisks) that coincide with a non-*U* number. It the case of this example, the number of non-*U* values counted equals 2.

To express constraint **SC3** in terms of the linear numberings method, we use the second numbering in Table 1. Within a day, the numbers are consecutive. The last time slot of a day should be at least 2 smaller than the first time slot of the day after. This avoids lectures being considered consecutive whenever they are assigned both to the last time slot of one day and to the first time slot of the next day. The corresponding numbering constraint is:

	T_1	T_2	T_3	T_4
D_1	*	*	*	-
D_2	-	-	*	*
D_3	*	-	*	-
D_4	*	*	-	-
D_5	*	*	*	*

Table 2: Example of a solution for a student group. Notice the violations of the SC4 constraint on day 2 and day 5.

$$min\_consecutive = 2.$$

The constraint expresses that a student group should have at least 2 consecutive lectures. Overlaying the numbering with Table 2 learns that there is one violation on day 3.

The other soft constraints (**SC1**, **SC2**, **SC5**, **SC6**) can be expressed and evaluated analogously.

Conclusion

By considering the soft constraints as the students' and lecturers' work regulations, we can apply the linear numberings method, that was originally developed for personnel timetabling, to evaluate different soft constraints of the university course timetabling problem.

References

Adriaen, M.; De Causmaecker, P.; Demeester, P.; and Vanden Berghe, G. 2006. Tackling the university timetabling problem with an aggregation approach. In *Proceedings of PATAT*, 330–335.

Burke, E. K., and Petrovic, S. 2002. Recent research directions in automated timetabling. *European Journal of Operational Research* 140(2):266–280.

Burke, E. K.; De Causmaecker, P.; Petrovic, S.; and Vanden Berghe, G. 2001. Fitness evaluation for nurse scheduling problems. In *Proceedings of Congress on Evolutionary Computation*, 1139–1146. Seoul: IEEE Press.

De Causmaecker, P.; Demeester, P.; Vanden Berghe, G.; and Verbeke, B. 2005. Evaluation of employee rosters with the extended linear numberings method. In *Proceedings of PlanSIG UK*, 125–133.

Vanden Berghe, G. 2002. *An Advanced Model and Novel Meta-Heuristic Solution Methods to Personnel Scheduling in Healthcare*. Ph.D. Dissertation, University of Gent.

McCollum, B. 2006. University timetabling: Bridging the gap between research and practice. In *Proceedings of PATAT*, 15–35.

Petrovic, S., and Burke, E. K. 2004. *Handbook of Scheduling: Algorithms, Models, and Performance Analysis*. CRC Press. chapter University Timetabling, 45–1 – 45–23.

Schaerf, A. 1999. A survey of automated timetabling. *Artificial Intelligence Review* 13(2):87–127.