Multi-objective aspects of the examination timetabling competition track

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Abstract We investigate multi-objective aspects of the new examination timetabling model introduced as part of the 2007 International Timetabling Competition. We propose one way to group together the objectives to represent the separate interests of the students and administration, and produce an example of an associated (Pareto) trade-off curve.

1 Introduction

The examination timetabling problem has been extensively studied, especially since the introduction of the Toronto benchmark dataset[1] by Carter et al (1996) (for a recent survey see Qu et al (2008)). This year, a significant extension to the set of realistic instances has been provided by the examination timetabling track (McCollum et al 2007) of the 2007 International Timetabling Competition[2] (McCollum et al 2008b). The new model used in the exam track instances is much more extensive than the Toronto ones in that it includes a wide variety of soft constraints designed to give timetables that match the requirements of the various individual parties. The associated penalties for violations naturally give rise to a multi-objective optimisation problem. Although exam timetabling has been previously treated as multi-objective (Burke et al 2001; Romero 1982), the much richer structure of the new formulation (McCollum et al 2007, 2008a) brings new opportunities and difficulties, and these form the topic of this abstract. For the purposes of keeping the competition manageable, the instances were presented as single-objective problems by means of giving weights for the various penalties. However, the purpose of this paper is to also encourage treatment of the instances as multi-objective problems. Also, although the weights expressing the trade-off between penalties are motivated by experience, they are still partially ad hoc, and so the effects of changing them is worthy of study.

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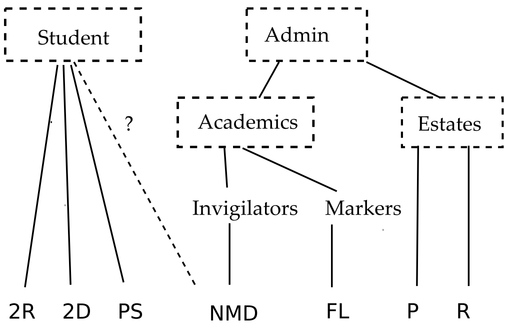
[1] ftp://ftp.mie.utoronto.ca/pub/carter/testprob/
[2] http://www.cs.qub.ac.uk/itc2007/

Fig. 1 Hierarchy of stakeholders associated with the seven base objectives.



2 Multi-Objective Aspects

The formulation of McCollum et al (2007) has 7 separate penalty costs in the objective function:

1. C^{2R}: "2-in-a-Row." For students having two events in consecutive periods of a day.
2. C^{2D}: "2-in-a-Day." For students having two events on the same day.
3. C^{2D}: "Period-Spread." For students having events within a period range specified a "period spread parameter."
4. C^{NMD}: "No-Mixed-Durations." For exams in a room and period being of more than one time duration.
5. C^{FL}: "Front-Load." For putting large exams at the end of the exam session.
6. C^{P}: "Period." For using deprecated time periods.
7. C^{R}: "Room." For using deprecated rooms.

The single-objective version of the competition is simply given by a linear sum using fixed weights $w^{2R}, \ldots, w^{R}$ for each of the penalty terms. This naturally gives a seven dimensional multi-objective problem, however, such high-dimensional problems are particularly difficult to solve and interpret. A standard response to this is to group together the objectives. Generally, the groups of objectives should represent the compromises between the various interested parties or "stakeholders". Here we give some candidates for such grouping, and that we believe make a reasonable representation of the key stakeholders. The initial grouping is based on four stakeholders:

- **Students**: the desire of student s is for a good individual timetable with good spread of exams, is represented by $w^{2R}C_s^{2R} + w^{2D}C_s^{2D} + w^{PS}C_s^{PS}$.
- **Invigilators**: their work is made harder when the exams have different durations, and so is associated with C^{NMD}
- **Markers**: exam markers want more time to mark exams with many students, and so are matched by the front load penalty C^{FL}.
- **Estates**: the management controls when rooms or periods are deprecated, and so is associated with C^{P} and C^{R}

The resulting four objective problem is possibly still too complex, hence, we further group together these stakeholders, giving the hierarchy of Figure 1. The simplest form is to reduce to students, and "the rest" which we collectively refer to as "admin". We believe this gives a reasonable way to explore the trade-off between the preferences of the students for well-spread out exams, and the preferences judged by the institution to be needed for smooth running of the exam session. (Although we do not use it here, the dashed line in Figure 1 is given because it is arguable that that

Table 1 Results on the small instance, giving the cost pairs resulting from a variety of weight pairs. The "gap" is the final gap reported by CPLEX on the linearized version – indicating the gap between upper and lower bounds.

W(Stud)	W(Admin)	C(Stud)	C(Admin)	Gap
10000	1	8	245	4.1
3	1	32	85	53.8
2	1	38	55	6.2
1	1	43	45	0
1	2	122	15	42.8
1	10000	225	5	99

NMD objective should also be included in the student interests, as mixing the duration of exams will lead to unwanted disturbance). Our aggregation of objectives differs significantly from the work of Burke et al (2001). For example, many of its soft constraints are hard constraints here. We are closer to that of Romero (1982) who splits into stakeholders: (central) administration, departments and students. Given the "(student,admin)" split then within each group the relative weights of the relevant objectives are given by the initial fixed weights:

$$C^{stud} = w^{2R}C^{2R} + w^{2D}C^{2D} + w^{PS}C^{PS} \tag{1}$$

$$C^{admin} = w^{NMD}C^{NMD} + w^{FL}C^{FL} + C^{P} + C^{R} \tag{2}$$

However, we should then minimise C^{stud}, C^{admin} in the bi-objective Pareto sense. Or, with the standard weighted sums approach, introduce new weights (w_{stud}, w_{admin}) and minimise

$$w_{stud}C^{stud} + w_{admin}C^{admin} \tag{3}$$

Notice this is equivalent to a rescaling of all the individual weights, and since the weights are part of the data rather than hard-coded into the formulation, it follows we do not require a modification to any single objective solver.

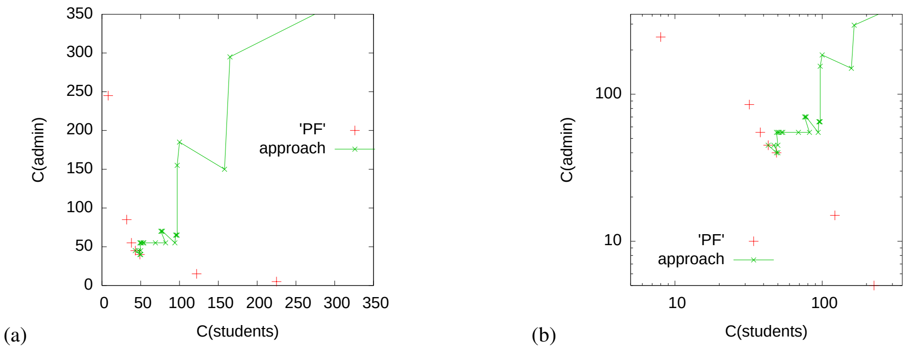
3 Initial Explorations

As a preliminary exploration of this bi-objective formulation, we used the integer programming formulation of McCollum et al (2008a), together with CPLEX 10 to solve the linearisations. However, the relatively unoptimized formulation meant that the full instances could not be solved. Hence, we created a new small instance: we took the instance "set4" and truncated it by hand. The truncation was random and ad hoc so we cannot claim realism for the resulting instance, but use it to illustrate possible behaviour.[3] Using CPLEX 10 we produced the results of Table 1. The runtimes were up to a week, but will hopefully be vastly improved: A challenge for solvers is to produce such data much more quickly.

The resulting (approximate) Pareto Front is given in Figure 2. Reassuringly, it seems to be a standard trade-off. (The log-scale plot is also given as it is relevant to deciding the trade-off between fractional changes to the objectives.) The 'approach' curve in Figure 2 is the progress on one run of the IP solver for the case $w_{stud} = w_{admin} = 1$ finishing at the optimal solution. As might be expected for a systematic solver, it seems to progress equally on both objectives: it would be interesting to see the equivalent approach for other solvers.

[3] The instance is available from `http://www.cs.nott.ac.uk/~ajp/TT/Exam/`

Fig. 2 The approximation, 'PF', to the Pareto Front obtained using various linear sums. Also, one particular path of 'approach' by the IP solver towards the Pareto Front, corresponding to the case of $w_{stud} = w_{admin} = 1$. (a) Linear axes, and (b) log-scale axes.



4 Conclusion

We give reasonable ways to group together the seven objectives of the examination timetabling track into those corresponding to the stakeholders. For the two objective case, this simply corresponds to considering the trade-off between the interests of students and administration. Future work will include improvement of the integer programming formulation, or other exact methods, so that we can aim to eventually fully solve the problems. We will also investigate whether the trade-off curves for the real instances are similar to those presented here for a small semi-artificial instance.

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