The Second International Timetabling Competition: Examination Timetabling Track

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Abstract

The 2nd International Timetabling Competition (ITC2007) is made up of three tracks; one on examination timetabling and two on course timetabling. This paper describes the examination timetabling track introduced as part of the competition. Both the model and the datasets are based on current real world instances introduced by EventMAP Limited. It is hoped that the interest generated as part of this competition will lead to the development, investigation and application of a host of novel and exciting techniques not previously trialed within this important real world search domain.

1   Introduction

Building on the success of the First International Timetabling Competition in 2002 [2], the second competition (ITC2007) is introduced with the overall aim of attracting researchers to develop and trial leading edge techniques within a competitive arena. It also aims to further generate interest in the research area by providing various formulations of the timetabling problems encountered within educational institutions based on 'real world' perspective. Particular emphasis is being placed on 'real world' scenarios with the objective of encouraging the production of techniques which have the potential to solve practical instances of the problem. The competition therefore has an important part to play in helping to bridge the current gap which exists between research and practice in this area.

To these ends three tracks are introduced along with a number of associated benchmark datasets. In this paper, we report on the Examination Timetabling Track (Track 1). The information presented here can be regarded as the official documentation for Track 1 and complements the content on the ITC-2007 web site at http://www.cs.qub.ac.uk/itc2007. Here, in addition to details on the three tracks, general information on the competition is provided in relation to background, motivation and rules.

The three tracks are examination timetabling (Exam TT), post enrolment course timetabling (PostEnroll CTT) and curriculum based course timetabling (Curriculum CTT). Although under the general 'umbrella' of educational timetabling, these three identified problem areas have significant differences which are discussed in detail at the Competition website. In addition, technical reports for all areas are available from the official website and can be found under each track. This paper details the examination track of the competition.

2 The Examination Timetabling Problem

As stated in the introduction, in order to tackle the main variations which exist within the practical area of educational timetabling, the current competition has been divided into three sections or tracks. From a research perspective this division is important in that it provides a framework to capture the main types of educational timetabling research currently taking place within the academic community.

Modeling the complexity of timetabling problems continue to represent important issues in the timetabling research area [1]. However these issues have not been widely discussed over the last ten years and there are still no universal complete models [3]. De Werra, Asratian and Durand [4] in 2002 presented a simple model and its possible extensions for class-teacher timetabling problems. The complexity of these problems was also studied, showing some variants of the problem as NP-complete. Further work to address these and related issues is needed to provide fundamental support for better understanding and development of exam timetabling research.

There is also research in the literature on building general timetabling languages and tools in an attempt to model real world instances of the problem. Tsang, Mills and Williams [5] developed a high level language to specify exam timetabling problems as constraint satisfaction problems. Di Gaspero and Schaerf [6] built a software tool called EASYLOCAL++ for easy implementation of local search algorithms on general timetabling problems. A general and reusable framework will further improve the current development and justify easy scientific comparisons.

The last ten years have seen a significant amount of research which addresses aspects from both theory and practice [3]. Meta-heuristics (i.e. Tabu Search [7, 8, 9], Simulated Annealing [10, 11, 12], Genetic Algorithms [13, 14], memetic algorithms [15], ant algorithms [16, 17], etc) represent

the most effective state-of-the-art approaches on standard benchmarks. There is also a large amount of work where hybridizations between meta-heuristics are studied. This includes the effective integration of early timetabling techniques such as graph heuristics [18, 19, 20, 21] and constraint based techniques [11, 22, 23]. Along with these main themes of research there are also a number of new trends including more effective design of neighborhood structures (i.e. variable neighborhood search [24, 25], etc). Flexibility of search is thus improved to tackle more complex problems with a wider range of constraints in exam timetabling. Some research motivated by the objective of raising the generality of timetabling approaches has also obtained promising results, hyper-heuristics [26] being one of the areas that is attracting much research attention [19, 20, 21, 24, 28, 29]. The last ten years of research on examination timetabling is discussed and reviewed in Qu et at [3].

The Examination Timetabling Problem addressed here introduces a practical formulation of the problem which, organisers believe, significantly adds to current research and provides a firm basis for future efforts in the area. In addition, it is hoped that the interest generated as part of this competition will lead to the development, investigation and application of a host of novel and exciting techniques not previously trialed within this important real world search domain. The problem model can be described as post enrollment. That is to say, students enrolled on particular courses which have associated exams are considered to be enrolled on or 'taking' those exams. Although other approaches to the problem are taken within institutions, this is by far the most common from a practical perspective as well as being the most widely reported model of the problem within the academic literature.

Recent Research has concentrated on a number of benchmark datasets introduced by Carter [27]. These benchmarks and the problems associated with them are discussed in more detail in Qu et al [3]. This particular track of the competition significantly adds to the research field by the introduction of a more 'real' model of the problem in terms of data, constraints and evaluation. All datasets used as part of this competition are taken from Institutions and have been anonomised for the purpose of competition use. At a future time, after the end of the competition, all 12 datasets will be released to the community.

3   The Problem Model

The examination timetabling problem model presented here extends the current model of the problem commonly worked upon. The fundamental problem involves timetabling exams into a number of periods within a defined examination session while satisfying a number of hard constraints. Like other areas of timetabling, a feasible solution is one in which all hard constraints are satisfied. The quality of the solution is measured in terms of soft constraints satisfaction.

New and additional Information is provided on constraints (hard and soft), resources and the examination session. For example, in terms of hard constraints, room numbers and sizes are provided. In addition, information on the structure, length and number of individual periods is also presented. In terms of soft constraints, much more practical information is provided in terms of how an organisation measures the overall quality of a solution.

4 Problem Description

The problem consists of the following:

- An examination session is made of a number of periods over a specified length of time i.e. examination session. Period lengths are provided.

- A set of exams that are to be scheduled into periods. Exam codes are not provided. As with all entities, competitors should assume sequential numbering beginning with 0.

- A set of students enrolled on individual exams. Each student is enrolled on a number of exams. Students enrolled on an exam are considered to 'take' that examination. For each exam, student numbers are provided.

- A set of rooms with individual capacities are provided.

- A number of Hard Constraints which must be satisfied

- A number of Soft Constraints which contribute to a penalty if they are violated.

- Details including a 'weighting' of particular soft constraints.

A feasible timetable is one in which all examinations have been assigned to a period and room and all the following hard constraints are satisfied:

- No student sits more than one examination at the same time;

- The capacity of individual rooms is not exceeded at any time throughout the examination session;

- Period Lengths are not violated;

- Satisfaction of period related hard constraints e.g. Exam_A after Exam_B;

- Satisfaction of room related hard constraints e.g. Exam_A must use Room 101.

The soft constraints can be outlined as follows;

- Two exams in a row
  The number of occurrences when students have to sit two exams in a row on the same day.

- Two exams in a day

The number of occurrences when students have to sit two exams on the same day. This constraint only becomes important when there are more than two examination periods in the one day. This is further explained later when the evaluation is described.

- Specified spread of examinations

The number of occurrences when students have to sit more than one exam in a time period specified by the institution. This is often used in an attempt to be as fair as possible to all students taking exams.

- Mixed duration of examinations within individual periods;

The number of occurrences of exams timetabled in rooms along with other exams of differing time duration.

- Larger examinations appearing later in the timetable

The number of 'large' exams appearing in the 'latter portion' of the timetable. Bothe 'large' and 'later portion' are user defined.

- Period related soft constraints

The number of times a period is used which has an associated penalty. This is multiplied by the actual penalty as different periods may have different associated weightings.

- Room related soft constraints

The number of times a room is used which has an associated penalty. This is multiplied by the actual penalty as different rooms may have different associated weightings.

These can effectively be split into two groups i.e. those which are resource specific and those which can have a global setting. Period related and room related constraints are resource specific i.e. settings can be established for each period and each room. This allows control of how resources would be used in constructing a solution. Values for these can be found after the introduction of periods and rooms in the datasets. All other soft constraints can be set relative to each other. These are referred to as global Settings.

Institutions may weight these soft constraints differently relative to one another in an attempt to produce a solution which is appropriate for their particular needs. This is known as building the 'Institutional Model' and is defined here as the Institutional Model Index. This is a relative weighting of the soft constraints which effectively provides a quality measure of the solution to be built. Within the datasets provided a number of variables are given with values.

It should be noted that when formulating a solution, it is common place for an institution to 'play' with various settings of soft constraints in an attempt to produce solutions which they judge satisfactory to all the end users. The details provided here significantly adds to the model of the problem commonly used within the research arena. Of course, how individuals judge that

particular solutions are 'satisfactory' is an interesting open research problem and is currently being tackled in a number of novel ways e.g. Asmuni et al [30]

5   The Evaluation Function

The quality of a timetable is reflected by two values: the number of hard constraint violations (*Distance to Feasibility*), and the number of soft constraint violations. In order to compare two solutions, first we will look at the *Distance to Feasibility*, and the solution with the lowest value for this will be the winner. If the two solutions are tied, we will then look at the number of soft constraint violations. The winner will be the solution that has the lowest value here.

The *Distance to Feasibility* is the total of the following numbers (all hard constraint counts as 1);

Conflicts: The number of occurrences of conflicting exams in the same period.

RoomOccupancy: The number of occurrences of more seating being required in any individual period than that available.

PeriodUtilisation: The number of occurrences when more time required in any individual period than that available.

PeriodRelated: The number of occurrences when ordering requirements not obeyed.

RoomRelated: The number of occurrences when room requirements not obeyed.

Although the nature of the practical problem described here usually leads to feasibility being found quite easily, this is not necessarily always the case in practice. It was felt essential that this measure was included here to allow solution evaluation to be consistent across all tracks of the competition and in order to establish an evaluation method that can be built upon for the future. After checking this, the solution will be classified based on the satisfaction of the soft constraints. On the website, in order to explain the calculation of the penalty a simple example is used allowing individual components of the overall penalty to be explained. This may be added to as competitors report issues which require clarification etc.. Trial datasets will also be introduced which will illustrate the calculations. The following provides a description of how each soft constraint is calculated.

Two Exams in a Row

This calculation considers the number of occurrences where two examinations are taken by students straight after one another, i.e. back to back. Once this has been established, the number of students are totaled and multiplied by the number provided in the 'two in a row' weighting within the 'Institutional Model Index'. Note that two exams in a row are not counted overnight e.g. if a

student has an exam the last period of one day and another the first period the next day, this does not count as two in a row.

Two Exams in a Day

In the case where there are three periods or more in a day, the number of occurrences of students having two exams in a day which are not directly adjacent, i.e. not back to back, are calculated. The total number is subsequently multiplied by the 'two in a day' weighting provided within the 'Institutional Model Index'. Therefore, two exams in a day are considered as those which are not adjacent i.e. they have a free period between them. This is done to ensure a particular exam placing within a solution does not contribute twice to the overall penalty. For example if Exam A and Exam B were in adjacent periods in the same day the penalty would be counted as part of the 'Two exams in a row penalty'. It should be noted that where the examination session contains days with 2 periods, this component of the penalty, although present for continuity, becomes superfluous. When this is the case this portion of the penalty will always be equal to zero.

Period Spread

This constraint allows an organisation to 'spread' an individual's examinations over a specified number of periods. This can be thought of as an extension of the two constraints previously described. Within the 'Institutional Model Index', a figure is provided relating to how many periods the solution should be 'optimised' over. The higher this figure, potentially the better the spread of examinations for individual students. In many institutions constructing solutions while changing this setting has led to timetables with which the Institution is much more satisfied.

If, for example, PERIODSPREAD within the Institutional Model Index is set at 7, for each exam we count all the occurrences of enrolled students who have to sit other exams afterwards but within 7 periods i.e. the desired period spread. This total is added to the overall penalty. It should be noted that the occurrences here will have contributed to the penalty calculated for the 'two exams in a row' and 'two exams in a day' penalties. Although, a single occurrence within the solution is effectively penalised twice, it is often necessary due to, as indicated above, many institutions requiring certain spreads to be minimised as an indication of solution quality.

Mixed Durations

This applies a penalty to a Room and Period (not Exam) where there are mixed durations. The intention here is to try and ensure that exams occur together which are of equal length. In calculating this portion of the penalty, the mixed duration component of the 'Institutional Model Index' is calculated by the number of violations detected.

Larger Exams towards the beginning of the examination session

It is desirable that examinations with the largest numbers of students are timetabled at the beginning of the examination session. In order to take account of this the FRONTLOAD expression is introduced. Within the 'Intuitional Model Index' the FRONTLOAD expression has three parameters e.g., 100, 30, 5. The first of these is the number of largest exams that are to be considered. Largest exams are specified by class size. The second parameter is the number of last periods to take into account which should be ideally avoided. The third parameter is the penalty or weighting that should be added each time the constraint is violated. This allows the Institution to attempt to ensure that larger exams occur earlier in the examination session.

Room Penalty

It is often the case that organisations want to keep certain room usage to a minimum. As with the 'Mixed Durations' component of the overall penalty, this part of the overall penalty should be calculated on a period by period basis. For each period, if a room used within the solution has an associated penalty, the penalty for that room for that period is calculated by multiplying the associated penalty by the number of times the room is used.

Period Penalty

It is often the case that organisations want to keep certain period usage to a minimum. As with the 'Mixed Durations' and the 'Room Penalty' components of the overall penalty, this part of the overall penalty should be calculated on a period by period basis. For each period, the penalty is calculated by multiplying the associated penalty by the number of times the exams timetabled within that period.

6   Conclusion and Discussion

Information is presented here on a formulation of the examination timetabling problem that is common to many institutions. This track introduces a practical formulation of the problem which, organisers believe, significantly adds to current research and provides a firm basis for future efforts in the area. In relation to this, the following points are made.

We do not consider minimising the number of periods as part of this formulation as, in our experience, educational institutions manage the process by using set times for the examination session. That is not to say of course that this is not a major issue in relation to planning examination sessions.

From experience we have found that, in general, gaining feasibility is not as important an issue as in some cases of course timetabling. That is not to say, of course, that competitors may have difficulty satisfying all the hard constraints within the competition time limit requirement. It is pointed out here that a competition time limit is essential to allow comparison of the techniques used. In practice, it can be argued that the need for such a time limit is not required as organisations are often happy to allow for longer running times in search for 'better' solutions. That being said, it is often the case that due to many changes having to be made during solution construction [1], an individual within an institution requires the ability to generate many solutions quickly after making various amendments to the underlying data. This style of solution construction will be well served by the techniques developed as part of this track. Please also see the associated Curriculum CTT technical report for a discussion of this issue.

Although a 'weighted sum' evaluation function is not ideal e.g. it may have adverse side effects for certain individual students, it is the chosen method here due to the ease of implementation for purposes of comparison. It is hoped that the interest generated by efforts here will lead to true multi-objective evaluation of potential solutions.

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