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Bullet TimeTabler Education: latest improvements towards a more efficient timetabling

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1 Introduction

In a time where the need to reduce costs has become part of day to day reality of all Educational Institutions, it is unthinkable to continue manually performing those tasks that can be automated and optimized – the creation of timetables.

The problem of creating timetables for Educational Institutions is typically defined as the scheduling of a set of lessons involving teachers and students, on a set of classrooms, in certain time slots, considering a number of constraints (Schaerf 1999; Bonutti et al. 2012).

Due to its combinatorial nature and associated complexity, the automatic creation of timetables for Educational Institutions is a problem studied by the scientific community since the decade of 1960, and by the Operational Research area in particular (Schaerf 1999; Murray et al. 2007). Over almost 50 years, hundreds of studies were published, with many different formulations of the problem and solving techniques.

In our previous work (Fernandes et al. 2013), a new automatic and optimized generator of timetables for Higher Education Institutions was presented – the product Bullet TimeTabler Education (BTTE), which is successfully used in more than

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half of the Portuguese Higher Education Schools, including the 10 major ones. In Fernandes et al. (2013), among other things, we describe a new model of the problem, the algorithms developed for solving it, and we also analyse twenty real cases of Portuguese institutions, users of BTTE.

This paper presents important updates to the aforementioned previous work (Fernandes et al. 2013) and the next research directions that were chosen by Bullet Solutions to improve the BTTE software.

2 Recent work and achievements

2.1 Information structure

As indicated in Fernandes et al. (2013), the data structure created for BTTE allows updating and manipulating all the existing data maps in real time. These data maps are crucial to the developed heuristics (both constructive and improvement), because they can, at any time, provide a clear view of the existing possibilities. They support the classification of the most urgent event in each moment, they help defining which is the best slot to place it, what is the impact of placing the event in other slots, which are the best events to swap or move, just to name a few possibilities.

A deep reformulation of this data structure was made. Tests and validations that proved to be redundant were eliminated, and the storage of the data maps was also improved. All these changes were made keeping the same quality control.

In the end, the preliminary tests showed that the speed performance of the system was improved by about 50%.

2.2 Algorithms

Besides the reformulation of the data structure, several improvements were made on the heuristics.

As showed in Fernandes et al. (2013), there are two different calculation phases in BTTE. First, a sequential heuristic is used to build an initial timetable from an empty timesheet (construction heuristics). Once the initial solution to the problem is found (the starting point), the optimization phase is initiated (improvement heuristics); based on appropriate methods, better solutions are progressively searched. In BTTE, the search for new solutions is based on neighbourhood structures.

In the construction phase, after the gains with the reformulation of the data structure were obtained, the focus of the research was directed to the implemented escape methods (crucial to achieve feasible solutions in very restricted problems). After analysing the critical points of the methods with the help of a performance profiling software, it was clear that almost all of the calculation effort was concentrated on the search for new possible allocations of the events previously placed. It was also possible to see that in the more complex cases, where some critical factors identified in Fernandes et al. (2013) are involved, the calculation time needed to complete a single move increased hugely. A new method to solve that type of cases was developed, with a performance about 5 times faster than the previous one (basically, for the very complex cases, where speed is fundamental, a new possible move is now obtained 5 times faster than before).

In the improvement phase, a different parametrisation of the heuristics was tested. In one of the attempts, by drastically reducing the number of neighbours created in each iteration of the normal phase (the phase where it is supposed to explore the solution space in a freer way), we found out that although the number of iterations where the solution was not improved was much higher than before (as expected), solutions of similar quality, in the end of the phase, were achieved 10 times faster.

2.3 Preliminary results

Besides the preliminary general tests made with some of the case studies presented in Fernandes et al. (2013), Cases 18 and 20 were tested live with the clients. In the two cases, this beta version of the heuristics needed respectively about 4 and 2 hours to calculate an initial solution (half of the time than before); moreover, the first big boost in the optimization phase ended about 5 times faster (about 4 hours for Case 18 and 24 hours for Case 20). These first live results, together with the other general tests performed, confirmed that very promising results were already achieved.

3 Future work

Currently, we are finishing the development of a logging framework that will be attached to the heuristics, which will provide access to crucial information. BTTE is used by dozens of heterogeneous clients and the potential of the information that will be collected, in real diverse scenarios, is huge, since it will allow much quicker adaptations in the future and the incorporation of additional intelligence in the critical points of the heuristics: urgency criterion of the events, escape methods, neighbourhood structures and the right parametrisation of all the variables involved.

Soon, we will be able to analyse new indicators, such as the type of moves that are more appropriated to restore the path of a feasible solution (escape methods), the number of iterations where a best solution is found in each of the phases and in each of the runs of the improvement heuristics, between many others. With the additional knowledge that will be obtained from this data, crossing with other information already known such as the critical factors that introduce complexity into the problem (Fernandes et al. 2013), we believe that it will be possible to place BTTE in an even higher level of quality.

We expect to present the results and conclusions of our current work in the Conference, not only the results obtained with the new heuristics after the conclusion of the tests, but also, at least, some preliminary analysis of the information collected with the logging framework, that we believe will provide precious information to future research directions.

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