A GRASP Algorithm for the University Timetabling Problem

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Abstract The university timetabling problem is one of great interest in the field of combinatorial optimization. Given a set of classes, students, teachers and rooms, the problem consists of assigning lectures or exams to a limited number of available timeslots and rooms, subject to a set of constraints mostly dependent on the particularities of the school. These constraints are classified as hard or soft. The hard constraints must be always satisfied. For example, a student cannot attend more than one class at the same timeslot. A solution for the timetabling problem is said to be feasible when it does not violate any hard constraint. The soft constraints are those which do not generate infeasibility, but reflect some preferences of teachers, students or even schools. For example, we can penalize a timetabling solution with large gaps between classes. The more soft constraints that are satisfied, the better the timetable. There are many timetabling formulations in the literature, but all of them can be grouped in three categories: school, university and exam scheduling. In this work, we develop an algorithm to solve the University Timetabling Problem in the context of the formulation adopted in the ITC-2007 competition [1]. The main advantage of adopting this formulation is that many authors have worked with it, making comparison of results from different researchers easier. We decided not use the ITC-2011 formulation [2], because our main focus is on university timetables. Many metaheuristics have been used to solve this problem, but none of them was considered as the best for this problem. Good results have been found with Simulated Annealing [3–5], Genetic Algorithm [6–8] and Tabu Search [9], among others. There are also some hybrid techniques combining several metaheuristics and exact methods, generally, each heuristic is consid-

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ered in various phases of these algorithms. The metaheuristic GRASP (Greedy Randomized Adaptive Search Procedure) is a technique that stands out in the combinatorial optimization field [10]. It has been applied to set covering problems, spanning tree, among others. Some researches of this algorithm have been found for timetabling problems, but all of them for school timetabling formulation [11,12]. This work implements a GRASP algorithm for generating timetables using the formulation of the ITC-2007. The algorithm has an initial phase where a greedy randomized solution is produced. The classes are ranked in order of difficulty (most difficult to easiest) and are selected one by one to enter the timetable. To choose a timeslot and room for a given class, a restricted list is constructed by counting how many violations of the soft constraints there are with each choice. When trying to insert a class into the timetable and a position does not exist, another class (or classes) previously scheduled is removed from the timetable to open a slot for the problem class. A feasible timeslot is selected randomly and all conflicting lectures allocated in that timeslot are removed from the timetable. If a conflicting lecture does not exist in timeslot, a non-conflicting lecture is selected. With this strategy, called explosion, we can generate feasible timetabling solutions for all competition instances. The random selection of lectures in explosion algorithm avoids lectures cycling. For the GRASP improvement phase, a local search is applied to the initial timetabling solution. The GRASP iteration (initial phase and improvement phase) is repeated several times generating different timetables. The final solution is the best of all generated timetables. Three different local search strategies are presented. The simplest uses a depth-first strategy. The neighbours are generated with two movements: MOVE and SWAP. The first reschedules a lecture in a empty timeslot. The second exchanges the timeslots of two lectures. The algorithm stops if n consecutive neighbours are generated and the objective function is not decreased. The second local search method is an adaptation of the breadth-first algorithm, where the neighborhood is not explored extensively: only k neighbours are generated and the best one is choosen to the next iteration. The neighbourhood generation and exploration are identical to the first method. The third local search is a depth-first strategy with a heuristic to reduce the violation of soft constraints. Also, a parallel version of the algorithm is presented. The implementation was tested with all the ITC-2007 instances. The results obtained are compared with the best solutions found in the Curriculum-Based Course Timetabling site [13]. Most instances are diffcult to find the optimal solution, but we could do this for two instances.

Keywords Timetabling · Metaheuristic · GRASP

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