Ant Algorithms for the Exam Timetabling Problem

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Abstract. Scheduling exams at universities can be formulated as a combinatorial optimization problem. Basically one has to schedule a certain number of exams in a given number of time periods so that a predetermined objective function is minimized. In particular, the objective function penalizes schedules where students have to write exams in consecutive periods or even in the same period. Ant colony approaches have been demonstrated to be a powerful solution approach for various combinatorial optimization problems. This paper presents two ant colony approaches for the exam timetabling problem, a Max–Min and an ANTCOL approach. Using the Toronto benchmark test cases from the literature, both algorithms arc compared to other timetabling heuristics. Finally, the Max–Min and ANTCOL algorithms are compared using the same set of test cases. In spite of some shortcomings, the ANTCOL approach turned out to be a worthwhile algorithm, among the best currently in use for examination timetabling.

1 Introduction

The exam timetabling problem faces the problem of scheduling exams within a limited number of available periods. Setting up a conflict-free timetable is not a trivial task due to limited resources like periods, examination rooms and teacher availability. The main objective is to balance out student workload and to distribute the exams evenly within the planning horizon. In particular, it should be avoided that a student has to write two exams in the same period. Such situations will be referred to as conflicts of order 0 in the sequel. Additionally, as few students as possible have to attend r exams within y consecutive periods. Such conflicts can either be totally forbidden by constraints or penalized in the objective function. For example, Carter et al. proposed in [14] a cost function that imposes penalties P_ω for a conflict of order ω, i.e. whenever one student has to write two exams scheduled within $\omega + 1$ consecutive periods. In the literature ω normally runs from 1 to 5 with $P_1 = 16, P_2 = 8, P_3 = 4, P_4 = 2, P_5 = 1$.

Solving practical exam timetabling problems requires that additional constraints have to be considered, e.g. some exams have to be written before other exams or some exams cannot be written within specific periods. References [8] and [13] give comprehensive lists of possible hard and soft constraints.

E.K. Burke and H. Rudová (Eds.): PATAT 2006, LNCS 3867, pp. 364–382, 2007.

The exam timetabling problem can be formulated as a graph coloring problem. Each node represents one exam. Undirected arcs connect two nodes if at least one student is enrolled in both corresponding exams. Weights on the arcs represent the number of student enrolled in both exams. The objective is to find a coloring where no adjacent nodes are marked with the same color or to minimize the weighted sum of the arcs that connect two nodes marked with the same color. The exam timetabling problem is a generalization of the graph coloring problem, as in the objective function also conflicts of higher orders are penalized.

A large number of papers presenting heuristic solution approaches to the exam timetabling problem have been published in recent years. Most of the approaches on exam timetabling are modified heuristics derived from graph coloring approaches or use local search methods. Additionally, hyper-heuristics, i.e. heuristics that choose heuristics, have been applied to the exam timetabling problem.

Carter et al. applied in [14] some well known graph coloring heuristics, i.e. saturation degree, largest degree, largest weighted degree, largest enrolment and color degree, which they combined with backtracking. These graph coloring heuristics have been integrated into various other approaches. Asmuni et al. [2] used fuzzy functions to find exams that arc difficult to schedule and those should be scheduled early when using graph coloring heuristics.

Di Gaspero aud Schearf [20] tested different variants of tabu search based techniques whose neighborhoods concerned those which contributed to the violations of hard or soft constraints. Di Gaspero [19] improved the approach by employing multiple neighborhoods. The first one considers only exams that contribute to the objective function and changes the period of a single exam. The second neighborhood exchanges the periods of two groups of exams at once. White and Xie [39] developed a tabu search approach. This approach was extended in [40] by employing long-term memory. Paquete and Stuetzle [30] developed a tabu search methodology for exam timetabling where ordered priorities were given for the constraints. The length of the tabu list was adaptively set by considering the number of violations in the solutions.

Merlot et al. [27] and Burke et al. [6] developed variants of simulated annealing approaches. While the first paper also uses simulated annealing in combination with constraint programming to generate the initial solution, the latter presents a great deluge algorithm. This approach was further studied in [10] and in [5]. Cote et al. [18] investigated a bi-objective evolutionary algorithm with the objectives of minimizing timetable length and spacing out conflicting exams.

As well as evolutionary algorithms, simulated annealing and tabu search, other local search techniques have been tested to solve exam timetabling problems. Abdullah et al. [1] developed a large neighborhood search based on the methodology of improvement graph construction. Ayob et al. [3] as well as Burke et al. [7] investigated variants of variable neighborhood search. The results of the latter approach were further improved by using a standard genetic algorithm to