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Solving the Examination Timetabling Problem Using a Two-Phase Heuristic: The case of Sokoine University of Agriculture

Egbert Mujuni[#1], Allen Mushi[#2]
[#1]Department of Mathematics, University of Dar es salaam
[1]emujuni@udsm.ac.tz
[#2]Department of Mathematics, University of Dar es salaam
[2]allen.mushi@gmail.com
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Abstract. Examination timetabling is an important operational problem in any academic institution. The problem involves assigning examinations and candidates to time periods and examination rooms while satisfying a set of specific constraints. An increased number of student enrolments, a wider variety of courses, and the growing flexibility of students' curricula have contributed to the growing challenge in preparing examination timetables. Since examination timetabling problems differ from one institution to another, in this paper we develop and investigate the impact of a two-phase heuristic that combines Graph-Colouring and Simulated Annealing at Sokoine University of Agriculture (SUA) in Tanzania. Computational results are presented which shows great improvement over the previous work on the same problem.

Keywords: Heuristics, Timetabling, Optimization, Graph Colouring, Simulated Annealing

1. Introduction

Examinations timetabling problem involves the assignment of examinations and candidates to time period and rooms while satisfying a set of specific constraints. This paper extends the work of Selemani et al. [14] in which a graph colouring based algorithm was designed and implemented to solve the examination timetabling problem at Sokoine University of Agriculture (SUA) using data for Semester I and II in the year 2011. The algorithm produced a collision-free examinations timetable. The results obtained showed that examinations for Semester I could be scheduled in 13 timeslots instead of the planned 30 slots. Thus, 17 timeslots could be saved. Similarly, 11 timeslots could be saved in Semester II. Unfortunately, the work of Selemani et al did not consider the importance of having gaps between examinations per each student. The aim of this work is to develop and implement an algorithm that produces a collision-free examination timetable in which large examinations are scheduled as early as possible and each candidate examinations are spread as much as possible within the planning horizon. We first give an overview of the examinations timetabling problem.

Timetabling is one of the most important administrative activities that take place at least once a year in all academic institutions. Timetabling can be classified into three groups, namely: School, university courses and university examinations timetabling. School timetabling is about scheduling of school classes in fixed rooms. University timetabling is concerned with determining which course should be assigned to which lecturer on which day and timeslot while satisfying a number of constraints. The examination timetabling problem consists of assigning examinations to periods and classrooms in such a way that all examinations are scheduled within given timeslots and a number of specific constraints are satisfied. Timetabling is hard, complex and time consuming task and is classified as NP-Hard [3, 9].

Formally, the examination timetabling problem can be defined as an assignment of a set of examinations $E = \{e_1, e_2, \dots, e_m\}$ into a limited number of ordered timeslots (time periods) $T = \{t_1, t_2, \dots, t_n\}$ and rooms of certain capacity in each timeslot $C = \{c_1, c_2, \dots, c_n\}$, subject to a set of constraints [11]. Constraints are usually divided into hard and soft. Hard constraints have to be satisfied in order to have a feasible timetable. Common hard constraints include: (i) exams which have common students cannot be scheduled into the same timeslot, and (ii) there must be enough seating capacity in the room for the number of students scheduled in it at any given timeslot. Soft constraints tend to be institution specific, and are given different priorities (weightings) in different institutions [11]. Soft constraints do not have to be satisfied but they are desired to be satisfied as much as possible.

Because of its importance, from both practical and theoretical point of view, the examination timetabling problem has attracted attention of researchers across the world from both Operations Research and Artificial Intelligence communities for many decades. The examination timetabling problem is known to be varying from one institution to another [9]. Unfortunately, the fact that it is NP-Hard implies that it is unlikely that the problem can be solved optimally in polynomial time. Thus, a large number of researchers have focused on finding heuristic algorithms to solve the problem. Below we present a brief survey of previous work on the problem.

A comprehensive survey can be found in [5] and [11]. Graph based heuristics were among the earliest approaches to be used for the timetabling problem. Welsh and Powell in [17] pointed out the connection between the timetabling and graph colouring problems. They presented a graph colouring heurist based on vertices ordering. Burke et al. in [2] presented graph colouring and room allocation algorithms for the university timetabling problem. A graph colouring algorithm is used to split the examination into non-conflicting clusters and the room allocation algorithm is used to place examinations into rooms. Recently, Sabar et al in [12] investigated a graph coloring constructive hyper-heuristic for solving examination timetabling problems. They utilized the hierarchical hybridizations of largest degree, saturation degree, largest colored degree and largest enrolment graph colouring heuristics to produce four ordered lists. For each list, the difficulty index of scheduling the first examination was calculated by considering its order in all lists to obtain a combined evaluation of its difficulty. The most difficult examination to schedule was scheduled first. To improve the effectiveness of timeslot selection, a roulette wheel selection mechanism was included in the algorithm to probabilistically select an appropriate timeslot for the chosen examination. They tested the proposed approach on the most widely used un-capacitated Carter benchmarks, and on the examination timetable dataset from the 2007 International Timetabling Competition. The graph coloring constructive hyper-heuristic produced good results and outperformed other approaches on some of the benchmark instances. Selemani et al. [14] designed and implemented a graph coloring based heuristic to solve the examinations timetabling problem at Sokoine University of Agriculture (SUA) in Tanzania. In average, the developed algorithm saved as much as 46.7% of timeslots in the dataset.

Simulated annealing, introduced by Kirkpatrick et al. [6], is a popular local search meta-heuristic used to solve optimization problems. The key feature of simulated annealing is that it provides a means to escape local optima by allowing hill-climbing moves (i.e., moves which worsen the objective function value) in hope of finding a global optimum. Simulated Annealing has been successfully applied to the examination timetabling problems (see, e.g., [3], [7], [11], [15]). A study by Mushi [10] investigated the use of simulated annealing in the course timetabling in the University of Dar es Salaam, Tanzania. The computational results indicated that Simulated Annealing and steepest descent combination performs better, faster and with much less effort compared to manually generated results.

In this paper, we present a two-phase hybrid heuristic algorithm which combines both the efficiencies of graph-colouring and Simulated Annealing algorithms. In the first phase we use a graph-colouring based heuristic to generate a feasible solution with minimum number of timeslots. This phase is implemented in such a way that those examinations with large number of students are scheduled first. The second phase uses simulated annealing heuristic to improve the quality of the solution by spreading the examinations evenly. A survey of Cowling et al [5] indicated that almost all students prefer to have at least a gap between exams. This constraint is usually called back-to-back constraint. The aim of the back-to-back constraint is to give the students enough revision time between examinations.

The remainder of the paper is organized as follows. We first present the Examinations Timetabling Problem at the Sokoine University of Agriculture (SUA), giving the main features of the problem. Then we give the general description of a two-phase heuristic. Lastly, we present a summary of results and conclusions.

2. Problem description

The examination session at SUA is fixed to 3 weeks, with 2 examination sessions per day. An examination week is made up of five days, from Monday to Friday. Thus, the total number of timeslots during the examination session is 30. Examinations are held in 59 rooms whose capacities range from 15 to 500. An examination with many students can be scheduled in more than one room. Similarly, a room can