Faculty of Computer Science and Information Technology

Improved Variable Neighbourhood Descent (VND) to Solve Universiti Malaysia Sarawak (UNIMAS) Course Timetabling Problem

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DECLARATION

I declare that the work in this thesis was carried out in accordance with the regulations of Universiti Malaysia Sarawak. Except where due acknowledgements have been made, the work is that of the author alone. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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ABSTRACT

Academic institutions face the timetabling problem every semester. The task of allocating lectures to limited timeslots and venues must fulfil certain constraints unique to each educational institution. This study investigated heuristic orderings and the variable neighbourhood descent approach to tackle the course timetabling problem at the Faculty of Computer Science and Information Technology (FCSIT), Universiti Malaysia Sarawak (UNIMAS) on the basis of the students. The objectives of the study were to formulate a mathematical model and improve a computational bounded heuristics-based solution to solve the course timetabling problem at the faculty. A two-stage heuristic algorithm is proposed. In stage 1, heuristic orderings were utilised to find a feasible solution using 31 timeslots instead of the 48 timeslots in the existing timetabling software. In stage 2, the variable neighbourhood descent approach with new neighbourhood structures was utilised to improve the quality of the solution. The improved algorithm was tested on real-world data instances (in semesters 1 and 2 of 2019/2020) at the FCSIT, UNIMAS. The results show that certain heuristic orderings (the largest degree or the combination of the largest degree and largest enrolment in descending order) are better than others in generating a feasible solution. In stage 2, the proposed algorithm with new neighbourhood structures managed to reduce the soft constraint violations for instances in semesters 1 and 2. Sensitivity analysis was performed on the proposed algorithm. The experimental results demonstrate the flexibility of the proposed algorithm in solving the university course timetabling problem (UCTTP) at the FCSIT.

Keywords: University course timetabling, optimisation, heuristic orderings, variable neighbourhood descent, perturbation

Penambahbaikkan Penurunan Pembolehubah Kejiranan Untuk Menyelesaikan Masalah Penjadualan Kursus Universiti Malaysia Sarawak (UNIMAS)

ABSTRAK

Institusi akademik berhadapan dengan masalah penjadualan pada setiap semester. Tugas memperuntukkan kuliah ke slot masa dan tempat yang terhad mesti memenuhi kekangan tertentu yang unik bagi setiap institusi pendidikan. Dalam kajian ini, kaedah penyusunan heuristik dan penurunan pembolehubah kejiranan dalam menangani masalah penjadualan kursus di Fakulti Sains Komputer dan Teknologi Maklumat (FSKTM), Universiti Malaysia Sarawak (UNIMAS) dengan berasaskan pelajar disiasat. Objektif kajian adalah untuk menghasilkan model matematik dan membangunkan satu kaedah heuristik dengan komputasi terhad untuk menyelesaikan masalah penjadualan kursus di fakulti. Heuristik dengan dua fasa telah dicadangkan. Pada fasa 1, penyusunan heuristik digunakan untuk mencari jadual waktu yang sah menggunakan 31 slot masa dan bukannya 48 slot masa seperti dalam perisian penjadualan yang sedia ada. Pada fasa 2, kaedah penurunan pembolehubah kejiranan dengan struktur kejiranan yang baru digunakan untuk meningkatkan kualiti jadual waktu. Algoritma yang dicadangkan diuji dengan menggunakan data sebenar iaitu semester 1 dan 2 tahun akademik 2019/2020 dari FSKTM, UNIMAS. Keputusan menunjukkan kaedah penyusunan heuristik (darjah terbesar dan kombinasi darjah terbesar dan pendaftaran terbesar) adalah lebih baik daripada yang lain dalam menjana jadual waktu yang sah. Pada fasa 2, struktur kejiranan yang baru berjaya meningkatkan kualiti jadual waktu untuk semester 1 dan 2. Analisis sensitiviti dilakukan pada algoritma yang dicadangkan. Keputusan eksperimen menunjukkan fleksibiliti algoritma yang dicadangkan dalam penyelesaian masalah penjadualan kursus universiti di FSKTM.

Kata kunci: *Penjadualan kursus universiti, pengoptimuman, penyusunan heuristik, penurunan pembolehubah kejiranan, gangguan*

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UNIMAS	Universiti Malaysia Sarawak
FCSIT	Faculty of Computer Science and Information Technology

CHAPTER 1

INTRODUCTION

1.1 Study Background

Educational timetabling is defined as the task of allocating events such as exams, subjects and courses to rooms and timeslots by fulfilling certain constraints (Tan et al., 2021; Thepphakorn & Pongcharoen, 2020; Tan et al., 2020; Assi et al., 2018). Timetabling is a challenging combinatorial optimisation problem in theory and practice (Schaerf, 1999). Universiti Malaysia Sarawak (UNIMAS) devotes significant resources to the development of a feasible and high-quality course schedule for each faculty. Efficient course allocation may result in the more effective use of valuable resources such as utility resources (Burke et al., 2005). For example, reducing the number of timeslots needed to generate a feasible solution. This saves valuable resources, such as electricity costs when lectures can be avoided to be conducted at night time. Therefore, it is crucial to find an optimal configuration for the variables defined to achieve specific objectives (Habashi et al., 2018).

The university course timetabling problem (UCTTP) involves allocating a set of courses to limited resources - namely lecturers, venues and timeslots - by fulfilling certain constraints (Goh et al., 2020; Goh et al., 2019; Erdeniz & Felfernig, 2018; Goh et al., 2017). The UCTTP can be divided into two different categories based on the problem settings and requirements, namely the curriculum-based course timetabling problem (CBCTTP) and the post-enrolment course timetabling problem (PECTTP). The UCTTP at UNIMAS is closely related to the CBCTTP. Constraints can be classified into two types, hard and soft. The fulfilment of hard constraints is mandatory in generating a feasible timetable. For example, a student cannot attend two lectures at the same time, while a lecturer cannot lecture on more

than one course simultaneously. Meanwhile, the fulfilment of soft constraints is optional but will determine the quality of the timetable generated. For example, students should not have only one lecture hour per day and lecturers should not have to lecture after five pm.

The UCTTP is known to be NP-hard (Wang et al., 2019; Song et al., 2018; Assi et al., 2018; Gunawan, Ng, & Poh, 2012); that is, the problem cannot be solved exactly in polynomial time as the growth of the problem size and its complexity are exponential (Babaei et al., 2015; Bardadym, 1996). Exact algorithms are guaranteed to provide optimal solutions but they are applicable to small-sized problems (Schaerf, 1999). As an alternative, heuristic algorithms are often utilised to provide relatively good solutions in an acceptable time (Gora et al., 2010).

To date, many studies have been conducted on the UCTTP, tackling either benchmark or real-world UCTTPs. For most real-world search problems, automatically generating high-quality solutions is a difficult challenge (Muklason et al., 2019). Benchmark UCTTP are usually oversimplified and meant for objective comparison of methodologies. Meanwhile, real-world UCTTP focus on the practicality of solution at academic institutions. Even real-world UCTTP vary between them in terms of requirements due to different policies, education systems and cultures. The objective is to find a feasible timetable with the fewest possible soft constraint violations. Furthermore, the UCTTP requirements differ across academic institutions as policies and regulations are unique to each institution. This study addresses the UCTTP at the Faculty of Computer Science and Information Technology (FCSIT), UNIMAS, using a real-world dataset. The performance of the improved variable neighbourhood descent (VND) is investigated. Its performance is compared against the existing timetable, which had been constructed using commercial timetabling software.

1.2 Problem Statement

This research focuses on a real-world course timetabling problem at Universiti Malaysia Sarawak. The issues addressed are as follows:

i. Pre-registration data practice

At UNIMAS, there is no practice of course pre-registration. Student course registration only takes place after the timetable has been generated. Therefore, the timetable generated cannot cater to all the students individually.

Student enrolment data is predicted by the program coordinators by gut feeling. There are uncertainties in preparing the student-course registration data. Eventually, the venue utilisation is low, especially since a large-capacity venue may be allocated but a low number of students register. Other than that, "critical courses" involving "graduating students" cannot be identified, creating drastic changes to the planned timetable. Critical courses refer to courses that must be registered by repeating students for them to graduate.

ii. Curriculum-based course timetabling

Curriculum-based course timetabling means that the timetable generated is based on the curriculum plan for each program. This causes the "repeaters", those who need to repeat the course/s they failed in the previous semester, to face a certain dilemma as they cannot attend both the repeated and current semester courses as these clash. The current timetable used by the FCSIT cannot cater to all the "repeater" students because each "repeater" is a unique case. For example, one student may need to repeat three courses from the previous semester, whereas another may only need to repeat one. In the worst case, a student may need to repeat courses from two or three previous semesters. The consequence may be that