



**Faculty of Information and Communication
Technology**

EXAM TIMETABLING USING GRAPH COLOURING APPROACH

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in fulfilment of the requirements for the degree of Master of Computer Science in
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DECLARATION

I hereby declare that work in this thesis is the result of my own research except as cited in the references. The thesis has not accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature :

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Date : June 2010

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LIST OF ABBREVIATIONS

FOSEE	Foundation Studies and Extension Education
MMU	Multimedia University
CDP	Centre for Diploma
ERU	Examinations and Records Unit
PATAT	Practice and Theory of Automated Timetabling
AI	Artificial Intelligent
TSP	Travelling Salesperson Problem
MPL	Mathematical Programming Language
ITS	IT Services Division

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ABSTRACT

Nowadays, many methods exist for the scheduling problem but it only perform well in particular isolated environments and cannot cope with the changing requirements of large educational institutions. At this time, exam timetabling at Foundation Studies and Extension Education (FOSEE), MMU has been departmentally led and the construction of the timetables is done manually. The purpose of this research is to investigate the current exam timetable system in order to understand the current processes and problems involved during preparing the timetables and to propose a cluster heuristic and graph colouring heuristic approach to solve exam timetabling problem in FOSEE, MMU. Semi-structured interview and literature review are the method that used for data gathering. Semi-structured interview help in collecting data and information about the current system and the problem faces by the user. While literature review help in search and analyze the best approach that can help to solve the problem in the exam timetable including the cluster heuristic, sequential heuristic, cased-based approach, meta-heuristic, integer programming approach, knowledge base approach and graph colouring. This study presents a solution method for exam timetable problem in FOSEE, MMU. The method of solution is a heuristic approach that include graph colouring, cluster heuristic and sequential heuristic.

ABSTRAK

Kini, terdapat pelbagai teknik untuk menyelesaikan masalah penjadualan tetapi hanya sesuai untuk persekitaran tertentu dan tidak dapat menyelesaikan perubahan mengikut keperluan dalam institusi pendidikan. Penjadualan peperiksaan di Jabatan FOSEE, MMU dilakukan secara manual. Tujuan kajian ini dilaksanakan adalah untuk memahami proses-proses dan permasalahan yang terlibat dalam penyusunan jadual peperiksaan dan mencadangkan teknik-teknik *cluster heuristic* dan *graph colouring* untuk menyelesaikan masalah penjadualan peperiksaan di FOSEE, MMU. Untuk tujuan pengumpulan data atau maklumat, kaedah wawancara dan ulasan dokumen telah digunakan. Kaedah wawancara membantu dari segi pengumpulan data dan maklumat mengenai system yang ada dan permasalahan yang dihadapi oleh pengguna. Sementara ulasan dokumen membantu dalam pencarian dan menganalisa pendekatan terbaik yang dapat membantu untuk menyelesaikan masalah dalam penjadualan peperiksaan termasuk *cluster heuristic*, *sequential heuristic*, *cased-based approach*, *meta-heuristic*, *integer programming approach*, *knowledge base approach* and *graph colouring*. Kertas kajian ini mengkaji dan meneliti suatu kaedah penyelesaian bagi masalah penjadualan peperiksaan di Jabatan FOSEE, MMU. Kaedah penyelesaian adalah pendekatan heuristik yang meliputi pewarnaan graf, *cluster heuristic* dan *sequential heuristic*.

CHAPTER 1

INTRODUCTION

1.1. Background of Study

Timetabling is a very large field covering many different types of problems which have their own unique characteristics. Timetable refers to an organized list that provides information about a series of arranged events in a specific location and duration. Normally, timetable is designed or set out in a tabular form using room-time slot matrix information. According to Wren (2006), a timetable shows when a particular events are take place and it does not necessarily imply the allocation of resources. However, in reality it is important to know whether the resources available are sufficient or not for the given event to take place at a particular time.

The development of a timetable involves continuous and dynamic processes because it is not fixed and needs to be changed based on the situation or constraints. Most of the timetable developments are NP-hard problem, which means it cannot be solved in polynomial time using deterministic algorithm. Every time we run a problem, it will produce a different answer. When the model expands in terms of size, the finding of an optimum solution gets more difficult. Timetabling problems arise in various forms, including transportation timetabling or vehicle routing, nurse scheduling, sports timetabling and educational timetabling. Each timetabling problem has its own functions,

methodologies, rules, requirements, constraints and presented in different form. Timetable for transportation refers to bus timetable, airline timetable, train timetable, etc. It provides a list of time of when a transport will arrive or depart during specific times and routes. It is based on depot, terminal station and the joint of main line with the branch lines of depot. It will define where and when the transport or vehicle should be. For example the KL Monorail timetable shows the monorail movement from one station to another station using a specific time, depot and route.

In education, the three most common academic timetabling problems are school timetable, university timetable and exam timetable. University timetables are more complex compared to school timetables which have equal time slot and it is weekly repeated during a semester. Time slot for university timetable is not equal in length, some subjects are taught every week in weekdays, some of them are only taught during weekends, others are only taught in first seven weeks in the semester, etc. At the end of each semester or trimester, most educational institution must prepare a set of examination schedules for their students. Normally, a timetable that has been used previously will be recycled and used again. Some minor adjustments may need to be made and this can be done manually so that the new exam timetable is acceptable.

Exam timetabling is the sub class of timetabling problem which its events take place in the university. Exam timetabling refers to a process of assigning exam entities to particular slots and rooms in the timetable. Students are required to seat for one exam in the specific room during a specific time slot. Exam timetabling is one of NP-hard problem; therefore creating an exam timetable is difficult to be done manually due to the complexity of the problem. The complexity of the problem arises due to some reasons such as dual academic

calendar, increasing student enrolments, limitations of resources, etc. Constraints involved in this problem can be divided into two categories which are hard constraints and soft constraints.

The exam timetabling problem is similar to university timetabling problem and both of them use time as the basic for scheduling. Most academic institutions face the problem of scheduling both university timetabling and exams timetabling for every semester or trimester. The problem becomes more complex due to a large number of students, flexible course structures and exams, rooms and invigilator constraints.

1.2. Problem Statements

Nowadays, many algorithms or approaches exist for the scheduling problem but they only perform well in particular isolated environments and cannot cope with the changing requirements of large educational institutions. Exam timetabling problems are dynamic problems or NP-hard problems but most of the approaches that have been applied to solve these problems are still focusing on static processes, which use deterministic algorithm. With static processes, if conflicts such as clashing, overlapping timetable or adding new constraints occur, the solution may be rescheduling the original timetable from scratch or revamp it, which is difficult and time-consuming.

Starting from Jun 2009/2010 session, Multimedia University (MMU) has changed their academic calendar to dual calendar. Faculty and Centre for Diploma (CDP) uses the same academic calendars while Foundation Studies and Extension Education (FOSEE) uses a different academic calendar. At the end of every trimester, Examinations and Records Unit

(ERU) staffs need to prepare exam scheduling for faculties, CDP and FOSEE. With dual trimester system, ERU staffs need to prepare six exam scheduling per year and system analyst will generate all the timetables without checking either the students have a gap between two exams that a student has to sit, empty resources for each slot per exam, invigilator constraints, etc. Therefore, a suitable approach should be applied in the exam timetable so that it can cater this problem systematically and effectively.

Currently, exam timetabling at FOSEE, MMU is departmentally led and the construction of the exam timetable is done using simple algorithms, which will perform exhaustive search due to the complexity of the problem. The main objective of this exam timetable is to guarantee that all exams are scheduled and students can sit for all the exams that they are required to do.

The current system at FOSEE, MMU only considers the hard constraints and ignores the soft constraints. For example, if the duration for the exam is seven days, the system will make sure the entire exam involve will be spread out within that duration without checking the resources allocation and student constraints. There are no standards for solution qualities that measure either the exam timetable is feasible or not. The system analyst just makes sure that there is no clashing between subjects and students can be fit in the specific room. Exam timetables should have a standard solution quality so that if the person in charge resigns or change, the new person in-charge has a benchmark to measure the quality of exam timetable.

1.3. Research Questions

The following are the research questions that lead to the forming of this research:

- a. What are the problems or issues faced by the user that lead to the implementation of new approach for exam timetabling?
- b. How does the heuristic approaches help in the exam timetabling problem in FOSEE, MMU?
- c. How effective the heuristic approach is compared to the current approach?

1.4. Research Objective

This study is concerned with exams timetabling problems in FOSEE, MMU. A real exam timetabling problem has various constraints specific to the requirement of an institution.

The objectives of this study are:-

- a. To investigate the exam timetable in order to understand the current processes and problems involved during preparing the timetables
- b. To propose a cluster heuristic and graph colouring heuristic approach to solve exam timetabling problem in FOSEE, MMU
- c. To analyze current exam timetables and suggested exam timetables

1.5. Scope of Study

There is a lot of timetabling problems from various areas, such as course, examination, transport, workforce, sport timetabling, etc. This study will concentrate on exam timetable in one of the centre in MMU, which is FOSEE. The data that will be used in the study will be collected from ERU and FOSEE administrator. ERU will provide data such as room availability, room capacities, duration of examination, etc. While FOSEE administrator will provide data such as subjects offered for exam, number of students that will seat for the exam, re-sit subjects, special subjects and etc. This study will focus on the exam timetable using graph colouring heuristic to minimize the resources used and exam duration.

1.6. Conclusion

This chapter gives a brief introduction on the project and a conceptual overview of the project. The problem statement of the project has been identified. The objectives of the project have been established with their scopes and limitations specified.

CHAPTER 2

LITERATURE REVIEW

2.1. Introduction

This chapter describes and discusses the techniques used in producing an examination timetable, especially at university level. Most of the research papers produced by researchers can only be used in their universities due to the needs, requirements and constraints. This is the actual problem faced by researchers.

2.2. Timetabling Problem

Many contributions related to the timetable or scheduling problem have appeared in the last 30 years and it will probably continue with the same rate due to the fact that timetable problems are often over-constrained, dynamic and their optimization criteria are hard to define. Timetable is one of NP-hard problem; therefore creating a timetable cannot be done by using hand or manually due to the complexity of the problem. A large amount of timetable researches have been presented in the series of international conferences on Practice and Theory of Automated Timetabling (PATAT) since 1995. Artificial Intelligent (AI) research community has developed a variety of approaches for solving timetabling and scheduling problem.

These approaches are divided into four types; sequential method, cluster method, constraint-based approach and meta-heuristic methods. Most of the existing timetabling systems focus on the static part of the timetabling problem and generate a near optimal solution. Moreover, the required modification or changes are usually done manually, which is difficult and time consuming.

University timetabling is a sub class of timetable that will ensure each subject offered will has students, lecturers and the room to be used. Bardadym (1996) classifies university timetabling into five groups.

- i. Faculty timetabling : assign qualified teachers to courses
- ii. Class-teacher timetabling : assign courses with the smallest timetabling unit being a class of students
- iii. Course timetabling : assign courses with the smallest scheduling unit being an individual student
- iv. Exam timetabling : assign exams to students such that students do not have two exams at the same moment
- v. Classroom assignment : after assigning classes to teachers, assign these class-teacher couples to classrooms

School and universities timetabling seem to be similar but they are different since a school has an equal time slot per week with very similar class sizes for all their courses and the same groups of students are associated with a specific set of courses. University courses have a more complex time slot with different lengths, class sizes (depends on student enrolment) and student's freedom (to select which courses to register). University course

timetabling and exam timetabling also differ because for university course timetabling, students can have the option of choosing another course but students cannot choose to take one exam over another exam.

2.3. Examination Timetable Problem Description

Exam timetabling is a subset of university timetabling which focuses on assigning a given number of exams to a time slot in a specific period of time and assign venues and invigilators to each exam based on certain constraints.

According to Schaerf (1999), exam timetabling problem has the following characteristics which differs it from the university timetabling problem:

1. There is only one exam for each subject.
2. The conflict condition is generally strict. In fact, we can accept that a student is forced to skip a lecture due to overlapping, but a student cannot skip an exam.
3. There are different types of constraints, e.g. at most one exam per day for each student and not too many consecutive exams for each student.
4. The number of periods may vary, in contrast to course timetabling
5. There can be more than one exam per room

In real exam timetabling problem, each exam needs an allocation of resources such as room and invigilators. Constraints in scheduling are concerned about resources, getting sufficient room for each exam, availability of resources and exam ordering.

The constraints on the problem can be divided into two categories which are hard constraints and soft constraints. Hard constraints are unacceptable problems which cannot occur at any percentage in order for the timetable to be considered as feasible. Burke et al. (1996) have carried out a survey on differences between hard and soft constraints among British universities.

According to the survey by Burke et al (1996), the most common hard constraints can be summarized as follows:

1. Every exam must be scheduled in exactly one time slot
2. Every exam must be assigned to a room(s) of sufficient size and assigned an invigilator(s)
3. No student must be scheduled to be in two different exams at the same time
4. There must be enough seats in each period for all exams scheduled
5. Certain exams must be scheduled into specific time slots or rooms
6. Certain exams must take place simultaneously

Normally, exam timetable will satisfy all hard constraints but the problem is how to measure that it is a good timetable. Thus, soft constraints will be used as the measurement which will evaluate either the timetable is good and practical or not. Soft constraints can be considered as preferences which will fulfil some of the user requirements to maximize the perfection of the timetable. In general, not all soft constraints can be satisfied.

According to the survey by Burke et al. (1996), soft constraints are often encountered, which include the following:

1. Exams for each student should be spread as far apart as possible
2. A student should not be required to take x exams in y periods
3. Time windows for certain exams
4. No more than x exams taking place simultaneously
5. No more than y students scheduled to sit exams at any one time
6. Exams should not be split across rooms
7. No more than one exam in a room at a time
8. Teacher or student preferences
9. Distance between rooms holding a given exam should be minimized (when the exam is split across two or more rooms)
10. The total number of periods should be minimized

Hard constraints and soft constraints are very subjective to define and it depends on the requirements of the universities. In some cases, constraint on room availability is unnecessary because that university have a large amount of rooms that can be used for exam. The constraints such as some exams must occur before other exams may not be relevant in some universities due to all exams have the same level and not a pre-requisite exam. According to Burke et al. (1996), for some exam timetabling problems, it is difficult to find a feasible solution at all. Whereas for other problems, there is a large number of feasible solutions and the focus of the problem solving are very much directed to the minimizations of soft constraint violations.