Examination Scheduling System Based on Quadratic Assignment

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ABSTRACT

Examination scheduling system is an important and one of the recurring administrative activities in almost all educational institutions. This system helps in arranging examination for student which determines when, where and how exanimation is to be conducted. Creating good examination timetable system that will satisfy students, lecturers and the institution management is a very difficult task due to the limited resources. This limitation makes exanimation scheduling very difficult to handle. This research is to create a Decision Support System that ensures the institution management, lecturers and student are well satisfied, and all institutional resources are fully utilized. Quadratic Assignment Problem (QAP) model was modified to reduce the level of conflict at each level of assignment and a hyper-heuristic to improve the assignment of resources. The proposed framework is shown to be a general examination scheduling problem because it does not require any prior information of the examination.

KEYWORDS

Decision support System, Quadratic Assignment Problem, Examination, Timetabling and scheduling

1. INTRODUCTION

Examination scheduling is a largely studied class of timetabling problem concerning the scheduling for testing student's performance after several meetings with their lecturers within a spefied period of time. A good examination timetable ensures that both student, lecturers and the school management are satisfied with the examination arrangement, making sure that all examination are scheduled within the stipulated time frame and both hard and soft constraint are well satisfied.

For many decades now, educational institutions have adopted computer-based systems to support a wide range of administrative functions such as course registration, student record management, courses and examination timetabling, personnel and financial management [1].

Timetabling problem in educational institutions is categorized in three groups: university examination, university course, and school timetabling. University examination timetabling defines the exact day, time slot, and room that each exam is held. In other words, which exam is scheduled on which day, the time slot, and in which building, floor, and room it is held are determined [2].

Setting up a conflict-free examination timetable poses a difficult challenge due to limited resources like periods and examination rooms. The main objective in the examination timetabling problem is no student takes more than one examination at any time period. This conflict can be regarded as a hard constraint and must be eliminated.

Many universities in Malaysia such as Universiti Sultan Zainal Abidin (UniSZA) run a cross-faculty courses and centralized examination process which greatly increases the difficulty in scheduling both the courses and examination timetables. In view of this, important to create an automated examination timetable scheduler using a mathematical model which will serve a base-model to create a Decision Support System ensuring the following constraints are satisfied:

- No student sits for more than one examination at the same time.
- No student should take more than one course in within a day.
- Achieve full capacity utilization of building facilities and ensure capacity of individual rooms is not exceeded at any time throughout the examination session.
- More than one courses can be conducted in the same room
- Duration of examination period are not exceeded.
- Lecturers are considered when assigning invigilating sessions to them.
- One of the invigilators is the lecturer who teaches the subject

2. PROBLEM STATEMENT

An improper examination timetable may result in students' poor performance as it may not let them enough preparation between two sequential exams. In addition, there are many exams to be scheduled, large number of students who have taken different courses, the limited number of rooms or exam halls are available, and some constraints such as no conflict in a single student's exams make it very difficult to schedule experimentally. The scheduling problem created by these set of circumstances clearly poses an interesting intellectual challenge. This study explores this challenge and proposes solution to this problem.

2.1 Related Theories

Examination timetabling is a well-researched and important educational timetabling problem [3]. It has been studied many times in other institutions since the mid-1960s. Although there are some novel research that focused on the modeling and formulation of Examination Timetabling Problem (ETP), a large number of researchers are interested in the applications of heuristics to solve the problem.

The table below in Table 2.1 provides related work done by different authors using Algorithm

Table 2.1 Related works using Optimization Algorithms

No	Author/Date	Algorithm
1	Desroches, Larporte, and Rousseau (1978) and White and Chan (1979)[4][9]	Travelling Salesman problem (TSP)
2	Aldy Gunawan 2008[5]	Hybrid
3	Mohd Zaki Bin Mohd Salikon 2005[6]	Genetic
4	Nelishia Pillay 2010[7]	Hyper-Heuristic
5	Nasser R. Sabar, Masri Ayob Rong Qu, Graham Kendall 2011[8]	Graph Coloring Heuristic

The earlier studies by [4][9]adopt the Travelling Salesman problem (TSP) approach with the use of list generation to eliminate the conflicts of when one or more students are assigned to sit for two or more papers in the same session. These methods do not consider more complex conflicts.

A related work by [8] investigated a new graph coloring constructive hyper-heuristic for solving examination timetabling problems using hierarchical hybridizations of four low level graph coloring heuristics. The solution lists all examinations by the level of difficulty of assignment and ensures the most difficult exam to be scheduled is scheduled first. This method was considered simple and yet efficient approach but suffers setbacks in handling higher level conflicts in examination scheduling. Graph coloring has the limitation which neglects hard constraints such as students cannot take two examinations consecutively by formulating the basic examination timetabling problem as a Quadratic Assignment Problem [5]. Aldy model assumes that the number of examinations is equal to the number of time periods and a hybrid algorithm based on a combination of GRASP (The Greedy Randomized Adaptive Search Procedure) and SA-TS (Simulated Annealing and Tabu Search) was introduced to get an optimal solution. This solution appears to be an efficient heuristic algorithm for solving examination scheduling problem for its ability to obtain the optimal or the best known solutions within reasonable computation time. One of the major limitations of this solution is its inability to handle a very large size problem and has not really been applied to real world problem. Table 2.2 below provides related works done by different authors using mathematical model.

In 2001, Dimopoulou and Miliotis tackled examination scheduling problem such as restricted availability of classrooms and the increased flexibility of the student's choices of courses by implementing an integer programming (IP) model that assigns courses to time slots and rooms. The quality of the schedule produced depends on the relative position of the courses assigned to the available time periods, a condition that the IP model attempts to satisfy by constructing groups of courses that are assigned to groups of time periods. The system was adopted by Athens University of Economics and Business for use and with success. The approach is said to be theoretical development and do not analyze an actual computer-based implementation.

Sagir and Ozturk, 2010 decided to address the issue of assigning invigilators to examination who may be faculty lecturers or graduate students in educational institutions with a computer based system. They adopted Analytic Network Process model for estimating exam and objective weights.

Table 2.2 Related works using Mathematical Models

Bil.	Authors date	Title	Model	Issues addressed
1	Dimopoulou and Miliotis 2001[10]	Implementation of a university course and examination time-tabling system.	Integer Programming	• Restricted availability of classrooms • Increased flexibility of the student's choices of courses
2	Alireza Rashidi Komijan and Mehrdad Nouri Koupaei 2012[2]	A new binary model for university examination timetabling: a case study	Binary Model	• Multi-offered courses in a single semester • Room sharing for two simultaneous exams
3	Sagir and Ozturk, 2010[11]	Exam scheduling: Mathematical modeling and parameter estimation with the Analytic Network Process approach	Analytic Network Process Model	• Invigilators Assignment (faculty lecturers or graduate students).
4	Salem M. Al-Yakoob, Hanif D. Sherali, Mona Al-Jazzaf[12]	A mixed-integer mathematical modeling approach to exam timetabling	Mixed-Integer	• Assignment to designated exam-periods and classrooms • Gender base • Proctor Assignment Problem

The model assigned the invigilators using arbitrarily assigned ratio scale numbers for the exam weights.
Recently, [2], developed a new binary model for examination time tabling problem, the model was presented in two directional novelty. The first one is that a course can be offered more than once in a semester. If a course is requested by a few students, then it is enough to be offered once. If the number of students requesting a course is more than the maximum number of students who are allowed to attend a single class, then the course is multi-offered. The second novelty is that sharing a room for two simultaneous exams is allowed. Also, the model considers some hard and soft constraints, and the objective function is set in such a way that soft constraints are satisfied as much as possible

3. PROPOSED FRAMEWORK

Timetabling problems have attracted the continuous interest of researchers mainly because they provide the opportunity of testing combinatorial solution methods in formulations that represent difficult practical problems (Dimopolou, Miliotis, 2000). With anticipated further increase in enrolment and number of courses, greater flexibility in choice of courses, and the need to keep the overall length of the final examination period short, a more systematic analytical procedure is necessary.

3.1 Quadratic Assignment Problem

The quadratic assignment problem (QAP) was introduced by Koopmans and Beckman in 1957 in the context of locating "indivisible economic activities". The objective of the problem is to assign a set of facilities to a set of locations in such a way as to minimize the total assignment cost. The assignment cost for a pair of facilities is a function of the flow between the facilities and the distance between the locations of the facilities.[13]

Due to wide assortment of applications, The QAP has been extensively used to formulate other practical problems such as economic problems, Scheduling problems, Timetabling problems, Facility layout problems,

3.2 Mathematical Formulation

Taking *E* exams need to be scheduled into a limited number of *T* time slots and limited number of *R* room and capacity, taking into account all examination must be scheduled within the time frame and the rooms capacities and the restrictions that students cannot take more than one examination at the same time among other constraints.

N= {1, 2, 3 … n}
$\Phi_n = T : E \to R$, the set of all permutations.
$t_{ij} \in T$, is the time slot for an exam to be assigned to a room

$$\min \sum_{i=1}^{n} \sum_{j=1}^{n} \phi_{ij} t_{ij}$$

i = 1, 2, 3 … n
j = 1, 2, 3 ... (n-1)

ϕ Is represent the assignment of exams to specific time slot and different room, so as to prevent conflict. The conflicts degree of each examination is minimized when exams i are assigned to room j at a specific time and is denoted by $\phi_{ij} t_{ij}$ where

$$\phi_{ij} \begin{cases} 1 \text{ if exam i is assigned to room r} \\ 0 \text{ otherwise} \end{cases}$$

$$\forall e_i \to r_j \Rightarrow se_i \le \sum_{j=1}^{n} sr_j$$

$e_i \in E \quad \forall$ i = 1, 2 … n
$r_j \in R \quad \forall$ j = 1, 2 … (n-1)

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se = Size of student in exam e_i
sr = Size of room r_j

In the scheduling, the Quadratic assignment problem (QAP) reduces the rate of conflicts as the examination is been scheduled, the examination with the highest cross faculty student is been prioritized in the schedule after which the examination with the highest number of cross program is considered and finally with the highest number of repeating student, at each stage group with the highest number of student are prioritized.

In order to help minimize the level of conflicts, we consider the basic matrices that help to generate our assignment procedure. Fig 3.1 below describes the Time Slot matrix prepares the distance between time slots available for exams which guides the system in assignment of examinations. Its aim is to guide on preventing consecutive examination and as well create a considerable distance between two examinations for each student. The matrix checks for the distance between time slots and ensures a more than 1 before assigning examination to time slots. The element in T_{13} indicates there is a distance of 2 time slots between T_1 and T_2.

	$T1$	$T2$	$T3$	$T4$	$T5$	$-$	Tn
$T1$	0	1	2	3	4		n
$T2$		0	1	2	3		n
$T3$			0	1	2		n
$T4$				0	1		n
$T5$					0		n
:						0	n
Tn							0

Fig. 3.1 Time Slots Matrix

Fig 3.2 below describes the Course matrix that helps to avoid conflict on courses having common students. A matrix C was defined where each element C_{xy} = 1 if exam *x* conflict with exam *y* having common students. This is considered to be a clash or conflict otherwise C_{xy} = 0.

	$C1$	$C2$	$C3$	$C4$	$C5$	$-$	Cn
$C1$	0	1	0	0	0		n
$C2$		0	1	0	0		n
$C3$			0	1	0		n
$C4$				0	1		n
$C5$					0		n
:						0	n
Cn							0

Fig. 3.2 Course Conflict Matrix

Fig 3.3 below describes the Examination-Time Slots Matrix. The matrix assumes (T_n = 4) signifying the total number of time slots and examination (E_n = 10) which signifies the total number of examination to be scheduled within 2 time slots per day for two days. The objective is to assign all examination to the available timeslot and avoid conflicts. In order to achieve this, the matrix considers the examination with highest number of cross-faculty students and set it to E_1 which is assigned to time slot 1, $T_{1.}$ The matrix takes the next cross-faculty examination with the highest number of students and set it to E_2. E_2 is then compared with E_1 to check for common student(s). If there exist a common student, one or more time slots is required between both assignments as presented in the matrix below. This process is repeated for all cross-faculty courses until they are all satisfied thereafter the examination with highest number of cross-program students is considered as well as the examination with the highest number of student is scheduled until E_n is assigned to a time slot.

	$T1$	$T2$	$T3$	$T4$
$E1$	1	0	0	0
$E2$	0	0	1	0
$E3$	0	1	0	0
$E4$	1	0	0	0
$E5$	0	0	0	1
$E6$	0	0	0	1
$E7$	0	1	0	0
$E8$	0	0	1	0
$E9$	1	0	0	0
$E10$	0	0	0	1

Fig 3.3 Examination-Time Slots Matrix

Exam E1,4 and 9 scheduled to take place in day1 session1 which is time slot1(T1), Exam E3 and 7 scheduled at T2, Exam E2 and 8 scheduled for T3 and Exam E5, 6 and 10 for the second day last session which is T4

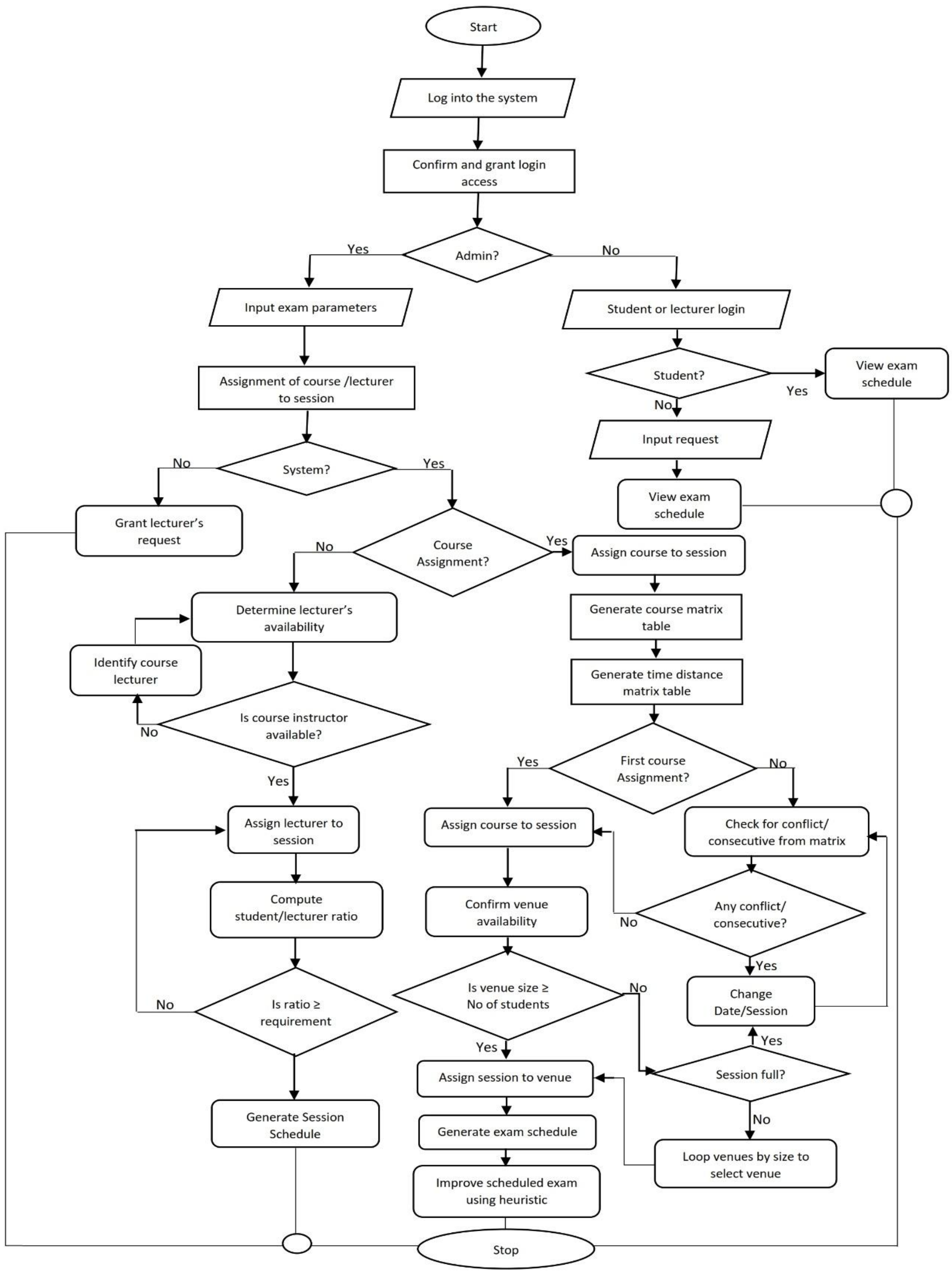

Fig. 3.4 Proposed Examination Scheduling Flow Chart

Proposed Algorithm

Here, we propose an algorithm based on heuristic. This solution identifies possible constraints and groups them as hard and soft constraints. The algorithm ensure the solution is improved if need be until an optimal solution is achieved and all constraints are satisfied.
The algorithm process is described below and also presented in the diagram in Fig 3.4:

1. Identify all possible constraints and group them in the order of hard to soft constraints
2. Select the hardest constraint and apply solution
3. Check if constraint is satisfied
4. If constraints are satisfied, then repeat process for all other constraint otherwise improve solution.
5. If solution is final solution, then apply to constraint until all constraints are satisfied.

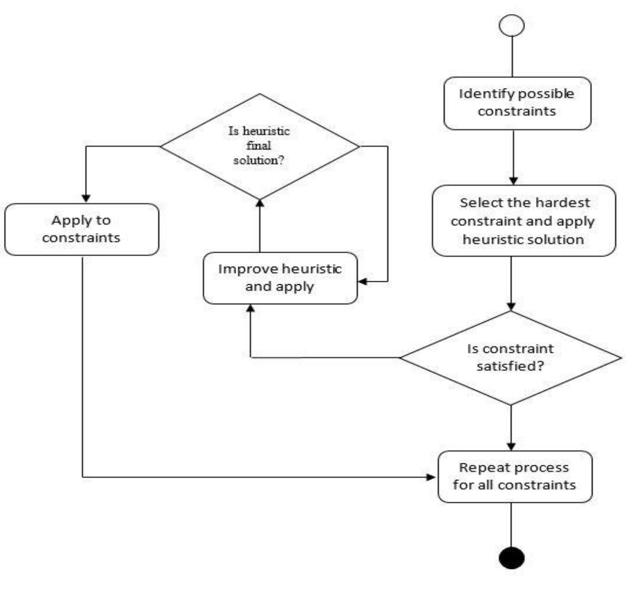

Fig. 3.5 Flow Chart

4. CONCLUSION AND RECOMMENDATION

In this study, we highlighted some weaknesses and strength of the related studies on examination scheduling. The proposed examination timetabling problem was formulated based a Quadratic Assignment Problem (QAP). Since the number of examinations can be greater than the number of time periods and in a quest to minimize all possible conflicts, the objective function is set in such a way that, hard constraint satisfaction is maximized. The future work of this research is to implement an examination scheduling system which will allow simulation and evaluation of various examination data and provide results that will help examination timetable planner achieve quality and valuable scheduling process.

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