A New Model for an Examination-Room Assignment Problem

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Summary
This abstract presents a survey of the undergraduate students from Universiti Kebangsaan Malaysia which asked about their perception and expectations towards university examination timetabling. Through this survey, and discussion with student registry officers (human schedulers), we formulate a new model for assigning examinations to room. The *Room Penalty Cost* aims to minimise students moving between rooms when they have been scheduled to sit consecutive examinations in a day. The proposed model also aims to minimise the number of rooms assigned to a single examination when it has to be split across multiple rooms. We suggest a heuristic that can be used to optimise the proposed model.

Key words:
Heuristic, Examination Room Assignment.

1. Introduction

The educational timetabling problem has been intensively studied for a number of years. The development of methodologies such as graph colouring (M.W.Carter et al. [1]), tabu search (Gaspero and Schaerf [2]), simulated annealing (Merlot et al. [3]), genetic algorithms (Sheibani [4]), memetic algorithms (Burke et al. [5]), case-based reasoning (Burke et al. [6]), hyper-heuristics (Hussin [7]), ant algorithms (Eley [8]), and others, have contributed to the efficiency and effectiveness in producing good quality solutions. Most of the above studies focused on the uncapacitated problem, in which the main constraint was ensure that students were not sitting two examinations in the same timeslot (see Qu et al. [9]).

According to Dammak et al. [10], there has been limited research on examination-room assignment. They also identified that the correlation between examination timetabling and examination room assignment has not been studied in as much depth as the sub-problems. However, both are tightly intertwined, where good quality, feasible solutions for exam timetabling, do not necessarily have an associated feasible solution for exam-room assignment due to the additional constraints that have to be respected. Therefore, in certain cases, re-scheduling the exam timetable might be necessary in order to generate a feasible solution for exam-room assignment. Schaerf [11] mentioned that the exam-classroom assignment was considered as the third phase of an algorithm where the main attention of this phase is to fix the exams into the rooms based on the total number of students. Although some researchers, such as Abdullah et al. [12] and Zampieri and Schaerf [13], have addressed the capacitated examination timetabling problem, they considered assigning exams to slots without violating the maximum seating capacity for each slot.

This work attempts to find a suitable assignment of examinations to rooms, using UKM (Universiti Kebangsaan Malaysia) as a case study. A short survey has been conducted with the objective of identifying the requirements of the undergraduate students. The results of this survey are presented in section 2. In section 3 we define the problem more fully and present a formal model in section 4. In section 5 we outline the heuristic procedure we intend to use to optimise the model. We conclude in section 6.

2. Undergraduate Survey

A survey was conducted in October 2006. One hundred questionnaires were randomly distributed among the undergraduate students of the university. From the 100 questionnaires, 83 questionnaires were returned and used for the analysis presented here. The background of respondents came from different educational streams of the university such as Science and Technology, and Social Sciences. Thirty two respondents were (38.5% of the 83 respondents) highlighted the *limited interval time* between consecutive exams (in a single day), where it indirectly contributes to "*distance difficulties*" for them having to move from one exam location to another. This has shown that this criterion should be given more attention, especially for the *three-timeslots per day* examination timetable. Indeed, based on our discussion with the student registry officers (human schedulers), they also try to avoid moving students between two consecutive exams, which

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demonstrates that the schedulers and students both have this as a key requirement.

3. Problem Definition

In practice, the process of generating examination timetables (using a semi-automatic scheduler which we call the manual scheduler) starts with generating the conflict table, i.e. identifying which exams cannot be scheduled in the same timeslot. The manual scheduler also generates the available examination timeslots; and identifies available exam rooms and the courses that need to be scheduled. Next, the manual scheduler (human expert) drags one exam at a time into a timeslot with guidance from the semi-automatic scheduler to avoid clashes. For each timeslot, they will manually assign exams to rooms and invigilators to exams. Finally, using the semi-automatic scheduler, the system will generate the seat identification for each student sitting each exam. This process usually takes more than two weeks. Unfortunately, in practice, there is no standard measurement to evaluate the quality of the exam timetable produced by the manual scheduler. Usually, the manual scheduler is only concerned with producing a clash free exam timetable. Although, they also wish to produce a good quality timetable, which satisfies student and lecturer preferences, this is beyond the scope of the current scheduling method. The need for an effective automated scheduler is important in producing a timetable which is able to evenly spread out exams over timeslots and attempt to satisfy personnel preferences.

In this work, we focus on the problem of assigning exams to rooms by considering those exams already assigned to slots. At this stage, we do not move exams between timeslots. In this dataset, we are given five exam rooms to be used. Table 1 shows a summary of the examination room capacities. When assigning exams to rooms, we consider virtual room capacity instead of actual room capacity in order to allow allocating additional students due to late student registration (after timetable has been distributed to students/lecturers/faculties). The room location (see table 1) indicating whether the rooms are close to each other or not (rooms with the same index show they are located nearby).

In order to avoid under-utilisation of room allocation and costs when assigning exams to room, the key factor to consider is to assign exams to larger room first. Thus, optimising larger room usage could indirectly optimise the utilisation of manpower such as invigilators that are involved during the examination period. Each examination should be assigned to a single room, unless this cannot be avoided. In exceptional cases, i.e. no room is available to fit the exam, then the exam can be assigned to multiple rooms but the location of the rooms should be close to each other as possible. Meanwhile, for the case of large examinations, where the number of enrolments is greater than the largest room capacity (i.e. more than 850 seats in this case), the examination can be assigned to any available room. The room can be shared with multiple exams depending on the availability of the seats. However, in assigning exams to rooms, priority should be given to assigning an exam to a room which can accommodate the exam. In addition, wherever possible, students should be assigned to the same room when they are sitting consecutive exams on the same day.

Table 1: Examination Rooms for dataset ukm0708-1

Room	**Actual room capacity**	**Virtual room capacity**	**Room location**
DPBestari	850	840	1
DGemilang	610	600	2
Dewan (DECTAR)	610	600	3
LobiUtama (DECTAR)	270	260	3

In this paper, we present our approach and experience in solving the examination timetabling (room assignment) problem for Semester I, year 2007/2008 at UKM. The dataset (UKM0708-1) has been preprocessed based on the supplied data which contains 818 exams, 14,047 students, 75,857 enrollments, 42 timeslots and 15 exam days (this excludes the weekend break). The UKM06-1 dataset is held in five text files: UKM0708-1.stu, UKM0708-1.slt, UKM0708-1.rom, UKM0708-1.lec, UKM0708-1.crs and UKM0708-1.isl, which represent student enrollment, slot, room, lecturer, course and isolated exams definition, respectively. The files are available at `http://www.ftsm.ukm.my/masri/Exam/`. The exam timetabling problems in UKM (particularly) have different datasets for each semester. In most cases, each student registers for different set of courses. That is the exam timetable of each semester is only valid for that semester. Therefore, in practice, the exam timetable need be generated at the end of each semester.

The dataset has 4 weeks examination period. Each week has 5 exam days (Monday to Friday). Each day has 3 timeslots (morning, afternoon and evening), except Friday which has 2 timeslots (morning and evening only). In order to model the real-world timeslots (in days), we present the vector of days in Fig. 1.

In Fig. 1, we can see that in most cases we have three entries for each day (e.g. day 1, we have three '1') except on Friday i.e. on day 5, 12 and 19; there are only two *5* entries (representing two timeslots on Friday). Saturdays (days 6 and 13) and Sundays (day 7 and 14) are missing because there are no examinations on Saturday and

Sunday. A corresponding timeslot vector is presented in Fig. 2.

(1, 1, 1, 2, 2, 2, 3, 3, 3, 4, 4, 4, 5, 5, 8, 8, 8, 9, 9, 9, 10, 10, 10, 11, 11, 11, 12, 12, 15, 15, 15, 16, 16, 16, 17, 17, 17, 18, 18, 18, 19, 19)

Fig. 1. Vector of days.

(1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 15, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 36, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 57)

Fig. 2. Vector of timeslots.

Fig. 2 shows that the timeslots are represented as indexes. Timeslots 1, 2 and 3 refer to day 1, timeslots 4, 5 and 6 refer to day 2, etc. Note that on day 5 (Friday the first week) there are only 2 timeslots i.e. 13 and 15 (morning and evening sessions). Since there is no afternoon session, we do not use a timeslot with an index of 14. The reason is that we want to utilise different weights since the students have gaps (2 gaps in this case i.e. 15-13=2) even though the exams are scheduled on the same day. Also notice that the timeslot indexes for Saturday the first week (16, 17 and 18) and Sunday the first week (19, 20, and 21) are missing because there are no exams scheduled on these days. The same representation is used for the second and third weeks of the exam period.

4. Modeling the Exam-Room Assignment Problem

For each timeslot, we have a set of non-conflicting exams that need to be assigned to a set of rooms without violating the hard constraints. In this section, we present the formulation for exam-room assignment model. The input for the exam-room assignment problem can be stated as follows:

- N is the number of exams;
- E_i is an exam where $i \in \{1,\dots,N\}$;
- D is the number of days;
- B is the set of all N exams, $B=\{E_1,\dots,E_N\}$;
- R is the number of available rooms;
- T is the given number of timeslots (including missing timeslots);
- r_i specifies the assigned room for exam E_i, where $r_i \in \{1,\dots,R\}$ *and* $i \in \{1,\dots,N\}$;
- t_i specifies the assigned time slot for exam E_i, where $t_i \in \{1,..,T\}$ and $i \in \{1,..,N\}$;
- d_i specifies the assigned day for exam E_i, where $d_i \in \{1,..,D\}$ and $i \in \{1,..,N\}$;
- $C=(c_{ij})_{NxN}$ is the conflict matrix where each element denoted by c_{ij}, ($i,j \in \{1,..,N\}$) is the number of students taking exams E_i and E_j;
- $\Delta t=|t_i-t_j|$ is the timeslot different between exam E_i and E_j;
- $\Delta d=|d_i-d_j|$ is the day different between exam E_i and E_j;
- β_{if} is a decision variable where $\beta_{if}=1$ if exam E_i is assigned to room f, or 0 otherwise.

The constraints of assigning exams to rooms are (for our dataset):

1) Special examinations, $E_i \in S$ where $S \subset B$ should be isolated from other exams (e.g. in UKM06-1 dataset, exam VVVA3213 requires audio), i.e. the special exams cannot share a room with other exams in the same timeslot.
2) Each exam must be assigned to a room.
3) Each lecturer has to invigilate an exam for his/her taught courses and if their courses are scheduled in the same timeslot, these exams should be assigned to the same room.
4) Students who have consecutives exams on the same day should be assigned to the same room, i.e. both exams are assigned to the same room.
5) Wherever possible, each examination must be assigned to a single room.

Constraints 1, 2 and 3 are rigidly enforced (hard constraints), whilst constraints 4 and 5 should be satisfied as far as possible. Therefore, we use *Room Penalty Cost*, as an evaluation function that attempts to minimise students moving between rooms when they were scheduled to sit consecutive exams in a day. In addition, *Room Penalty Cost* also attempts to minimise splitting exams across different rooms. That is, we aim to minimise violating soft constraints 4 and 5. The *Room Penalty Cost*, R_{cost} can be defined as follows:

$$\textbf{Minimise } R_{cost} = \sum_{i=1}^{N-1}\sum_{j=i+1}^{N} c_{ij}.\mu_{ij} + \sum_{i=1}^{N}\rho_i \qquad \textbf{(1)}$$

Where,

$$\mu_{ij} = \begin{cases} 1 & \text{if } |\Delta t|=1,\ |\Delta d|=0 \text{ and } r_i \neq r_j \\ 0 & \text{otherwise;} \end{cases} \qquad \textbf{(2)}$$

$$\rho_i = \begin{cases} \sum_{f=1}^{R}\beta_{if} & \text{if } \sum_{f=1}^{R}\beta_{if} > 1 \\ 0 & \text{otherwise;} \end{cases} \qquad \textbf{(3)}$$

The *Room Penalty Cost* counts the number of students sitting consecutive exam, on the same day, in different rooms (the first term), and the number of exams assigned to multiple rooms multiplied by the number of rooms for the exam. As far as we know, no other researchers have formulated the objective function for assigning exams to rooms (see Dammak et al. [10]). Therefore, we recommend future research in this area to consider our proposed objective function in evaluating the quality of generated solutions for exam-room assignment.

5. Heuristic Procedure for Exam-Room Assignment

In order to optimise the model presented above, we use a heuristic procedure called *BestFitRoom* assignment. For each timeslot, we first sort the available rooms in non-increasing order of the room capacity. Then we arrange exams in the slot in non-increasing order of student enrollment. If there is an isolated exam (special exam) in the slot, we first assign the isolated exam to the best fit slot and exclude the room from the set of available rooms for that slot. Otherwise, the first exam in the list for each slot will be assigned to the best fit room. After each assignment, we re-rank the available rooms. The process is repeated until all the exams has been assigned to rooms. We will report our results in our future paper.

6. Conclusion and Future work

This work has proposed a new objective function, *Room Penalty Cost,* for assigning exams to rooms. The *Room Penalty Cost* attempts to minimise students moving between rooms when they are scheduled to seat consecutive exams in a day as well as minimising assigning exams to multiple rooms. We now plan to produce high quality solutions to this problem, using (but not limited to) the heuristic procedure we outlined in section 5.

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