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A Survey on the Requirements of University Course Timetabling

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Abstract**—**Course timetabling problems occur every semester in a university which includes the allocation of resources (subjects, lecturers and students) to a number of fixed rooms and timeslots. The assignment is carried out in a way such that there are no conflicts within rooms, students and lecturers, as well as fulfilling a range of constraints. The constraints consist of rules and policies set up by the universities as well as lecturers' and students' preferences of courses to be allocated in specific timeslots. This paper specifically focuses on the preferences of the course timetabling problem in one of the public universities in Malaysia. The demands will be considered into our existing mathematical model to make it more generalized and can be used widely. We have distributed questionnaires to a number of lecturers and students of the university to investigate their demands and preferences for their desired course timetable. We classify the preferences thus converting them to construct one mathematical model that can produce such timetable.

Keywords**—**University course timetabling problem, integer programming, preferences, constraints.

I. Introduction

University course timetabling is a process of assigning courses taken by students taught by a specific lecturer to a limited number of timeslots and to a suitable lecture room in a way that there are no conflicts, taking into account several constraints. The university course timetabling problem has been widely studied and solved with many approaches. Several different formulations of the problem exist since some specific constraints may differ from one university to another [1].

In university course timetabling problem (UCTP), constraints are classified into two categories, hard constraint and soft constraint. In order to generate a feasible and optimal timetable, all hard constraints have to be satisfied while considering as much as possible the soft constraints. However, if a soft constraint is satisfied, it is much likely to be a more acceptable timetable. A sufficiently good timetable is the one with a feasible outcome but a timetable with better quality is having minimum total violation of the soft constraints. In certain cases, the hard constraints can also be considered as the soft constraints in order to find a feasible solution.

Initially, the constraints which are looked at (as hard constraints) are the completeness, conflicts among the resources, and its availability, lecturers' working load together with a few types of meeting patterns. The meeting patterns employed are basically to have the class meetings of the same course or unit assigned consecutively or having a day off between the class meetings. Therefore, we can classify the university course timetabling features into:

- *Completeness:* This particular feature means that every element of a course or unit has to be assigned into a slot
- *Conflict of resources:* Resources here refer to the teaching staff (full and part time lecturers), group of students and the classrooms. These elements should be assigned once at a time.
- *Work load:* This is similar to a type of distribution constraint where staffs and student groups have a limited number of teaching and learning hours either for a day or week.
- *Availability of resources:* Basically this availability feature is with respect to the lecturers and rooms.
- *Meeting patterns:* This specific category of features stipulates how the elements of a course or unit are to be assigned.

Table I shows the features described in previous studies. As stated in [2], the constraints will vary according to each institution. Every university has their own studying environment organized to satisfy the requirements they need [3].

Many researchers focused on different types of solution methods for different kinds of problem [5], [7]-[9], [21], [22]. The solution methods are divided into two categories which are exact method and approximate method. Table II presents some of the related methods on timetabling problem. The various methods listed below are reported to be successfully applied in solving specific timetabling problem. However, their applicability is often only to specific institutions, making its application in all timetabling problem from various institutions unrealistic.

For this study, we will emphasize on constraints or requirements from the user themselves into our existing university course timetabling model [26]. We expect to produce a timetable that suits most of the users.

II. Methodology

Generally, this study will be divided into two parts. The first part will be the survey. We will develop two sets of questionnaires. The first set of questionnaire is developed for lecturers while the second set of questionnaire is developed for students. Both set of questionnaires consist three sections. The first section requested demographic information, followed by

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respondents' perspective on desirable timetable. This is the main part in the questionnaire. The final section is for open ended questions where we will get more requirements. From this survey, information of the preferences from timetabling communities will be gained and employed to produce a human friendly timetable.

TABLE I
EXAMPLE OF FEATURES DESCRIBED IN PREVIOUS STUDIES

Reference	Constraints				
	Completeness	***Conflict of resources***	***Work load***	***Availability of resources***	***Meeting patterns***
Dammak et al. [1]	*	*	*		*
Banowosari and Valentine [3]		*	*		
Badoni et al. [4]		*	*	*	*
Basir et al. [5]	*	*			
Aladag et al. [6]	*	*	*	*	*
Boland et al. [7]	*			*	
Al-Yakoob and Sherali [8]				*	*
Adriaen et al. [9]		*		*	*
MirHassani [10]		*	*	*	*
Zhang and Lau [11]		*	*	*	*
Daskalaki et al. [12]	*	*	*		*
Rudova and Murray [13]		*		*	*
Burke and Petrovic [14]		*		*	*
Dimopoulou and Miliotis [15]		*		*	
Abdennadher and Marte [16]		*		*	*

TABLE II
EXAMPLE OF METHODS USED IN PREVIOUS STUDIES RELATED TO TIMETABLING PROBLEM

Reference	**Method**
Boland et al. [7] MirHassani [10] Daskalaki et al. [12] Dimopoulou and Miliotis [15] Sanchez-Partida et al. [17] Kanjana [18] Ribiu and Konjicija [19] Daskalaki and Birbas ([20]	Integer linear programming
Bakir and Aksop [21]	Binary integer programming
Al-Yakoob and Sherali [8]	Mixed-integer programming
Dandashi and Al-Mouhamed [22] Redl [23] Asratian and de Werra [24]	Graph coloring
Banowosari and Valentine [3] Basir et al. [5]	Simulated annealing
Aladag et al. [6] Adriaen et al. [9] Alvarez-Valdes et al. [25]	Tabu search

In the second part of the study will be the model development. Previous research had successfully constructed more general university course timetabling model which include essential features.

Based on the survey, we will improvise the previous model mentioned. The model will not only consider most features that are applicable to the university, but also emphasized on the demands of all parties involved.

III. PROBLEM DESCRIPTION

Course timetabling in a university involves assigning courses taken by students taught by a specific lecturer to a limited number of timeslots and to a suitable lecture room in a way that there are no conflicts. Reference [14] mentioned in their article that many researchers attempted to solve UCTP, but only for their specific institution. However, in recent years, an attempt on this has been done using mixed integer linear programming [26]. We gather all possible constraints, basic and additional constraints in the literature and form a general mathematical model for university course timetabling problem.

As a continuity of the work, we analyzed thoroughly to find possible slackness in consideration of certain constraints, as well as creating some possible soft constraints that may be of demand from the timetabling community. Individual demands can influence a timetabling development but it is often disregarded in timetabling construction. Therefore, this study aims to determine the demands of lecturers and students. This would help in creating a better mathematical model that can be applied in the university. By producing an effective timetable considering the needs of timetabling communities, it will help to create a better teaching and learning environment for both lecturers and students.

IV. SURVEY

A total of 500 of questionnaires were distributed randomly among students and lecturers. 380 from students and 71 from lecturers responded to the questionnaire and considered to be legitimate for this research.

TABLE III
TYPE OF CLASSES VERSUS TIME SESSION

	Theoretical Classes		**Practical Classes**	
	Student	Lecturer	Student	Lecturer
Morning Session	71.60 %	91.50 %	28.40 %	8.50 %
Afternoon Session	17.10 %	7.00 %	82.90 %	93.00 %

In both student and lecturer questionnaires, respondents were asked to choose the type of classes preferred to be taught during morning and afternoon session. The results are clearly shown in Table III. Table IV presents the percentage of respondents' perspective on desirable timetable. In this survey, we consider lecturers' workload in order to have a balance time between teaching, research and other administration job.

TABLE IV
PERCENTAGE OF EACH QUESTION OF RESPONDENTS' PERSPECTIVE

	Disagree		Agree	
	Student	Lecturer	Student	Lecturer
Two different subjects should be scheduled on the same day	5.00 %	71.90 %	95.00 %	28.10 %
Two different subjects should be in two consecutive timeslots	35.70 %	77.50 %	64.30 %	22.50 %
Two different subjects should be in the morning and evening sessions of the same day	14.80 %	59.20 %	85.20 %	40.80 %
Tutorial class and lecture of same subject should be scheduled on the same day	22.60 %	66.20 %	77.40 %	33.80 %
Tutorial class and lecture of same subject should be in two consecutive timeslots	32.40 %	54.90 %	67.60 %	45.10 %
Tutorial class and lecture of same subject should be in the morning and evening sessions of the same day	26.30 %	66.20 %	73.70 %	33.80 %
Tutorial class and lecture of same subject should be in two consecutive days	30.60 %	73.30 %	69.40 %	26.70 %
Lecturer/students need at least a day gap between tutorial class and lecture of the same subject	24.20 %	25.30 %	75.80 %	74.70 %
In a case where a subject is enrolled by many students, resulting in division into multiple classes (lectures, tutorials or labs). These classes should run simultaneously.	14.50 %	62.00 %	85.50 %	38.00 %
For each subject, students should have tutorial class only after the lecture is conducted	7.10 %	7.00 %	92.90 %	93.00 %
The number of student classes for each day should be spread evenly over the week	17.60 %	-	82.40 %	-
The number of student classes *increases* by day in a week	68.20 %	-	31.80 %	-
The number of student classes *decreases* by day in a week	27.60 %	-	72.40 %	-
Lecturer/students prefer to attend class early in the morning	33.40 %	18.30 %	66.60 %	81.70 %
Lecturer/students prefer to have all classes in morning session	25.60 %	25.30 %	74.40 %	74.70 %
Lecturer/students prefer to have all classes in afternoon session	46.60 %	86.00 %	53.40 %	14.00 %
Lecturer/students prefer to attend class in the late evening	26.30 %	97.20 %	73.70 %	2.80 %
Lunch breaks should be provided.	1.30 %	9.90 %	98.70 %	90.10 %
Break for prayer should be provided	0.00 %	0.00 %	100.00 %	100.00 %
There is maximum number of students in each class that must be considered	3.20 %	0.00 %	96.80 %	100.00 %

Lecturers were asked to specify the total of subjects that they can teach comfortably in one semester. 62% of them state that they can teach 2 subjects per semester. 21.1% of lecturers agree to teach only one subject for a semester while 15.5% and 1.4% of them agrees to teach 3 and 4 subjects respectively per semester.

The final section is regarding the respondents' opinion. Different respondents came out with different opinion.

For lecturer, the examples of the suggestions are as followed:

1) Each lecturer must be given not more than two classes per day and they must be not consecutive
2) For class with more than one credit hours, it is advised to have the hours divided properly throughout the week instead of having one session that goes for 2 to 3 hours straight

For student, the examples of the suggestions are as followed:

1) Students prefer a loose timetable which have lunch break and break for pray
2) There is no class during night time and weekend.

V. PROBLEM FORMULATION

Previously, Aizam and Caccetta [26] have successfully constructed a more general university course timetabling model that includes features that are essential. We improvised the model not only by identifying through the literature but also over the survey and our own observation about the requirements needed to be included to suit the demands from lecturer and students of the university.

Sets

C	Set of class meetings.
R	Set of room type available.
L	Set of lecturers.
S	Set of student groups.
T	Set of timeslots.
Day	Set of days.
C_{theory}	Set of theory class meeting
$C_{practical}$	Set of practical class meeting
C_r	Class meetings requiring type of room $r, \forall r \in R$.
C_l	Class meetings that are taught by lecturer l, $\forall l \in L$.
C_s	Class meetings that have the same group student s, $\forall s \in S$.
T_{morn}	Timeslots consisting only the morning slots for each day
T_{eve}	Timeslots consisting only the evening slots for each day
T_s	Set of early morning and late evening timeslots
T_{prayer}	Set of prayer timeslots
T_{lunch}	Set of lunch break timeslots
T_l	Set of non-available times for each lecturer l, $\forall l \in L$

T_r Set of non-available times for each room r, $\forall r \in R$.

T_c Set of non-available times for each class meeting c, $\forall c \in C$.

F Set of class meetings in pairs (c_i, c_j) that needs to be scheduled in the same day, $(c_i, c_j) \in C$

F' Set of class meetings in pairs (c_i, c_j) that cannot be scheduled in the same day, $(c_i, c_j) \in C$

G Set of class meetings in pairs (c_i, c_j) that needs to occur consecutively in the same day, $(c_i, c_j) \in C$.

G' Set of class meetings in pairs (c_i, c_j) that should not be scheduled consecutively in the same day, $(c_i, c_j) \in C$.

H Set of class meetings in pairs (c_i, c_j) that needs to be scheduled in the morning and afternoon sessions, $(c_i, c_j) \in C$.

K Set of class meetings in pairs (c_i, c_j) that needs to have a day off between two of the classes, $(c_i, c_j) \in C$.

Par Set of class meetings in pairs (c_i, c_j) that needs to be scheduled parallel in one timeslot, $(c_i, c_j) \in C$.

Pre Set of class meetings in pairs (c_i, c_j) that needs to be scheduled one after the other, $(c_i, c_j) \in C$.

Model Parameters

$D_{\max}$ Maximum number of courses a lecturer can teach in a semester.

N_r Number of rooms available in each room type, $r \in R$.

n_d Number of timeslots in day, $d \in Day$

T_d Set of timeslots in day d

$Q_{\max}$ Maximum number of students in each class meeting

$P_{c,t}$ Preference of having class meeting c at timeslot t.

Model Constraints

This part is divided into two which are basic model and additional model.

A. Basic Model

Basic model is a model which incorporates features that are mostly used by all researchers. Generally, these features are the rules set up by the university which needs to be satisfied by the scheduler. Each of the mentioned features is mathematically written as follows:

1) All class meetings must be assigned to a timeslot

$$\sum_{t} X_{c,t} = 1 \qquad \forall c \in C \tag{1}$$

2) The room limitation restrictions

$$\sum_{c \in C_r} X_{c,t} \le N_r \qquad \forall t \qquad \forall r \in R \tag{2}$$

3) Availability of lecturer

$$\sum_{t \in T_l} \sum_{c \in C_l} X_{c,t} = 0 \qquad \forall l \in L \tag{3}$$

4) Availability of room

$$\sum_{t \in T_r} \sum_{c \in C_r} X_{c,t} = 0 \qquad \forall r \in R \tag{4}$$

5) Availability of timeslot

$$\sum_{t \in T} X_{c,t} = 0 \qquad \forall c \in C \tag{5}$$

6) A lecturer cannot teach more than one class meeting at a time

$$\sum_{c \in C_l} X_{c,t} \le 1 \qquad \forall t \qquad \forall l \in L \tag{6}$$

7) A student cannot attend more than one class meeting at a time

$$\sum_{c \in C_s} X_{c,t} \le 1 \qquad \forall t \qquad \forall s \in S \tag{7}$$

Thus, we can write the basic model for the course timetabling as:

$$\text{Maximize} \sum_{c} \sum_{t} P_{c,t} X_{c,t}$$

Subject to: Constraints (1) – (7) and $X_{c,t} \in \{0,1\} \ \forall c \ \ \forall t$

B. Extended Model

In this part, we introduce a number of additional features to the basic model which do arise in literature and survey. We also added some new practical restrictions motivated from the existed features. These features are expressed as:

1) Some specific class meetings should be scheduled in the same day

$$\sum_{t \in Day_d} (X_{c_i,t} - X_{c_j,t}) = 0 \qquad \forall (c_i, c_j) \in F \quad \forall d \in Day \tag{8}$$

2) Some specific class meetings should not be scheduled in the same day

$$\sum_{t \in Day_d} (X_{c_i,t} + X_{c_j,t}) \le 1 \qquad \forall (c_i, c_j) \in F' \quad \forall d \in Day \tag{9}$$

3) Class meetings that should occur consecutively

$$X_{c_i,t}=X_{c_j,t+1} \qquad \forall(c_i,c_j)\in G \quad \forall d\in Day \quad \forall t\in\{1,2,...,n_d-1\} \tag{10}$$

4) Class meetings that should not occur consecutively

$$X_{c_i,t}+X_{c_j,t+1}\le 1 \qquad \forall(c_i,c_j)\in G' \quad \forall d\in Day \quad \forall t\in\{1,2,...,n_d-1\} \tag{11}$$

5) Having an interval between two class meetings (morning and evening sessions) on the same day

$$\sum_{t\in T_{morn}} X_{c_i,t} = \sum_{t\in T_{aft}} X_{c_j,t} \qquad \forall(c_i,c_j)\in H \tag{12}$$

6) Multiple classes running simultaneously (same subject)

$$X_{c_i,t}=X_{c_j,t} \qquad \forall t \quad \forall(c_i,c_j)\in Par \tag{13}$$

7) Students taking tutorial classes only after the lecture is conducted

$$X_{c_i,t} - \sum_{t=t+1} X_{c_j,t} = 0 \qquad \forall(c_i,c_j)\in pre \quad \forall t\in\{1,2,...,t-1\} \tag{14}$$

8) Having a day off between two classes of the same course

$$\sum_{t\in Day_d} X_{c_i,t} + \sum_{t\in Day_d+Day_{d+1}} X_{c_j,t}\le 1 \qquad \forall d\in Day \quad \forall(c_i,c_j)\in K \tag{15}$$

9) Avoid early morning and late evening class

$$\sum_c \sum_{t\in T_s} X_{c,t}=0 \qquad \forall c\in C \tag{16}$$

10) Avoid lecture during lunch break

$$\sum_c \sum_{t\in T_{lunch}} X_{c,t}=0 \qquad \forall c\in C \tag{17}$$

11) Avoid lecture during prayer time

$$\sum_c \sum_{t\in T_{prayer}} X_{c,t}=0 \qquad \forall c\in C \tag{18}$$

12) The number of lectures each day is monotonically decreasing, either the same number of class meeting or less

$$\sum_{t\in Day_1} X_{c,t}\ge \sum_{t\in Day_2} X_{c,t}\ge ...\ge \sum_{t\in Day_d} X_{c,t} \tag{19}$$

13) Theory class meeting must be scheduled in the morning session

$$\sum_{t\in T_{morn}} X_{c,t}\le 1 \qquad \forall c\in C_{theory} \tag{20}$$

14) Practical class meeting must be scheduled in the evening session

$$\sum_{t\in T_{eve}} X_{c,t}\le 1 \qquad \forall c\in C_{practical} \tag{21}$$

15) Maximum number of total subject a lecturer can teach in a semester.

$$\sum_{c\in C_l} X_{c,t}\le D_{\max} \tag{22}$$

16) Maximum number of students in each class meeting

$$\sum_{c\in C_s} X_{c,t}\le Q_{\max} \tag{23}$$

Thus, the extended integer programming model for a course timetabling problem in the university can be written as:

$$\text{Maximize } \sum_c \sum_t P_{c,t} X_{c,t}$$

Subject to: constraints (1)-(23) and $X_{c,t}\in\{0,1\} \quad \forall c \quad \forall t$

VI. Discussion

In this study, we have undergone the survey to obtain the preferences and demands from the timetabling communities in a university. From the survey, we have listed all the information needed to understand the features that are best being considered in the model development. It is essential in producing a friendly schedule for the timetable communities

From the additional features in the previous section, one existing requirement motivated us to create two other new requirements regarding the theory and practical classes. The formulations are shown in (20) and (21).

From the survey too, five new constraints were introduced. Requirements that are related to meeting patterns (16), time restrictions (17) and (18), and also limitations (22) and (23).

We will be looking into more such requirements for a better output from more in progress surveys.

VII. Conclusion

A mathematical model that includes all important features of university course timetabling has been developed by [26]. They tested the developed models on a randomly generated data as well as on a data obtained from literature. To further test the applicability of these developed models, especially for the university, it is essential to understand the demand of individuals in timetabling community which includes lecturers, students as well as the administrative staffs. The demand from the timetabling community influences the construction of an effective timetabling. However, these demands are often ignored. Satisfying the demands from timetabling communities in constructing a timetabling will create a desirable outcome that will indirectly generate an excellent environment for teaching and learning process.

The ongoing research on this topic includes the solution of the model to generate a robust solution for course timetabling problem.

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