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Cite as: AIP Conference Proceedings **2016**, 020001 (2018); https://doi.org/10.1063/1.5055403
Published Online: 27 September 2018

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A Brief Review on the Features of University Course Timetabling Problem

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Abstract. University course timetabling problem (UCTP) has become a well-known study among universities and researchers for various fields. Generally, UCTP is the allocation of events into timeslots and rooms considering the list of hard and soft constraints presented in one semester, so that no conflict is created in such allocations. Hard constraints should not be violated under any conditions while satisfying as much as possible the soft constraints. In this article, we review and classified all the constraints from the literature. This is an article that aims to prepare the information of variety constraints used in previous study of timetabling problem. Although improvements on the features have been done since the automation approached was first introduced in the 1960's, we restrict our review only within the last ten years. More features reflecting the timetabling communities were being identified recently. Based on the review and through our thorough analysis, we have managed to compile mostly used features in researchers' model to introduce a more general mathematical model. Seven new constraints, which cover requirements related to class meeting pattern and preferences from timetabling communities, were added in our general mathematical model developed in previous study.

INTRODUCTION

It is realized that a timetable is a table with all the data one has to know in regards to specific events are scheduled to occur. Information like events, time and places all can be alluded to timetable. It might seem to be simple yet because of different features and limitation, numerous researchers still trying to decipher the solution for this problem. Timetabling appears in various field including education, transport, logistic institutions etc. [1]. This paper will be focusing on the educational timetabling problem.

Educational timetable can be divided into three significant types; school timetabling, course timetabling, and exam timetabling problems [2]. Basically there are two characterizations of timetabling problems in universities which are course and examination timetabling problems. The differentiations between the two arrangements are, course timetable are utilized more than once over semester and it is restricted into days in a week while the examination timetable are planned once in a given day of a month or perhaps two and it is relies on upon the number of the examinations.

DESCRIPTION OF THE PROBLEM

University course timetabling problem (UCTP) involves assigning courses taken by a group of students taught by a specified lecturer to a limited number of timeslots and to an appropriate classroom. The assignment are carried out

Proceedings of the 3rd International Conference on Applied Science and Technology (ICAST'18)
AIP Conf. Proc. 2016, 020001-1–020001-7; https://doi.org/10.1063/1.5055403
Published by AIP Publishing. 978-0-7354-1734-2/$30.00

in a way 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 lecturer's and student's preferences of courses to be allocated in specific timeslots. Constructing a timetable is a tedious task but creating a high quality timetable is even a tougher assignment. A high quality timetable is a timetable that can fulfill the user preferences while considering all the availability and conflict of the resources. In most institutions, this is left to the administrative staff and has become a major problem to deal with.

The objective of the UCTP is to create a timetable satisfying all the requirements. The problem comprise of a set of:

- Days and timeslots: number of teaching days per week and each day is divided into a fix number of timeslot
- Class meeting: refer to a lecture, tutorial or lab for each course
- Resource: resources involved such as rooms, lecturers, students and etc.
- Constraint: a constraint is a restriction or limitation that arise in scheduling the class meetings
- Conflict: all the resources should be scheduled once at a time and at a place

The aim of this article is to review all the essential features in solving UCTP since this is very important part in this problem and it is rarely be reviewed by other researchers. The remainder of this paper is organized as follows; Section 3 will review the various constraints from ten years back. Next, Section 4 will focus on the new general ILP model for university course timetabling problem. Finally, concluding remarks and perspectives for future research are given in the conclusion. Note that, the discussions for each part are presented at the end of each section.

CONSTRAINTS

In UCTP, constraints can be referred as the prerequisites expected to make a feasible timetable. Constraints can be categorized into two classes, hard constraint and soft constraint. Hard constraints are the ones that should not be violated in any condition. Conversely, the soft constraints are the attractive kind of requirements which can be managed as insignificant however enables conditions that are optional. An adequately good timetable is the one with a feasible outcome but a superior quality is the one having least total violation of the soft constraints. For specific cases, the hard constraints can also be considered as the soft constraints in order to find a feasible solution.

In [3], meeting patterns are presented. The meeting patterns utilized are essentially to have the class meetings of a similar course allotted continuously or having a day off between the class meetings. Extra limitations on working load whereby students' workload is considered on top of lecturers' workload is applied in [4]. The priority of the class meeting is also incorporated in the similar study. There are assortments of other constraints that exist in a timetable problem. Yeasin and Khader [5] recorded two basic constraints in any timetabling problem which are conflict and availability of the resources. Schimmelpfeng and Helber [6] grouped the limitations into 4 classifications which are lecturers' essential task restrictions (accessibility, clashes, and parallel), school prerequisites (back to back timeslots), and institutes 'restrictions (precedence) and restrictions related to lecturers preferences (work load, day-off and meeting pattern).

The improvement of constraints proceeds throughout the years. Scarcest adjustments to a constraint have shown enormous advances in this area of research. In this way, from the literature, the university course timetabling features can be grouped into:

- Completeness: each class meeting has to be scheduled into a slot. All course activities (lectures, tutorials, labs) included in the curriculum must be assigned in the timetable.
- Conflict of resources: resources here refer to the lecturers, group of students and the classrooms. They should be scheduled once at a time and at a place.
- Work load: it is the amount of work an individual has to do where not only for staffs but also for student groups. They have a limited number of teaching and learning hours either for a day or week that should be considered.
- Availability of resources: basically this feature is related to the availability of lecturers, rooms, students and timeslot. For example, the lecturer may not be available on a given day or during certain periods.
- Meeting patterns: this feature stipulates how the class meetings are to be assigned. There are various types of meeting pattern as stated below.

We can consider that meeting pattern is directly related to human factor since various people favour distinctive types for meeting pattern. In light of our review, meeting pattern can be: (A) session preferences (morning or night session); (B) time preferences (particular time required); (C) day preferences (day-off, on particular days); (D) activity preferences (lunch, Friday prayer and faculty activities); (E) compactness preferences (sequence) and (F) course frequency preferences (avoid single class in a day, same course in a day).

All of the requirements from literature are gathered and recorded to see the different constraints accessible. Table 1 display the elements utilized from the past 10 years mostly to show the different of requirements utilized by various researchers for various universities or different instant problems. From the table, we can see that none of the researchers able to incorporate every one of the components in tackling their timetabling problem.

There are some researchers consider working load in their model yet disregard the meeting pattern of the class meeting and vice versa. Subsequently, the fundamental reason for this table is to overview every one of the components accessible for further investigations of UCTP. A decent timetable is the one that can incorporate as many as possible features which can fulfill both lecturers' and students' preferences.

TABLE 1(a). Features described in some previous study

Reference	Constraints													
	Complete-ness	Conflict of resources	Work load		Availability of resources				Meeting patterns					
			Lec	Stud	Lec	Stud	Room	Slot	A	B	C	D	E	F
Schimmelpfeng and Helber [6]		*	*	*	*		*						*	
Bellio et al. [7]		*	*	*			*	*					*	
Phillips et al. [8]		*					*			*	*			
Badoni and Gupta [9]		*					*			*			*	*
Lewis and Thompson [10]		*					*	*		*			*	*
Aizam and Caccetta [11]	*	*	*	*	*		*				*		*	*
Torres Ovalle et al. [12]		*					*						*	
Badoni et al. [13]		*					*			*			*	*
Abuhania and Ivanchenko [14]		*	*	*	*	*	*						*	
Sanchez-Partida et al. [15]		*		*	*		*						*	
Fong et al. [16]		*					*			*			*	*
Bolaji et al. [17]		*					*			*			*	*
Modupe et al. [18]		*					*			*		*		
Chen and Shih [19]		*	*									*	*	
Cacchiani et al. [20]	*	*			*		*	*					*	
Ceschia et al. [21]		*					*	*		*			*	*
Lukas et al. [22]		*	*	*	*		*						*	
Abdullah and Turabieh [23]	*	*			*		*						*	*
Banowosari and Valentine [24]		*	*	*	*								*	
Ribiu and Konjicija [25]		*	*	*	*	*	*							*
Chaudhuri and Kajal [26]		*	*	*	*		*				*		*	
Aladag et al. [27]	*	*		*	*		*	*	*				*	*
Aycan and Ayav [28]		*			*		*	*			*			*
Jat and Yang [29]		*					*			*			*	*
Oladokun and Badmus [30]	*	*					*			*		*		*
Boland et al. [31]	*	*			*		*							
Jat and Yang [32]		*					*			*			*	*
Bakir and Aksop [33]	*	*	*				*			*			*	
Abdullah and Hamdan [34]		*					*			*			*	*
Dammak et al. [35]	*	*	*							*	*		*	*
Pongcharoen et al. [36]		*	*				*			*			*	
Aladag and Hocaoglu [37]	*	*		*	*		*						*	*

TABLE 1(b). Features described in some previous study

Reference	Constraints													
	Completeness	Conflict of resources	Work load		Availability of resources				Meeting patterns					
			Lec	Stud	Lec	Stud	Room	Slot	A	B	C	D	E	F
Abdullah et al. [38]		*					*			*			*	*
Abdullah et al. [39]		*					*			*			*	*
Al-Yakoob and Sherali [40]	*						*			*	*			
Redl [41]		*	*	*	*		*		*	*				*
De Causmaecker et al. [42]		*		*			*			*	*		*	*
MirHassani [43]	*	*	*	*					*		*			*
Gunawan et al. [44]		*	*		*		*							

In this research, we have undergone surveys to obtain the preferences and demands from the timetabling communities in several local universities. There are still gaps between theory and real-world applications. Through the survey, we managed to list all the information gained and analyzed the additional requirements to be included in our previous general university course-timetabling model [11]. It is essential to produce a friendly schedule for the timetable communities as long as institutions' rules and policies are not violated. Therefore, it is necessary for us to develop a more general timetable that includes as many requirements as possible obtained from our surveys and observations through a number of literature search so that it could be implemented in all universities.

INTEGER LINEAR PROGRAMMING FORMULA

We improvised our previous model not only by identifying through more literatures but also over the surveys done and self-observation on the requirements needed to be included to suit the demands from lecturers and students. Below are the notation used in our integer linear programming formulation:

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_{lec} Class meetings that are taught by lecturer l, $\forall l \in L$.
C_{stud} 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 late evening timeslots
T_{break} Set of prayer and lunch break timeslots
$P_{c,t}$ Preference of having class meeting c at timeslot t.
D_{max} Maximum number of courses a lecturer can teach in a semester
Q_{max} Maximum number of students in each class meeting

Mathematical Model

The improvised mathematical model is developed using the features obtained through the conducted survey. Here, the objective function is to maximize the timeslot preference, $P_{c,t}$ of assigning class meetings. According to the approach of assigning values of $P_{c,t}$, all lecturers will provide different level of preferences for the time periods.

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

Subject to:

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

$$\sum_{c \in C_{lec}} X_{c,t} \leq D_{\max} \tag{1}$$

Maximum number of students in each class meeting

$$\sum_{c \in C_{stud}} X_{c,t} \leq Q_{\max} \tag{2}$$

Avoid late evening class

$$\sum_{c} \sum_{t \in T_S} X_{c,t} = 0 \qquad \forall c \in C \tag{3}$$

Avoid lecture during break

$$\sum_{c} \sum_{t \in T_{break}} X_{c,t} = 0 \qquad \forall c \in C \tag{4}$$

Theory class meeting must be scheduled in the morning session

$$\sum_{t \in T_{morn}} X_{c,t} \leq 1 \qquad \forall c \in C_{theory} \tag{5}$$

Practical class meeting must be scheduled in the evening session

$$\sum_{t \in T_{eve}} X_{c,t} \leq 1 \qquad \forall c \in C_{practical} \tag{6}$$

Minimize the number of days having only one class meeting

$$\sum_{t \in Day_d} \sum_{c \in C_{stud}} X_{c,t} \geq 1 \qquad \forall d \in Day \qquad \forall stud \in S \tag{7}$$

$$X_{c,t} = \begin{cases} 1, \text{if a class meeting, } c \text{ is assigned to timeslot } t \\ 0, \text{otherwise} \end{cases} \qquad \forall c \quad \forall t$$

The features have shown above incorporated another seven new requirements from our previous general university course-timetabling model, with a complete list of other constraints as found in [11]. One existing requirement motivated us to create two other new requirements regarding theory and practical classes. The formulations are shown in equation (5) and (6). Through survey, all respondents agree to have theory classes during morning session while practical classes during evening session. From the survey too, five new constraints were introduced. Requirements that are related to lecturers' work load (1), limitations of the number of students (2), meeting patterns (3), and also time restrictions (4). Constraint (7) is for saving electricity and it gives benefit on the administration. These additional constraints are really on high demand to the timetabling communities.

In another study, the developed model is tested using experimental data to ensure its effectiveness in solving timetable problem. We used AIMMS mathematical software with CPLEX as the solver to obtain the optimal solution of the university course timetabling problem.

CONCLUSIONS

In this article, we focused on reviewing the features used to solve timetabling problem. We have reviewed the features that are usually employed in university course timetabling. The problem which complicates timetabling construction is mainly due to variation of constraints. We have introduced the requirements for university timetable by identifying features that can improve the level of satisfaction among lecturers and students regarding their preferred timetable. These requirements, if considered could possibly change the outcome of the whole learning and teaching environment. Targeting the individuals closely attached to the timetable provided is what really matters. Improving what has been done by emphasizing more on the requirements is one way to achieve this, with the hope of a better future. The ongoing research on this topic includes the solution of the mathematical model to generate a robust solution for course timetabling problem. We will be collaborating with researchers from the computer science department in coming up with software that incorporates this general university course timetabling model for the use of the most universities.

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