An Efficient Automated Timetable for Distance Education of the Open University of Sri Lanka

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Abstract- This paper presents an efficient automated timetable suitable for universities that follow the distance learning education methodology. This study generates a first semester automated timetable and shifts the weekday schedule of the faculty of Natural Science (NSC) at Open University of Sri Lanka (OUSL) to weekends and Fridays. The timetable was modeled considering all three levels. Initially, graph coloring approaches were used to derive course groups, and then those groups were assigned to available time periods using the Binary Integer Linear Programming (BILP) model. A growing number of student registration and introducing new courses yearly made this problem harder which also result in many variables and constraints to the model. The quality of the solution improves according to the date and the time slot allocated to the set of course groups. The model results in a feasible timetable that optimizes the effectiveness of the student's academic performances and it can be implemented with the lecture halls currently available in the faculty of NSC, The OUSL. Changes to this model can be done according to faculty requirements.

Index Terms- Course Timetabling, Graph Coloring, Integer Linear Programming

I. INTRODUCTION

Timetable is a primitive time management tool, which allocates certain resources over time to perform a collection of tasks. For instance, The Public Transportation timetable allocates public transport to certain time periods to assist passengers. There are a variety of timetables such as transportation timetables, working schedules, etc…. This research is based on university course timetabling which can be categories under academic timetables. It assigns course groups having no common students to certain time slots, according to the requirements of the institute. The university course timetable can be scheduled as a weekly or semester wise.

Timetabling is a lengthy process that involves several steps until it assigned courses to time periods. The timetabling problem should be converted to a mathematical model to get a conflict free timetable. Hard and soft constraints are the two categories of objectives imposed by the relevant institute. Hard constraints are compulsory. Those are the requirements that the timetable must follow to get a feasible timetable. Soft constraints are necessary but not essential to generate a feasible schedule. Since under real-world conditions, it's almost impossible to achieve all those requirements. A feasible timetable becomes optimum if it satisfies more soft constraints imposed by the user. The Faculty of NSC at OUSL does not possess an automated timetable and they conduct day schools even on weekdays. To achieve new requirements, they do minor changes to existing semester timetables each year.

OUSL deliver their courses for student through Open & Distance Learning methodology. Therefore, regular attendance at university is not essential for students. Hence, this educational environment motivates employers to follow degrees at OUSL.

However, NSC faculty offer courses under four levels. Those are level 03, 04, 05, and 06. To complete a general degree, students should follow level 03, 04, and level 05 courses. The Special degree students must follow, level 06 courses in addition to the other three levels. Each course can be identified using a unique course code. Instead of weekly lectures, OUSL conducts day schools. The duration of a day school is three hours and it is independent of the credit value of the course. Since day schools conduct only to clear the doubts students have on printed course material which OUSL staff provide when students register for a particular course.

As previously mentioned, the majority of their undergraduates are employers who have busy working schedules. So, weekdays day schools reduced student attendance which also leads to poor academic performances. This will negatively affect the effectiveness of OUSL degree programs and besides causes to drop the number of students register for programs. This research addressed this issue and shift the timetable to weekends.

This study intends to provide a feasible optimum weekend timetable to encourage students to attend day schools. This automated timetable also reduces the wastage of both physical and human recourses as much as possible.

II. MATERIALS AND METHODS

Maple 12 mathematical software was used to implement the early mentioned mathematical model. Before defining an integer linear programming model, the graph colouring approach was used to originate conflict-free course groups (i. e each course group contains courses which followed by a different group of students). Then those course groups can be assigned to different time slots using the ILP model.

The graph colouring process takes courses as vertices and those are connected if courses have at least one common student. Consequently, adjacent vertices received different colours. Courses having a similar colour gather to the same group. A student who registered under the faculty of NSC can select a major subject and two minor subjects. For instance, students following Mathematics won't select Botany or Zoology as the other two subjects. Then these subjects can be placed in the same course groups.

In order to obtain course groups, graph colouring was applied to each level separately. Then those level-wise groups were used to draw another graph. Level wise course groups were considered as vertices and those groups were connected using edge only if those groups contain courses are in the same departments. So, each time slot of the resulted timetable will contain only one subject from each department. This procedure will avoid the difficulties obtained when allocating lecturers to the courses. Since OUSL has eight other regional centres additionally to the main campus, day schools should be conducted at those centres as well. it would be hard to assign lecturers to courses with their lesser number of academic staff in regional centres.

The model-

This is the Formulated binary integer linear programming model which defines the objective and the set of constraints. This model was solved using the branch and bound method. In this model k and t are positive integers which represent the number of course groups and number of available time slots respectively.

$I = \{Set\ of\ course\ unit\ groups\ in\ the\ first\ semester\} = \{1, 2, 3, \cdots, k\}$

$J = \{Set\ of\ time\ periods\} = \{1, 2, 3, \cdots, t\}$

Basic variable-

x_{ij} is the decision variable where $i \in I$ and $j \in J$. This model defines $k \times t$ number of decision variables.

$$x_{ij} = \begin{cases} 1 & if\ i^{th}\ course\ assinged\ to\ j^{th}\ time\ period \\ 0 & otherwise \end{cases}$$

ILP model is formulated as a minimization problem. Following objective function minimize the undesirability of assigning a group of courses to a time slot.

$$minimize\ z = \sum_{i=1}^{k} \sum_{j=1}^{t} x_{ij} p_j$$

p_j values represent the desirability of the assignment of a set of courses to the time slot j. Moreover, higher p_j values imply less desirability to assign a course group j^{th} period.

NSC faculty conduct at least four day school of three hours duration for each course. Therefore, for one day, we can fix only two groups as DSM (Day school morning, 9.00 am − 12.00 noon) and DSA (Day school afternoon, 1.00 pm − 4.00 pm). When assigning $p_j$values to each time slot minimum values were allocated to Saturdays and Sundays in order to shift the weekday's timetable to the weekends. Fridays were also considered to avoid getting a lengthy semester. When considering Friday's minimum values were allocated to evenings. Each semester goes through 16 weeks so when creating timetable four weeks were considered and allocate course groups to those time slots. So that timetable was repeated four times to obtain the complete semester timetable. Table 1 shows the allocation of p_j values.

Table 1: Coefficient of the objective function for quarter of first semester timetable

Time Periods	Saturday	Sunday	Friday
9.00 am-12.00noon	1	9	19
1.00 pm-4.00 pm	2	10	17
9.00 am-12.00noon	3	11	20
1.00 pm-4.00 pm	4	12	18
9.00 am-12.00noon	5	13	21
1.00 pm-4.00 pm	6	14	
9.00 am-12.00noon	7	15	
1.00 pm-4.00 pm	8	16	

Constraints-

The model is solved subject to the following hard constraints. The feasible solution must satisfy these constraints.

$$\sum_{j=1}^{t} x_{ij} = 1 \qquad \forall i \in I \longrightarrow C_1$$

This constraint ensures that all planned courses are assigned to timeslots. This would result k number of constraints.

$$\sum_{i=1}^{k} x_{ij} \leq 1 \qquad \forall j \in J \longrightarrow C_2$$

Set of constraints C_2 assigns exactly one group of courses to a time period. This would generate t number of constraints and automatically provide conflict-free solution.

$$0 \leq x_{ij} \leq 1 \qquad \forall i \in I, and\ \forall j \in J \longrightarrow C_3$$

C_3 is to limit x_{ij} values to a positive value in between 1 and 0, while C_4 confirms the integer solutions.

$$x_{ij} \text{ is an integer } \forall i \in I \text{and } \forall j \in J \ \longrightarrow C_4$$

This model results $t \times k$ binary integer solutions for a quarter of the first semester timetable.

III. RESULTS AND DISCUSSION

Details for this research were gathered from the Natural science dean office and from the OUSL prospectus of 2017-2018. NSC faculty of OUSL has six departments and they offer the following seven types of courses. Botany (BYU), Zoology (ZYU), Mathematics (ADU: Applied mathematics, PEU: Pure mathematics), Computer Science (CSU), Physics (PHU), and Chemistry (CYU).

The first graph created using those departments, this would result set of subjects that can be scheduled in the same time slot for each level.

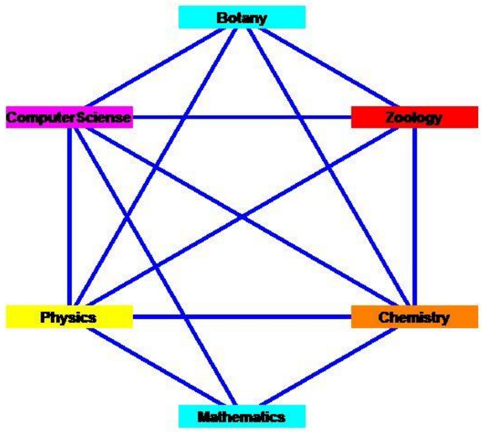

Figure 1: Groups of the Departments

Those groups are,

1. Botany, Mathematics
2. Computer Science
3. Zoology
4. Physics
5. Chemistry

Subjects in the same color can be scheduled simultaneously. For instance, it is possible to schedule Mathematics course units together with the Botany or Zoology subjects.

However, the faculty of NSC offers 56 courses. A graph coloring computer program was used to get conflict-free course groups for each level separately. It resulted the following graphs. Level 03, 04, and 05 have 08, 12, and 21 course groups respectively.

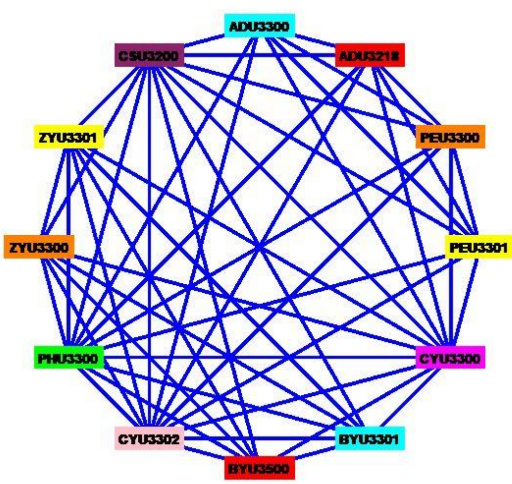

Figure 2: Groups of the Level 03

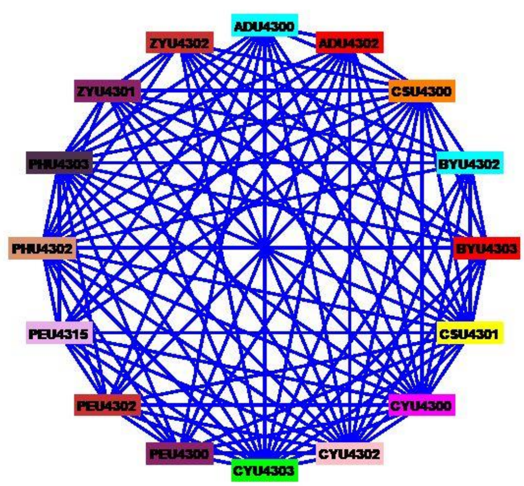

Figure 3: Groups of the Level 04

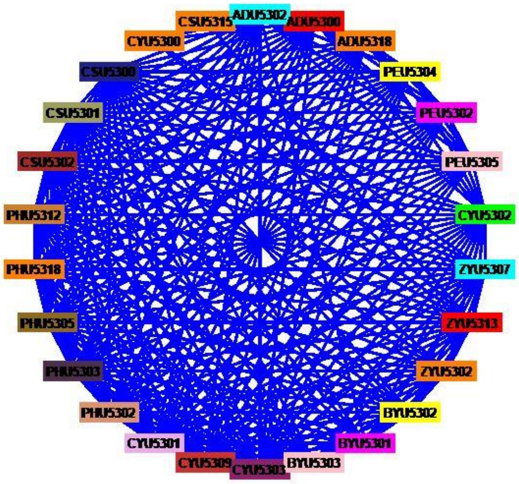

Figure 4: Groups of the Level o5

The final graph drawn in order to avoid complexity occurs when assigning lecturers resulted 21 course groups. This graph contained 41 course groups obtained from all three levels and 443 edges. Those groups are:

1. CSU4300, CYU3300, ADU5300, BYU5301
2. CSU4301, CYU3302, ADU5302, BYU5302
3. CYU4300, PHU3300, ADU5318, BYU5303
4. CSU5300, CYU4302, ADU3300, BYU3301
5. CSU5301, CYU4303, ADU3218, BYU3500
6. CSU5302, PHU4302, PEU3300, ZYU3300
7. CSU5304, PHU4303, PEU3301, ZYU3301
8. CSU3200, CYU5301, ADU4300, BYU4302
9. CYU5302, ADU4302, BYU4303
10. CYU5303, PEU4300, ZYU4301
11. CYU5309, PEU4302, ZYU4302
12. PEU5302, ZYU5302
13. PEU5304, ZYU5307
14. PEU5305, ZYU5313
15. PEU4315, PHU5302
16. PHU5303
17. PHU5305
18. PHU5312
19. PHU5318
20. CYU5300
21. CSU5315

It's essential to schedule four day school per course for a semester. In order to do that ILP would assign 21 course unit groups to 21 time slots. This same timetable repeated four times to generate the complete first semester timetable.

With the results obtained in the graph coloring process, an ILP model was developed which then be solved with the use of MAPLE 12.

$$minimize\ z = \sum_{i=1}^{21}\sum_{j=1}^{21} x_{ij}p_j$$

Subject to;

$$\sum_{i=1}^{21} x_{ij} \leq 1 \qquad \forall j \in J$$

$$\sum_{j=1}^{21} x_{ij} = 1 \qquad \forall i \in I$$

$$0 \leq x_{ij} \leq 1 \;\; \forall i \in I \text{ and } \forall j \in J$$

$$x_{ij} \text{ is an integer } \forall i \in I \text{ and } \forall j \in J$$

Since there are 21 different course groups with 21 of three hours' time periods, the model would result array of (21 × 21) 441 elements.

Table 2 is the model timetable for a quarter of the first semester. This timetable generated for general degree students using the MAPLE12 program. In the new timetable, students do not have day schools on weekdays other than Fridays. It is desirable since most of the students do not prefer lectures on weekdays.

Table 2: Timetable of First Quarter of the First Semester

Time Periods	Saturday	Sunday	Friday
9.00 am-12.00noon	[CSU5304, PHU4303, PEU3301, ZYU3301]	[CSU5304, PHU4303, PEU3301, ZYU3301]	[PEU5302, ZYU5302]
1.00 pm-4.00 pm	[CSU4300, CYU3300, ADU5300 BYU5301]	[PHU5305]	[CYU5300]
9.00 am-12.00noon	[CSU4301, CYU3302, ADU5302, BYU5302]	[CSU3200, CYU5301, ADU4300 BYU4302]	[CSU5315]
1.00 pm-4.00pm	[CSU5302, PHU4302, PEU3300 ZYU3300]	[PEU5304 ZYU5307]	[PHU5318]
9.00 am-12.00noon	[CSU5301, CYU4303, ADU3218, BYU3500]	[CYU4300, PHU3300, ADU5318 BYU5303]	[PHU5312]
1.0 pm-4.00pm	[CSU5300, CYU4302, ADU3300 BYU3301]	[CYU5303, PEU4300, ZYU4301]	
9.00 am-12.00noon	[PEU4315, PHU5302]	[PHU5303]	
1.00 pm-4.00pm	[CYU5302, ADU4302, BYU4303]	[PEU5305 ZYU5313]	

Table 2 shows the distribution of day schools in the first quarter of the first semester. So complete timetable received after repeating the quarter semester schedule would assign each course to four time slots. It reveals that each student in the faculty has two day schools before the Open Book Test (OBT) and one day school before the No Book Test (NBT) and Revision day school before the final exam. This implies that day schools are properly distributed. OBT and NBT exams didn't take to account assuming that those exams are conducted after office hours on weekdays and (4.15 pm-5.15 pm). Also, each time slot contains one course from one subject hence it would be convenient for them to assign lecturers for courses without conflict.

However, those available Friday's time slots can be used to schedule level 6 courses or to conduct workshops and additional day schools.

IV. CONCLUSION

This model is able to shift all NSC first semester day schools to weekends and Fridays only. Further, it is possible to implement the result with currently available lecture halls and academic staff. Hence this model helps to utilize both physical and human resources in the faculty successfully. The problem was solved effectively for the first semester which can be extended to the second semester. This timetable would act as a basis for other faculties as well.

However, as a further development one can find the complexity of the computer programme used to generate this timetable. Moreover, the ordering of course unit groups are taken to be arbitrary since one cannot give preferences to the subjects. But at the department level, they have their own preferences which are difficult to gather. If some ordering method can be applied, one would obtain more efficient results.

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