EXPLORING MATHEMATICAL TOOLS IN DESIGNING EFFICIENT TIMETABLE ALGORITHMS

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ABSTRACT

The problems that can be caused by having too many soft limitations in a timetable should be minimized as much as possible by a university's course schedule. Even though UCTP is widely considered to be one of the most intriguing difficulties that schools are currently facing, some of them are still generating their timetables manually using basic office software like spreadsheets. A large number of educational establishments at the higher education level employ a varied teaching staff that works together to accomplish the educational goals. However, one of the challenges that is faced by the majority of educational institutions is developing a schedule for these lecturers that is free from any potential conflicts. A table that details several events along with the times at which they take place is called a schedule. The curriculum for the forthcoming semester is something that the teaching staff and administrative staff at a variety of educational institutions spend a significant amount of time planning each year. The activities that must be accomplished for the faculty course assignment, for instance, are laid out as linear programmers. Linear programming, which entails the creation of mathematical models or algorithms, can be used to solve the problem of the faculty course assignment. One of the newest tools for dealing with problems that come up with academic course assignments is integer programming. For the purpose of this study, we dealt with the difficulties that arose from faculty course scheduling by employing a method that was based on fuzzy preferences. As a consequence of this, the objective of this research is to build algorithms that may be utilized to optimize resource timetables while producing course schedules for faculty members.

Key words*: mathematical models, algorithms, timetables, educational institutions*

INTRODUCTION

Timetabling can be characterized as the task of certain people to explicit timeframes to accomplish a bunch of goals. Because of the uncertainty in settling on the goal capability, an ideal answer for timetabling is trying with just a single imaginative strategy. Subsequently, a method is important to address every one of the pertinent limitations to get a nearby answer for the enhancement. Since making a course of events is a troublesome and tedious activity for the dependable staff, having it done naturally can diminish their responsibility. Because of the expanded number of courses, scholastic subjects, and booked courses in a college, designating a reasonable site without programming is very difficult because of space requirements, client area, suitable time, and Teacher. There are generally two sorts of cutoff points with these issues: serious and delicate requirements. Under all conditions, serious constraints can be given. Serious limitations are conditions that should be seen to have exact and adequate plans. In every timeframe, every teacher is simply expected to show one class. All classes that are being considered should stick to the plan. As far as subject, all planned rooms ought to be in concurrence with the guidance.

The planning required for university on a weekly basis is difficult. As a direct consequence of this, the courses need to have their timing adjusted in accordance with the relaxed and strict limits. The purpose of this exercise is to identify soft limitations, but the idea is to identify severe constraints (some of which may be reversible under specific conditions and at a significant cost). Due to the fact that both students and teachers are placed in certain courses, course groups, or classes, the process of weekly planning takes on multiple dimensions. After the issue has been resolved, there are a few constraints concerning the level of customer demand that need to be taken into consideration. It is a task that entails dividing up specified activities (such lessons and tests) into a number of time slots or classes. The following might serve as a simple definition of university course scheduling:it is a task that involves the assignment of specified events. According to this interpretation, the process of scheduling university classes can be broken down into two distinct categories: course planning and test planning. Exam planning and course planning share some similarities in terms of the nature of the considerations that universities take into account, but the most significant distinction lies in the fact that in exam planning, multiple events can be scheduled concurrently in common periods and classes, whereas in course planning, this is not possible. When constructing courses, only one group course and one course in total can be allotted to each period of time.

LITERATURE REVIEW

Algethami, Haneen (2021) the challenge of developing an automated schedule for classes within the confines of a university's limited resources is referred to as the university course timetabling problem (UCTP) Timetables that are generated manually are prone to inaccuracies and need a significant amount of effort to produce workable solutions. As a consequence of this, solutions that are both effective and rapid to implement are necessary. The complexity of the timetabling task is increased when dealing with limits connected to the faculty, such as their requirements, preferences, and availability. This can make the challenge feel even more insurmountable. As a consequence of this, the solutions that are developed by UCTP concentrate on the limits that are associated with the students, while the faculty members' limitations are restricted to their teaching schedules or preferences. This work provides a multi-objective mixed-integer programming model for a preregistration UCTP with faculty-related restrictions. When arranging event assignments, the goal is to maximise faculty members' happiness while following university standards. The quantity of unscheduled activities and student learning days is being reduced at the same time. We employ a total of eight various real-world scenarios for assessing the model. Computational experiments are performed in order to show the model's utility.

AbdoulRjoub (2020) Manual school timetable scheduling is not only time-consuming and tedious, but it also frequently results in the assignment of the same teacher to multiple classes, the assignment of multiple teachers to the same classroom at the same slot time, or even the exercise of deliberate partialities in favour of a particular group of teachers. All of these circumstances are bad for the following reasons, but not only those listed below: In order to help with the settlement of the customary conflicts that arise from human scheduling, this research proposes a method for the automated scheduling of school schedules. In order to get beyond the method's inherent hard and soft restrictions, hill climbing algorithms have been improved. In the majority of cases, it will be challenging to follow lax regulations, yet severe rules must be followed anyway. This approach has been used in a variety of educational contexts and has proven beneficial, although there are a number of limitations. Within the first five seconds and the second iteration, the initial answer can be improved by 72% and 50%, respectively, toward the ideal solution, with the optimal solution being attained after 15 iterations.

Anderson Goes (2019) This article covers the subject of school timetabling, which is the process of choosing the day and time that instructors will teach lessons at educational institutions. In order to produce and optimise Elementary and High School schedules while taking into account instructors' preferences for certain days or sequenced (twinned) lessons, a tool based on operational research (OR) methodology was developed. The following is how the document is set up. In addition to the Local Search (LS) and Iterated Local Search (ILS) techniques, a mathematical model known as Non Linear Binary Integer Programming (NLBIP) was used to solve the problem. Araucária, a city in the state of Paraná, Brazil, underwent an inquiry into a severe issue regarding the daily schedules of 14 public schools. The results show that the computational time demanded by the mathematical model is feasible under the current conditions. The ILS approach can test bigger scale issues since it has a dispersion that is between 3.5 percent and 7.7 percent lower than the best solution (which was generated by the NLBIP) and a computation time that is between 15 and 338 times quicker.

Mohd Rahman (2018) Course scheduling is one of the most time-consuming and important jobs that any educational institution must complete. The process of course scheduling, on the other hand, takes a lot of time and can be very taxing due to the fact that it needs to be done for every typical semester. This study's objective is to evaluate several optimization algorithms that can be used to address the challenge of successfully scheduling classes. A classification of Hard Constraints and Soft Constraints, in addition to a classification of Optimization Methods, is used to collect and distribute the information. According to the findings, the use of meta-heuristics is the method that is put into practise the most frequently in order to solve the problem of course scheduling. When compared to the other processes that were examined, it was determined that this method should be regarded appropriate for use in the future. An examination and a close watch will be maintained for the continuation of the investigation.

Genetic Algorithms

The university course scheduling problem must first be resolved in order for scheduling algorithms to discover a solution that satisfies a set of constraints. Depending on the circumstances, these restrictions are either required or optional. The definition of an essential limitation is one that, if not met, would lead to an impractical timetable. The ones that aren't necessary, on the other hand, raise the standard of the framework. GAs, a type of technique, may be used to quickly identify answers to certain difficulties. They are founded on the ideas of genetics and natural selection, and their main tenet is that the healthiest members of a population are chosen, who later mix with other members of the population or mutate into new forms to establish new groups. The challenge of timetabling is that it calls for instructors and students to work together to arrange the scheduling of several classes within a limited period of time while adhering to a variety of regulations. Any educational institution can experience this difficulty, but as a school's size grows, the intricacy of the problem also rises.

University timetabling regulations

The key scheduling requirements of the university are considered to be stringent limits.

a. When two or more classes for the same teacher are scheduled at the same time in the same classroom for the same group of students, there is a scheduling conflict. Finally, when two or more classrooms are assigned to the same course and group of students at the same time; when two or more teachers are assigned to the same group of students in order to teach two independent courses at the same time.b. A timetable is considered to be finished when the total number of hours for the course has been established and the teacher's teaching load has not surpassed a limit that was previously established. There are also regulations that are considered soft limitations; examples of them are as follows:· Preferences for teachers in the allotted time intervals are honoured to the best of our ability. Every member of the faculty has the ability to name their favourite subject area.

Mimetic Algorithm for the University Course Timetabling Problem

It's feasible that a work's specifics will make scheduling issues considerably more challenging. If a general algorithmic solution relies on certain limitations that might be required in a given instance of the issue, it might not be applicable to other instances of the problem. It is essential to schedule activities (subjects, courses) into a number of time slots while following to a number of restrictions in order to resolve the university course scheduling problem, commonly known as UCTP. Each university has a varied class schedule because of its unique set of resources and limitations. For the UCTP, no deterministic polynomial time method is currently known to exist. The UCTP issue is an NP-hard problem, to put it another way. Traditional computer-based timetabling techniques primarily concentrate on creating the schedule; nevertheless, these approaches fall short of meeting all essential requirements It might be difficult to come up with answers utilising knowledge-based or operations research-based methodologies when dealing with such problems. Due to the unique assumptions about the nature of the problem on which they are based, these approaches are often characterised by their slowness and rigidity.

Mathematical Model for an Educational Institution's Timetable Scheduling Problem Optimization

Concerns pertaining to scheduling constitute an important tactic that have to be implemented in virtually every sector of the economy in the present day. Problems with scheduling can manifest in a variety of contexts, including the departure times of flights, the shift schedules of nurses or doctors, factory shift plans, course timetables, and test schedules at educational institutions. In this study, we take a look at one of the time scheduling approaches that were discussed earlier, namely the educational time scheduling approach. The assignment of courses that belong to teacher and student groups to classrooms of appropriate capacity at appropriate time intervals in educational institutions is the focus of the education time scheduling problem. The overarching goal of this problem is to make the best possible assignments given the resources, needs, and expectations of the educational institution.

METHODOLOGY

mixed integer linear programming technique was used to formulate the mathematical programming model of the school timetabling problem for the high school system. An Enhanced Simulated Annealing (ESA) algorithm for solving the school timetabling problem was formulated, which incorporates specific features of Simulated Annealing(SA) and Genetic Algorithms(GA). The formulated mathematical model with ESA algorithm and SA algorithm were implemented using Matrix Laboratory 8.6 software on an Intel(R) Core(TM) i3-7100 CPU with 2.50GHz speed, 32GB Hard Disk, 4GB Random Access Memory and 32-bit Operating System, with the Window 7 operating system, and validated using a highly constrained high school dataset. The implemented algorithms were evaluated using constraints violation, simulation time and solution cost as performance metrics.

RESULTS AND DISCUSSIONS

For the remaining courses, the XYZ institution has 8 tenured faculty members and 4 new faculty members. Table 1 shows the administrator preferences for twelve faculty members and the remaining course teaching load that can be assigned. For -assigning courses to faculty, the administrator preference levels are 1, 2, 3, and 4. The table of interpretation is as follows: Course 3 is 3rdoption, course 6 is 4thchoice, and course 13 is 1stchoice for F' faculty given preferences by the administration, whereas the rest of our blanks signify those courses will not be assigned to him/her. In the same way, the administrator's other faculty course preferences are listed in Table.1:

Table 1: Administrator preferences level for assigning courses to the faculty

Course(i)	tenured faculty(j)								new faculty(j)			
	1	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***	***10***	***11***	***12***
1		4	4	4	4	4	4		1			
2				4	2			3	1		2	1
3	3	3			1	4			1	1		
4(2)		2	2	3	4		4	2		2	1	1
5		4			4			1				1
6	4	2			4							
7			2			1				2		
8			1							1		

9		1	3	4	2	4	4		2			
10		3	1		3	3	2		2	1		
11		3		2			3				2	
12				1		4						
13	1							2				2
14					3		2	2				2
15		2		4	2	4	3				2	
16		3			4			1				
17			2			3						
18				3			3					
19		3		1	4		3					
20					3		1	4				
Number of courses are assigned	1	3	2	2	2	2	2	2	<= 2	<= 2	<= 2	<= 2

The goal functions f_k for the faculty preference levels for the courses to be assigned for 12 faculty and 20 courses utilizing this data are as follows; The remaining 20 courses to be assigned to the faculty member in the faculty course assignment problem We've introduced new variablesx_r. in our approach for computational simplicity. This x_r is used to substitute x_{ij} for the straightforward calculation of professor assignments.The variable x_l indicates the 1st course to the 2nd faculty, while variable; x_{45} indicates the 9th course to the 6th faculty, according to the table. Similarly, all additional faculty courses are listed in Table.2 as variables.

Table 2: New variables given for the preferences of faculty courses assignment

course (i)	tenured faculty(j)								new faculty (j)			
	1	2	3	4	5	6	7	8	9	10	11	12
1		x_1	x_2	x_3	x_4	x_5	x_6		x_7			
2				x_8	x_9			x_1	x_1		x_1	x_1
3	x_1	x_1			x_1	x_1			x_1	x_1		
4(2)		x_2	x_2	x_2	x_2		x_2	x_2		x_2	x_2	x_2
5		x_2			x_3			x_3				x_3
6	x_3	x_3			x_3							
7			x_3			x_3				x_3		

8			x_3							x_4			
9		x_4	x_4	x_4	x_4	x_4	x_4		x_4				
10		x_4	x_4		x_5	x_5	x_5		x_5	x_5			
11		x_5		x_5			x_5				x_5		
12				x_5		x_6							
13	x_6							x_6				x_6	
14					x_6		x_6	x_6				x_6	

When we use LINGO software to solve this model of the first stage, the allocation plan is indicated in Table3, and the objective values are documented in Table 4.Faculty course assignment is provided in Table 3, which was derived using the linear membership function. The value x_{14} in Table 3 denotes the 3rd course to the 1st faculty, with an ideal value of 1. All other courses are assigned to the faculty in the same fashion, as stated below:

Table 3: Courses assigned to the faculty according to preference levels

Faculty (j)	1	2		3		4		5	6		7		8			9		10	11		12
Course (i) assigned	x_1	x_{34}	x_{41}	x_{36}	x_{39}	x_{56}	x_{82}	x_{85}	x_{60}	x_{78}	x_{72}	x_{80}	x_{62}	x_{76}	x_7	x_{11}	x_{54}	x_{27}	x_{27}	x_{32}	x_6

We utilized a linear membership function to solve the model for the first stage. Table 4 shows the obtained objective values.

Table 4: The computational result of objective functions using LMF

Objective function	f_1	f_2	f_3	f_4		f_5	f_6	f_7	f_8	f_9	f_{10}	f_{11}	f_{12}	f_{13}	f_{14}	f_{15}^{O}	f_{15}^{M}	f_{1}^{P}
Objective values	1	2	2	2		1	2	2	2	2	1	2	2	39.00	3.00	4.60	6.70	8.80

In the second stage, the output of the first stage, as shown in Table , is used to determine faculty course timeslot preferences for each course.

CONCLUSION

This study made use of a random mathematical algorithm (RMA) and a probabilistic mathematical timetabling algorithm in order to answer the problem of faculty subject assignment in educational timetabling. Both of these algorithms are mathematical (PMTA). Because of the algorithms, the allocation of subjects is fair among all of the faculty members. The challenge of developing an automated schedule for classes within the confines of a university's limited resources is referred to as the university course timetabling problem (UCTP). When prepared by hand, timetables run the risk of being inaccurate and require a significant amount of time before they can deliver useful results. Because it provides algorithms with a bigger search field in the first phase, allowing them to meet hard constraints while disregarding soft constraints, we decided to go with and implement a two-phase technique to solve the timetabling issues we encountered in this article. In order to solve the issue of timetabling, we proposed metaheuristic-based solutions. As a result, the majority of our conversation was devoted to discussing metaheuristic-based algorithms, such as evolutionary algorithms, simulated annealing, tabu search, ant colony optimization, and honey bee algorithms. In addition to the challenges associated with timetabling, these methods have been used to the resolution of a large number of additional combinatorial optimization issues by modifying an algorithmic framework designed for universal use.

REFERENCE

1. *Algethami, Haneen&Laesanklang, Wasakorn. (2021). A Mathematical Model for Course Timetabling Problem With Faculty-Course Assignment Constraints. IEEE Access. PP. 1-1. 10.1109/ACCESS.2021.3103495.*
2. *Almutairi, Badr. (2020). An Integer Linear Programming Model for Solving Radio Mean Labeling Problem. IEEE Access. 8. 162343 - 162349. 10.1109/ ACCESS.2020.3021896.*
3. *Anderson. Goes, (2019). Optimization in timetabling in schools using a mathematical model, local search and Iterated Local Search procedures. Gestão & Produção. 26. 10.1590/0104-530x3241-19.*
4. *Kanmani, Selvadurai. (2011). Design of GAmut-Lssahc: A solver for course timetabling problem. International Journal of Mathematics in Operational Research. 3. 10.1504/IJMOR.2011.043012.*
5. *Nordin, Syarifah. (2018). Mathematical model for timetabling problem in maximizing the preference level. AIP Conference Proceedings. 1974. 020037. 10.1063/1.5041568.*
6. *Rahman, Mohd. (2018). A study on optimization methods for solving course timetabling problem in university. International Journal of Engineering and Technology(UAE). 7. 196-200. 10.14419/ijet.v7i2.14.12824.*
7. *Rjoub, Abdoul. (2020). Courses timetabling based on hill climbing algorithm. International Journal of Electrical and Computer Engineering (IJECE). 10. 6558. 10.11591/ijece.v10i6.pp6558-6573.*
8. *SagirOzdemir, Mujgan. (2019). A New Mathematical Model And Random Key Based Metaheuristic Solution Approach For Course-Room-Time Assignment Problem. Eskişehir Osmangazi Üniversitesi MühendislikveMimarlık Fakültesi Dergisi. 27. 10.31796/ogummf.549986.*
9. *Sajadi, Seyed. (2013). A mathematical model for university course timetabling problems by considering multi functions. Int. J. of Modelling in Operations Management. 3. 282 - 295. 10.1504/IJMOM.2013.058336.*
10. *Sherali, Hanif. (2015). Mathematical models and algorithms for a high school timetabling problem. Computers & Operations Research. 61. 10.1016/j.cor.2015.02.011.*