Using Iterated Local Search to Solve the Course Timetabling Problem at Engineering Faculty of Necmettin Erbakan University

Kemal Alaykiran, Mehmet Hacibeyoglu

Abstract— **Timetabling of courses, lecturers and available rooms at an educational institution is a hard optimization problem to solve. In this study, the timetabling problem at Engineering Faculty of Necmettin Erbakan University located in Konya,Turkiye is considered. The Engineering Faculty of Necmettin Erbakan University is a new but rapidly developing educational unit. Although it is established in 2010, in 2016 it has reached to 12 undergraduate engineering departments with about 1500 undergraduate students. As the literature for the timetabling problems investigated, it is figured out that the problem considered in this study best fits the curriculum based course timetabling problem which is detailed and structured at International Timetabling Competition (ITC) in 2007. The main objective of the problem is to develop an algorithm and methodology to achieve feasible timetables for the faculty for all semesters. The side goals of the study are to decrease the total number of rooms for all courses and to decrease the periods of courses in a day which is ten at the current situation. In order to achieve these goals, an iterated local search algorithm is coded and run for different scenarios. The experimental results are analyzed comprehensively.**

Index Terms— **Course timetabling, Necmettin Erbakan University, Iterated Local Search.**

I. INTRODUCTION

Timetabling of courses, lecturers and available rooms at an educational institution is a hard optimization problem to be solved at least once a year. As a special form of scheduling problems the timetabling problem is also an NP-hard problem [1] however this problem is mostly solved by human experience. The literature of timetabling problem may be divided into various sub groups. Since the objective of this paper is to solve a local case of curriculum based course timetabling problem using a metaheuristic, the literature related to this group of studies are investigated. Since timetabling problem is an important practical problem, three international competitions are carried out for researchers and practitioners to challenge their solution methods for different classes of timetabling problem in 2002, 2007 and 2011. In this study, the curriculum based course timetabling (CBCTT) problem described and structured at the competition in 2007 is considered with the data of Engineering Faculty of Necmettin Erbakan University. In [2], a technical report on CBCTT problem for ITC 2002 is given where the objective, the constraints and the notation of the problem is described. At [3], the CBCTT instances at ITC 2002 are solved using adaptive tabu search algorithm. Lü et. al [4] solved CB-CTT instances of ITC 2007 using three different metaheuristic algorithms, tabu search, iterated local search and adaptive tabu search respectively. At [5], a threshold accepting metaheuristic is provided for CBCTT. At [6], CBCTT is solved using a hybrid method which combines the features of genetic algorithms and tabu search where at [7], an hybrid of simulated annealing and tabu search is used. At [8], the problem is solved using simulated annealing method.

In this paper, the timetabling problem of courses, lecturers and rooms at Engineering Faculty of Necmettin Erbakan University is structured as a CBCTT instance using the data of 2016-2017 fall semester. The problem is defined in detail at Section 2. In order to solve this problem for various scenarios, an iterated local search (ILS) algorithm is coded. The ILS method provided is described at Section 3. The problem is solved multiple times for different parameters of total number of available rooms and total number of periods a day. These experimental results are given at Section 4. The paper is finalized with conclusions.

II. PROBLEM DEFINITION

Although Engineering Faculty of Necmettin Erbakan University is established in 2010, it has shown a rapid progress and reached up to 12 undergraduate programs with about 1500 students. In fact there are 14 departments when Architecture department and department of City and Regional Planning are added but these two have their own building but the remaining 12 departments are sharing the same temporary building until the main campus construction is finished. The data of 2016 – 2017 fall semester is used to structure the problem. There are 40 curricula which represents every class of every department. There are 313 courses with 856 lectures. The average of students having courses is 57.4 where the maximum is 143 and the minimum is 6. These courses are given by 100 individual lecturers and average course load of lecturers is 8.56 hours per week where the maximum is 22 and the minimum is 2 per week. There are five different room types, 5 lecture theaters (LT) with 150 student capacity, 4 Type-1 classrooms with 88 student capacity, 4 Type-2 classrooms with 60 student capacity, 5 Type-3 classrooms with 48 student capacity, and finally 6 Type-4 classrooms with student capacity of 75 which are located at another building. At the current situation, the courses are scheduled for 5 days a week and 10 periods a day.

In order to solve this timetabling problem with these data,

Kemal Alaykıran is currently working as an Assistant Professor at the Industrial Engineering Department of Necmettin Erbakan University (Konya, Turkey).
Mehmet Hacibeyoglu is currently Assistant Professor at the Computer Engineering Department of the Konya Necmettin Erbakan University (Konya, Turkey).

the methodology of CBTT problems described at [2] are used. There are two different kinds of constraints: hard and soft, where hard constraints denote to the feasibility of the solution and soft constraints denote to the quality of the solution. There are three hard constraints all of which must be satisfied by a solution to be feasible in this study. First, all lectures of all courses must be assigned to available time periods and rooms. Second, a room can host at most one lecture at a period. Third, at a specific time period at most one lecture of a curricula can be scheduled also a teacher can be scheduled exactly one lecture at a time period. In order to evaluate the quality of a feasible solution to another, four soft constraints are considered as weights of the objective function. First, a minimum working day is determined for each course if the course is scheduled and partitioned less than this number, the objective function is added a penalty of 5 per day per course. In this study, for the courses with less than 4 lectures, the minimum working day is considered to be 1, for those of the courses with 4 to 5 lectures, the minimum working day is assumed to be 2, and for the courses with 6 or more lectures the minimum working day is assigned as 3. This soft constraint is named as Minimum Working Days. As the second soft constraint, it is intended to minimize the idle time for students of a curricula. In order to achieve this, a penalty of 2 units is given per empty time periods for a lecture which is not adjacent to any other lecture of that curricula in the same day. This soft constraint is named as Curriculum Compactness. As the third soft constraint, it is intended to achieve a solution where the number of students of a course does not exceed the capacity of the room the course is assigned. For every student exceeding the capacity of the room assigned, a penalty of 1 unit is calculated. This soft constraint is named as Room Capacity. As the fourth and the last soft constraint, it is preferred that all lectures of a course are taught in the same room. A penalty of 1 unit is given to each additional room assignment of a course. Finally this soft constraint is named as Room Stability.

In this study, the main objective is to establish an algorithm to find out timetables of courses, rooms and lecturers at Engineering Faculty of Necmettin Erbakan University. In order to achieve this goal, the data of 2016-2017 fall semester is considered. The timetabling problem is structured adapting the hard and soft constraints of ITC 2002 which are described at [2]. The side goals of the study is to analyze the availability of accurate timetables with less classrooms used or with less time periods per day is considered. In order to achieve this analysis, an experimental study is conducted for multiple scenarios.

III. Iterated Local Search (ILS) Algorithm

The ILS algorithm developed for solving the timetabling problem at Engineering Faculty of Necmettin Erbakan University starts with a feasible initial solution. Since the feasibility of the solution requires satisfying all hard constraints, once a hard constraint is violated another random initial solution starts until all hard constraints are satisfied. Once a feasible initial solution is reached, the objective function of this solution is calculated using the soft constraint violations. Then the local search procedure starts with finding two random lectures. These are swapped, and the feasibility of the new solution is checked. If the solution is still feasible then the quality of the solution is calculated using soft constraints. If the new solution is better than the existing one the new solution is chosen. The search procedure continues until no solution improvement is occurred during a number of iterations which is experimentally chosen as 20000 for this study. The pseudo code of the ILS developed for timetabling in this study is given at Figure 1.

```
procedure ILS
        s0 ← GenerateInitialSolution
        s* ← LocalSearch(s0)
        while Stopping criteria is not met do
                s' ← Perturb(s*)
                s*' ← LocalSearch(s')
                s* ← AcceptanceCriterion(s*, s*')
        end
end
```

Fig. 1. Graphical representation of computational results

IV. Computational Results

In order to analyze the performance of the ILS method developed for the solution of the timetabling problem at Engineering Faculty of Necmettin Erbakan University, first the current scenario is solved which consists all 24 rooms and where the lectures are given at 10 periods of 5 days. This problem is solved five times and the objective function values and soft constraint violations are shown at Table I.

Table I. Solutions for the first scenario

Case	Run	Objective Function Value	Soft Constraint Violations			
			Minimum Working Days	Curriculum Compactness	Room Capacity	Room Stability
Current Situation	1	102	-	-	2	100
	2	113	-	-	5	108
	3	106	-	-	2	104
	4	**83**	**-**	**-**	**2**	**81**
	5	89	-	-	4	85

As seen at Table I, the primary objective of this paper which is finding a feasible schedule for the courses, lecturers and rooms at the Engineering Faculty of Necmettin Erbakan University is achieved and for all runs a suitable timetable is found. When the results shown at Table 1 are analyzed from the solution quality point of view, it may be seen that Minimum Working Days and Curriculum Compactness soft constraints are never violated where Room Capacity and Room Stability soft constraints are violated at variant values while the best objective function value found is 83.

Since the validity of the solution procedure is proved solving the current situation of the system, a new scenario is tested for decreasing values of available periods in days. In the current situation, the system allows assigning at most 10 periods a day. At Table II, the results of scenario analysis for decreasing available time periods a day parameter are given where total number of rooms is hold as constant. Since there are 856 lectures to be scheduled and there are only 24 rooms, theoretically the time periods a day cannot be less than 8.

Table II. Solutions for the second scenario

Available periods a day	Run	Objective Function Value	Soft Constraint Violations			
			Minimum Working Days	Curriculum Compactness	Room Capacity	Room Stability
8	**1**	**94**	**-**	**-**	**3**	**91**
	2	**94**	**-**	**-**	**5**	**89**
	3	100	-	-	5	95
	4	100	-	-	6	94
	5	95	-	-	6	89

As it may be seen at Table II, when the number of periods per day is decreased to 8 from 10, the algorithm still finds feasible solutions with different objective function values for all of the 5 runs. Also, it may be said that only Room Capacity and Room Stability soft constraints are violated for this scenario.

As the third scenario, the number of available rooms are changed while the available periods per day is hold at 10. Theoretically, since there are 856 lectures and 10 time periods for 5 days, at least 18 classrooms are needed. At the current situation there are 24 classrooms with varying capacities. At this case, all of the Type-4 classrooms (C4) which are at another building are dismissed, and the problem is solved for five runs.

Table III. Solutions for the third scenario

Case	Run	Objective Function Value	Soft Constraint Violations			
			Minimum Working Days	Curriculum Compactness	Room Capacity	Room Stability
Type-4 Classrooms are dismissed	**1**	**108**	**-**	**6**	**4**	**98**
	2	114	-	4	6	104
	3	116	-	4	10	102
	4	118	-	6	9	103
	5	121	-	6	10	105

The experimental results of the third scenario when all 6 of the Type-4 classrooms are dismissed are shown at Table III. Since these classrooms are at another building and both the students and the lecturers should change the building for the lectures, this scenario is an important improvement to the current situation. As it may be seen at Table III, the algorithm finds feasible solutions to the problem even if the number of available rooms is decreased from 24 to 18 which is the theoretical minimum number of rooms for feasibility. However, for this case, the objective function values increase and Curriculum Compactness soft constraint is violated. The best solution is found at the first run of the problem where the objective function is found to be 108.

The experimental results show that the ILS algorithm developed to solve the timetabling problem at Engineering Faculty of Necmettin Erbakan University is capable of finding feasible solutions for not only the current situation of the problem but for some cases of the problem. Decreasing total number of periods a day from 10 to 8 is beneficial for both the students and the lecturers whereas decreasing the number of rooms which are at another building also serves both students and lecturers.

V. CONCLUSION

In this study, the timetabling problem of courses, lecturers and rooms of the Engineering Faculty of Necmettin Erbakan University is considered. First the problem is structured as a CBCTT problem as it is described at ITC 2002. Every class of every department is considered as a curricula where a total of 40 curriculum is achieved. An ILS algorithm is developed for the solution of the problem. The main objective is considered to find a feasible solution to the current situation of the problem. With 313 courses and 856 lectures given by 100 lecturers at 24 rooms at 10 periods for 5 days a week, the problem is quite complex. The experimental results show that the feasibility condition of the problem which is satisfying all hard constraints is achieved for varying values of soft constraints which denotes to the quality of the solution. Once the current situation of the problem is solved, two different scenarios are considered. First, the effect of decrease in available periods a day parameter is considered. The theoretical minimum value of eight periods a day scenario is solved with the developed ILS algorithm and the feasibility condition is satisfied. As the second scenario, the number of rooms is decreased to its theoretical minimum value of 18 by dismissing 6 of the Type-4 classrooms which are located at a different building. Again, the algorithm successfully achieved feasible solutions with varying objective function values.

As a future remark, the problem may be considered with different performance criteria such as maximizing the idle days of students of different curriculum or maximizing the free days of lecturers while satisfying the existing constraints. Also, the algorithm may be used to solve the timetabling problem of other faculties.

ACKNOWLEDGEMENTS

This study is supported by the Scientific Research Projects Unit of Necmettin Erbakan University of Turkiye under grant number 151219011.

REFERENCES

[1]. E. Burke, J. Marecek, A. Parkes and H. Rudova, "Decomposition, reformulation, and diving in university course timetabling", Computer Operations Research, 37(3), 582–597, 2010.
[2]. L. Di Gaspero, B. McCollum and A Schaerf, The second international timetabling competition (itc-2007): curriculum-based course timetabling (track 3). Technical report, School of Electronics, Electrical 123348, 2007.
[3]. Z. Lü and JK. Hao, "Adaptive tabu search for course timetabling", European Journal of Operational Research, 200(1), 235–244, 2010.
[4]. Z. Lü and JK. Hao and F. Glover, "Neighborhood analysis: a case study on curriculum-based course timetabling", Journal of Heuristics 17(2), 97–118, 2011.
[5]. MJ Geiger, "Applying the threshold accepting metaheuristic to curriculum based course timetabling", Annals of Operations Research, 194(1), 189–202, 2012.
[6]. S. Abdullah, H. Turabieh, "On the use of multi neighbourhood structures within a tabu-based memetic approach to university timetabling problems", Information Science, 191,146–168, 2012.
[7]. R. Bellio, L. Di Gaspero and A. Schaerf, "Design and statistical analysis of a hybrid local search algorithm for course timetabling", J Sched, 15(1):49–61, 2012.
[8]. R. Bellio, S. Ceschia, L. Di Gaspero, A. Schaerf and T. Urli, Feature-based tuning of simulated annealing applied to the curriculum-based timetabling problem, Computers and Operations Research, 65: 83-92J, 2016.

Kemal Alaykıran is currently working as an Assistant Professor at the Industrial Engineering Department of Necmettin Erbakan University (Konya, Turkey). He received the B.Sc., M.Sc., degrees in Industrial Engineering at Selcuk University and Ph.D. Degree in Industrial Engineering at Gazi University (Ankara, Turkey). His research interests are mathematical modeling, optimization and simulation of systems.

Mehmet Hacibeyoglu is currently Assistant Professor at the Computer Engineering Department of the Konya Necmettin Erbakan University (Konya, Turkey). He received the B.Sc., M.Sc., and Ph.D. Degrees in Computer Engineering at Selcuk University (Konya, Turkey) in 2003, 2006, and 2012, respectively. His research interests are machine learning, feature selection, logic circuits, meta heuristic algorithms, information security and data mining.