Survey on UniversityTimetabling Problem

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Abstract-*The University course timetabling problem is confirmed to be an NP-Hard problem. It tackles the problem of assignment, set of course set of room in the given timeslot according to the given constraints. With the help of given constraints we assign the available resources. In this paper after a brief history account, we describe different types of timetabling problem and afterward describe some widely used methodologies to solve the timetabling problem like artificial ant colony(ACO), hybrid bee colony optimization method(HBC), PSO(particle swarm optimization), genetic algorithm etc.*

Keyword: University Timetabling,Metaheuristic,scheduling,local search, bio-inspired computing.

I. INTRODUCTION

The basic idea of this problem is the assignment of available resources in the given set of time slot which can reduces the overhead and the chance of error. Timetabling problem is referred to as a NP hard problem study by Even and Itai [1], so it is difficult to get the optimal solution for the given large instances. Timetabling problem is also known as the resource allocation of the predefined constraints contains two types of constraints hard constraints and soft constraints. Where hard constraints like classroom, class timing etc. it should be fulfilled at any cost, while the soft constraints such as teacher preferences they can be violated if necessary, but it is panelized. Each violation contains a small panelty.In order to obtain a feasible timetable it is forced to satisfy all the hard constraints [2].The problem is mainly concern by the computer science, operational research and artificial intelligence.The course timetablingdiffers from university to university. Conventionally this problem is done manually but due to the large number of various Constraints, resource limitation and complicated human factors involved the problem become harder to solve .for this reason various algorithms and approachesare proposed. For finding the optimal solution various methodologies are studied by a large number of researchers they used different methods to solve this problem to get the optimal solution [3].metaheruistic based, cluster based, constraint based, hyperheuristic, adaptiveapproach, and various search based methods are used.in[3]graph coloring is used to get the optimal solution limited numbers of colors are given which the nodes which connected to same edge does not colored with the same color, they must have the different color. Particle swarm optimization [13] is a bio-inspired algorithm which shows fast convergence toward NP complete problem. Due to its NP hard nature timetabling problem is solved by using various metaheuristic algorithm they are nature – inspired algorithm [4], genetic algorithm [8], simulated annealing [5] it is a probabilistic local search method. [3] Constraint based reasoning is another successful technique to solve University timetabling problem, in this approach the problem is firstly described as CSP and then solve this CSP by using various CSP solving approach ,backtracking ,path consistency are oftenused. The university timetabling problem is composed by the examination timetabling problem(ETTP),course timetabling problem(CTTP),lecture timetabling problem(LTTP), and the tournament timetabling Problem (TTTP).where course timetabling se the combination of weekly scheduled leacture.The examination problem is differ from both lecture and course timetabling problem. Tournaments are mostly scheduled after the class hours.In this paper first section contains introduction a brief description of the problem, in second section there is the problem description and its mathematical notation here we give the definitions of UTTP problem, afterward previous work is described in the next section than in next sectionthe section 4 we describe the proposed solutions for the problem and in last section we give the conclusion.

978-9-3805-4421-2/16/$31.00

II. PROBLEM DESCRIPTION

The solution of Timetabling problem depends upon various factors mainly the constraints which imposed, hard constraints which is for giving the feasibility of solution and soft constraints giving the quality to the solution.Whereas the problem is consist of large number of variant, so it is hard to get the optimal solution, thus for solving this problem we first categorized it.

A. University Timetabling Problem (UTTP)

It refers the scheduling of weekly course lectures and the monthly or yearly examinations. The schedule must have satisfied all the given constraint and the assignment of lecture and class should be fit in a given time slot.

B. Course timetabling problem(CTTP)

CTTP refers the weekly scheduled lectures of the given course. There is a number of courses in the university, the problem is assignment of teachers, and classroom in the given time slot.

C. Lecture Timetabling Problem(LTTP)

The LTTP is defining the scheduling of a single lecture of courses as per university ordinance in a day, without overlapping to one another. LTTP is differ from CTTP one course can have multiple lectures but a single lecture have not multiple courses.

D. Examination timetabling problem (ETTP)

The ETTP contains a variety of situations and large set of constraints, it is differs from the LTTP and CTTP. The ETTP is the special case in UTTP.With the help of classification we can easily deal with the problem and can focus on each and every factor which can help in finding the optimal solution. With the help of mathematical model and listing the constraints we can understand this and can move toward the feasible solution.

Different types of constraints:

1. Hard constraints for the UTTP which me satisfied for the feasible solution:
2. First we describe the hard constraints which are necessary to be followed:
3. Student and teacher are not allowed to attend more than one event at a time. There should be no clash.
4. Each classroom must be engaged for only one event at a given timeslot.
5. The capacity of the classroom should be big enough for students.
6. The availability of teachers is must for the predefined class of allotted class.

In addition to this there should be some soft constraints which can be violated but each violation is penalized:

1. The lecture should not be scheduled in last slot of the day.
2. Preferences of teachers to take the lectures
3. Student can select the course according to their preferences.

Mathematical Notation

- $W = \{w_1, w_2\, w_3 \ldots\ldots w_{n-1}\}$ assigned working days in a week
- T= given timeslots in a day
- R=contains the total available rooms
- $G = \{g_1, g_2, g_3 \ldots\ldots\ldots g_{n-1}\}$ number of total events
- S= total given timeslots
- U= total count of the students
- F=features of the room
- C_i= capacity of the room i
- $\boldsymbol{R=\{r_1, r_2, r_3 \ldots\ldots r_{n-1}\}}$ setof rooms
- $\boldsymbol{T=\{t_1, t_2, t_3, t_4, \ldots\ldots\ldots t_{n-1}\}}$ set of timeslot
- $\boldsymbol{U=\{u_1, u_2, u_3 \ldots\ldots\ldots u_{n-1}\}}$ set of students
- $\boldsymbol{X=\{x_1, x_2, x_3 \ldots\ldots\ldots\ldots x_{n-1}\}}$ set of solutions of timetabling
- $D_{u,k}$= mapping of student and day in this matrix where mapping is one on one . Only one event is assigned to student

$$D_{u,k} = \begin{cases} 1, if\ condition\ is\ true \\ 0, if\ condition\ is\ false \end{cases}$$

$P_{i,k}$= matrix of event g_i and room features f_i

$$\begin{cases} 1, if\ the\ condition\ is\ true \\ 0, if\ the\ condition\ is\ false \end{cases}$$

$Y_{i,k}$=matrix of room –room features

$$\begin{cases} 1\ is\ the\ condition\ is\ true \\ 0\ if\ the\ condtion\ is\ false \end{cases}$$

Mathematical formulation of both hard and soft constraints. In [6] formal definition is given as below:

- The obtained timetable is feasible only when if the events satisfied all the hard constraints. For the feasibility of timetable the event g_i must ensure the following conditions:

Q_1:$x_i \bmod S \neq x_j \bmod S \forall x_i \in X$
Q_2 :$x_i \neq x_j$

Where Q_1, Q_2 are the hard constraints and the x is the possible solution. For obtaining the feasible timetable the solution x must have satisfy all the constraints. All the events g_1 g_2……..g_{n-1} should mapped the defined Q(set of hard constraints). Mathematical formulation of soft constraints:

- Lecture should not defined in the last of the day

$f^{'}(x, s) = \sum_{i=0}^{W-1} uD_{DH\times(J+1)}$

- All student must attend more than one event a day:

$f^{''}(x,s) = \sum_{j=0}^{W-1} D_{u,j.}$

Total cost of the objective:
From the mathematical notation x is defined as the feasible solution of timetabling problem so the objective cost is given as f(x).the objective cost is sum of all defined soft constraint which are violated.

$f(x) = f^{'}(x,s) + f^{''}(x,s)$
This f(x) value is used as penalty for the feasible solution. This mathematical formulation is adopted from[6].

III. BRIEF HISTORY OF TIMETABLING PROBLEM

The timetabling problem is mainly concerned by computer science,artificial intelligence and operational research, for more than researchers 45 years. it is basically the problem of assignment of events in the given time slot which satisfied the imposed constraints..
The timetabling problem is NP hard in nature, it means the problem is solvable in non – deterministic polynomial time and as the problem increases the computation time is also increases exponentially (Daskalaki et al., 2004; Socha et al.,2003), this reason the researchers are focusing on the evolutionary search algorithms to get the optimal solution which can approximately give the feasible solution. There are various papers and research work in this field which focus on (EA) evolutionary algorithms. Colorni et.al(1991,1992, 1997) give the earliest EA for UTTP.Deris et.al (1997) gives the constraint – based techniques for the timetabling problem. Carter(1986) gives the earliest survey on the timetabling problem. Corne et.al (1994) they give survey on the application of genetic algorithm in timetabling..[5] Give the overview of automated timetabling problem this paper conclude the previous work in timetabling problem,[4] This paper is the survey on the metaheuristic approach for the timetabling problem.Carter et.al(1986)give the linear programming approach ,Carter et.al(1996) again give the graph coloring approach to get the optimal solution ,in this approach the problem is represented in the form of graph where the event is in the form of nodes and constraints are in the form of edges and the adjacent nodes must have different colors .Rakesh P Badoni et.al,2014 give the two phase graph coloring algorithm they use bipartite multigraph in first phase for making the matrix of weekly and daily requirement and in next phase bipartite graph to assign lectures or event in the unconstraint time slot in a day.Recently, most of the researcher are giving the bio-inspired approach to solve this problem.M.Alzaqebah et.al, 2014 give the hybrid bee colony optimization technique in their paper they uses the metaheuristic and swarm intelligence, combining with the foraging behavior of bee .[14] This paper is based on (ACO) ant colony optimization algorithm.due the convergence nature of PSO(particle swarm optimization) toward the NP-hard problem [13] Ruey – Maw Chen proposed the algorithm with local search. ABC(artificial bee colony) with hill climbing is discussed in [6].Rake P.Badoni et.al(2014) gives a new hybrid algorithm using event based on grouping .they use genetic algorithm with local search using the event based on clustering of students. PATAT(practice and theory of automated timetabling) is the conference series on the timetabling problem which is held in every two year .this conferences play a vital role to motivate the researchers. Here they share their work and results.Which gives a standard and well established experimental result .ITC(international timetabling competition) is the international competition on timetabling, the problem formulation given by the ITC-2002 is quite standard it raises the quality of research and leads toward feasible optimal solution. Afterward the ITC-2002,ITC is held in 2007 in ITC 2007 many of the researchers main issue is the instances benchmark to generate the standard solution otherwise they generate the ad-hoc solution.RongQu created a website in 2006 for the instances benchmark ,which allows the researcher download the instances and validate their result .although this website is not efficient. Di Gaspero and Andrea Scharef (2007)[10] created a website for promoting the research in the is field it allows to download instance benchmark in different data format as well as result

validation, the data is available in document or XML form .

IV PROPOSED METHODS FOR UTTP

Now here we give the brief overview of the various proposed approaches for the TTP (timetabling problem).Here we discuss various techniques and approaches. In this section our main focus on the feasible solution approaches, and categorized them on the basis of their problem solving approach. As we discuss earlier the TTP problem is solved by stochastic algorithms.

A. Linear Programing Approach

Carter(1986),Deries et.al(1997) Lajos(1996) give the earlier solution of timetabling problem using the integer programing approach.[5] Kang and White(1992) propose the logic programming approach for the TTP. He use the backtracking technique and implemented his work in PROLOG .the main outline of their algorithm is the sequentially implementation of the given constraients.[4] Recently Schimmelpfeng and Helber(2007) uses the both the CPLEX and the mixed – integer solver. In their work they use the real world instances and the result shown in their paper describes that it required a very short running time.

B. Constraint – Satisfaction Approach

In the constraint satisfaction approach the problem is firstly represented in the form of constraint satisfaction problem and afterward using the CSP solving techniques like backtracking and path consistency. Constraint satisfaction imposed the constraints and represents the problem in the form of linear equation and a set of variable describe the possible solution. These constraints must be satisfied for the feasibility of the solution. Example no lecture should be idle in the first half of the given time slot in a day, for this the availability of teacher must be required. [2] Banks Van and Msels (1998) give the backtracking method for timetabling problem.

C. Graph- Coloring Approach

Graph coloring techniques attracted most of the researcher this is the reason recently graph theory is highly studied for solving the timetabling problem. [5] Neufeld and Tartr (1974) give the earliest graph coloring approach for the solution of timetabling problem he reduced the problem in the form of vertex and edges the events are in the form of vertex and the given constraints are in the form of arc , and the vertex which are connected to the same node should not have the same color. [15] Given the graph coloring approach in two phases. In this paper they use bipartite multi-graph in first phase,they represent the graph in the form of matrix which give the daily and weekly requirement and obtained a linear equation, for the variable they use the integer values.In the second phase they use the bipartite graph for assigning the lecture in the unconstraint time slot and the randomly generated dataset for example expert lecture and extra classes for each day.

D. Metaheuristic And Local Search Algorithms

Metaheuristic is formally defined as an iterative generation process which guides a subordinate heuristic by combining intelligently differently concept for exploring and exploiting to search space, learning strategies are used to structural information in order to find efficiently near – optimal solutions. Techniques which constitute metaheuristic algorithm range from simple local search procedures to complex learning procedure.In the past decade the researcher shows their great interest in metaheuristic algorithms for the timetabling problem. Most of the metaheuristic algorithms are bio – inspired(ACO) ant colony optimization, bee colony optimization(BCO), swarm intelligence based algorithms PSO(particle swarm optimization), AFS(artificial fish swarm) and the genetic algorithm. According to the website of the [4] metaheuristic algorithm Metaheuristic Network (http://www.metaheruistic.org) there are five paradigm of metaheuristic– Local search ,Tabu search ,ACO, Simulated annealing and evolutionary algorithms.metaheuristic algorithm basically work on three stages.-: highest degree , neighborhood search and the tabu search.

E. Genetic Algorithms

A genetic algorithm combined with a sequential local search for the curriculum based course timetabling problem which also used the two phased approach i.e the construction phase and the improvement phase. Here the set of possible solution is known population and each probable solution is known chromosomes. In [2] there is improvement of hybrid algorithm with genetic algorithm and local search algorithm. In [8] timetabling problem is solved using undirected graph with the genetic algorithm.They use genetic algorithm incorporating chromosomes encoded and the fitness value is used to solve the timetabling problem and the mapping is done by undirected graph.

V. CONCLUSION

Now here we conclude the above overview, in this paper we introduce various approaches for solving the timetabling problem. Every university has their own timetable. A feasible and standard timetable contain some rules, limited timeslot and the given constraint The timetabling solving approach give a standard result. Comparison between various techniques gives the quality result. It is stated previously, timetabling problem is NP hard for this reason deterministic algorithms are not used for the solution and the evolutionary algorithm attracts the researches.For large instances it is not possible to satisfy all the constraints so there is approximation is required, various theoretical approach give the approximation. ITC gives a standard platform to the researcher to show their experiment and validated their results.

VI.REFERENCES

1-Even, S.; ltai,A.;Shamir,A.on the complexity of timetable and multi-commodity flow problem. In proceeding of the 16th IEEE annual Sympoisum on foundation of computer science,California,CA.USA,13-15october 1975;pp 182-193.

2-Rakesh P badoni,D.Kgupta . Pallavi Mishra .a new hybrid algorithm for university course timetabling problem using event based on grouping of students journals of computer and industrial engineering

3-Anmar Abuhamdan et al. Population basedlocal search for university course timetabling problems. Springer science + business media New York 2013.

4-Rhydian Lewis.A survey of metaheuristic-based technique for university timetabling problem, springer verlag 2007.

5-A. Schaerf. A survey of automated timetabling: Artificial intelligence Review 13,87-127(1999).

6-A.L Bolaji, et al., University course timetabling using hybridized artificial bee colony with hill climbing,j.comput.Sci(2014).http://dx.doi.org/10.1016/j.jocs 2014.04.002.

7- Robert AsinAcha.RobertNiecuwenhuis. Ccurriculum.based course timetabling with SAT &MAXSAT.springer science business media, LLC 2012 annoper res doi.10.1007/s10479-012-1081-x.

8-M.Alzaaqebah, S.Abdullah, hybrid bee colony optimization for examination timetabling problems, computers and operational research, http://dx.doi.org/10.1016/j.cor.2014.09.005.

7-Edmund K Burke et.al .A graph Based Hyper-Heuristic for Education timetabling problems,European Journal of Operational research 176:177-192,2007.

8-Younis R.Elhaddadand MohamadA.Alshaari. Solving timetabling problem as undirected graph using genetic algorithm.international journal of computing , communication and instrumentation engineering (IJCCIE)Vol 1.Issue (2014).

9-Iosif V. Katasaragkis, IoannisX.Tassopoulos and GrigoriosN.Bleigiannis. A comparative study of modern heuristics on the school timetabling problem.Algorithms 2015,8,723-742;doi:10.3390/a8030723.

10-Di-Gaspero, L. Fortune, A.Schaerf. Educational timetabling @UniUd(2006)(viewd March 13,2007) http//www.diegm.uniudd.it/satt/project/EduTT/.

11-E K Burke and M.Rudova (Eds):PATAT 2000,2NCS,3867,pp.40-49,2007.@springer Veolagr Berlin Heidelberg 2007.

12-herz,A.tabu Search for large scale timetabling problems.Eur.j.oper.res1991,54,39-47.

13-Ruey-Maw Chen and Hsiao-fang Shih .solving University Course Timetabling Problem Using Constriction Particle swarm optimization with local search .Algorithm 2013,6,227-244;doi:10.3390/a6020227.

14-Thatchai Thepphakornet.al,An ant colony based timetabling tool,Int.J.ProductionEconomics(2103),http://dx.doi.org/10.1016/j.ijpe.2013.04.026.

15-Rakes P Badoni and D. K Gupta,international journal Mathematics in Operational Research Vol 6 No.1, 2014

16-Metaheuristic Network (http://www.metaheruistic.org)