A SURVEY ON EXAM SCHEDULING TECHNIQUES

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Abstract—**Timetabling is a common problem faced in various organizations and is the most important issue every University has to solve. It is one of the computationally difficult problems in scheduling the exams without conflicts. Scheduling problems can arise in different situations, but most of the times it is referred to scheduling of exams in educational institutions. In fact, examination-timetabling is an important area to be studied and a number of researches have been developed in this area. Many novel researches that focused on modeling and formulating examination-timetabling problems are studied and analyzed in this study. Depending on the nature of the scheduling problem, the objective may vary from one research to another to find the most feasible solution that can cope with a specific environment. This literature survey focuses on examining the major solution approaches for the timetabling problem and compare them, in order to provide directions for academicians and researchers for further work.**

Keywords- Timetabling, Scheduling, Examination-Timetabling

I. INTRODUCTION

Timetabling is, in a general sense, assigning of a set of resources such as rooms, workers or machines to a period [1]. It is a common activity especially in educational institutions, whether it be schools or universities. The timetabling problem in educational institutions can be divided into two types: course/lecture timetabling and examination timetabling. Course timetabling is the scheduling of university courses and lecturers by weeks with the aim of eliminating conflicts in schedules [2]. In contrast, examination timetabling is assigning exams over a limited number of available timeslots while satisfying a set of constraints [3].

In a University, a class can range from 25 to reach about 300 students (Integrated Postsecondary Education Data System (IPEDS) [4]. For a small institution, manually assigning exams or lectures to timeslots could be the most efficient timetabling method. However, as the number of exams or lectures grow, the problem becomes more complex, and manual timetabling could result in a huge waste of time and labor while resulting in less than optimal and conflict-ridden schedules. One reason behind the complexity of the problem is the involvement of many people in the process. There are three key stakeholders affected by the scheduling process: administrators, departments and students [5]. The stakeholders have roles in timetabling. First, administrators have their own requirements that the timetable must obey. Second, departments will have their own preferences regarding exam and course scheduling. In addition, they will have their own requirements when assigning classrooms. Third, students are restricted to follow the schedule. For that reason, automated timetabling has been a very hot research topic with literature dating back to the 1970s.

II. EXAMINATION TIMETABLING PROBLEM

Exam timetabling is a common form of timetable in which exams are assigned to time-slots in a certain period. As it has been presented at the beginning of this section, most of the timetabling problems are related to educational institutions to coordinate main four resources, which are students, teachers, rooms and finally time slots to schedule courses [6]. Exam timetabling shares the same resources in coordination with focus on scheduling final exams. Once the final form of examination timetabling is finalized, an exam timetable will display the information of exam/courses, time of the exam, place of the exam and sometimes the proctors and observers.

The success of a timetabling solution is measured by the degree in which it satisfies a set of pre-set constraints. Constraints in a timetabling problem can be categorized into hard and soft constraints. All hard constraints must be satisfied for a solution to be considered feasible. After all feasible solutions are found, soft constraints are secondary measures that are used to determine the quality of a solution. In most cases, soft constraints are desirable to have in a solution but are often impossible to fully satisfy. Therefore, the objective is to minimize the violations of soft constraints. Hard and soft constraints usually differ according to the specific institution. Some of the common hard constraints used in scheduling problems are: no student can be assigned to two or more exams in the same time period, availability of sufficient resources in each time period for all exams, assign a proper number of invigilator according to the number of students in room, and have the appropriate exam locations and resources for students with special. The common soft constraints are found to be: minimize the number of consecutive exams, have exams spread

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evenly for each student, publish exam schedule as early as possible, and flexibility in moving a number of exams to another time period without the need to change the whole schedule [7] (Similarity Measures for Exam Timetabling Problems).

III. Solution Approaches And Techniques

A. Direct Heuristics (Based on Graph Coloring)

Graph coloring is a topic that has been studied since the early 1970s. There has been many researches in graph theory. Graph coloring considers a special case of graph labeling. It defines as an assignment of labels called "colors" to elements in a graph that is subjected to defined constraints [8]. Graph coloring has been used in many application and widely used for scheduling problems. In its simplest form, the method goes by coloring the vertices of a graph such that no two adjacent vertices can share the exact color called a "Vertex Coloring" [9]. In a research done by E.K.Burke et. Al, a university timetabling system problem was solved based on Graph Coloring and constraint manipulation [10]. The methodology consists of **two phases, first a heuristic algorithm based on graph coloring is used to split up exams into mutually independent group set, the second phase is combining this algorithm with another algorithm based on listing courses in order to assign exams into rooms. The** result of the method designed to be computerized for general university timetabling problem and solve multi constraints to fit changing environmental requirements. In corresponds to E.K. Burke and D.G. Elliman, a time table research was implemented by Baki Koyuncu and Mahmut Seçirin which graph coloring algorithm is utilized [11]. The designed algorithm followed the similar phase of implementation by using C++ platform but is different in which its solves course timetabling problem rather than exam timetabling problem. **The graph coloring algorithm is said to be user-friendly and easy to implement compared to different approaches with such powerful methods and can give efficient results in a short time.**

B. Mixed Integer Linear Programming

Ever since George Bernard Dantz developed an algorithm for solving linear programming (LP) models in 1946 [12], there has been many development and focus on LP along the history. LP has been used by many scientist and researchers to solve scheduling problems. The techniques of solving scheduling problems using LP derived from its main goal of optimizing a linear objective function which is to maximize or minimize the o.f subjected to its constraints. The mathematical formulation requirements are represented by linear relationship. A number of researches in optimization of timetabling has been developed using binary models, integer programming and mixed integer programming which fall under LP that differs in the formulation of the o.f and constraints. In 2001 a model by Dimopoulou and Miliotis was done using Integer programming that addressed a problem such solving a constraint of restricted availability of classrooms and the choice of students in choosing multi courses. The approach was successful but is said to be theoretical and was not a computer-based implementation [13]. Likewise, another research was done using binary model on the demands for an effective Examination Timetabling, the aim is studying the preference of students in Universiti Malaysia Terengganu while keeping in mind the university conditions [14]. In a research done in Kuwait University (KU), a model was developed using mixed-integer programming approach to a class timetabling. The paper also presented a case study with gender policies and traffic considerations. The technique used is a LP model in which some and not all of the decision variables are constrained to be integer values. Improvements were achieved via the model compared with the manual scheduling in terms of solving availability of classrooms and parking issues and resolving class conflicts [15].

C. Genetic Algorithm

The Genetic Algorithm it is a method for solving an optimization problem created by John Holland in the early 1970's. The aim is to find the solution that fits the criteria (constraints). The first step in the Genetic Algorithm is to start with a set of different designs of feasible solutions to timetabling problems. The group of solutions will represent a population and a single solution is often called chromosome. Each feasible solution has different traits that can be mutated randomly [16]. This results in having a new population. After that, the selection of the best solution process happens where the fittest solution is picked. There are many universities that apply this technique, for example, The Faculty of Electrical Engineering and Computing in the University of Zagreb successfully implemented the Genetic Algorithm based solution. The algorithm was created and tested on real data [17]. The best quality result was with a population of 50 to 100. The method was also tested in an Italian high school where two versions (with and without local search) of Genetic Algorithm were tested against manual, and two other approaches; simulated annealing and Tabu Search. The results illustrated that Genetic Algorithm and Tabu Search performed better than simulated annealing and the manual scheduling. Although Tabu Search performed better, the Genetic Algorithm has the flexibility to allow the user to select within a different set of timetables. Both papers proved that Genetic Algorithm is easy to implement and give better results when scheduling a small population.

D. Simulated Annealing

Simulated annealing is a probabilistic local search technique that finds a global optimum solution for objective functions that may have many local optima. The technique was proposed by Kirkpatrick et.al in 1983 [18]. The algorithm draws concepts from the field of statistical mechanics to solve combinatorial optimization problem. A fundamental question in statistical mechanics is how atoms in a system act in the limit of low temperature. To test this, experiments are conducted by melting a substance, then slowly lowering the temperature while spending a certain amount of time at each temperature, essentially, growing large, solid crystals from the melted substance by annealing. In their paper, Kirkpatrick et. al sought to develop a technique to simulate the annealing process in physical systems to solve combinatorial optimization problem. In the physical annealing analogy, the objective cost function is the energy, and the neighborhood of solutions is a population of configurations at each temperature. The system to be optimized is "melted" at a high temperature, and then the temperature is gradually lowered until the system "freezes". The simulated annealing process begins with an initial solution generated at random or by another heuristic. The algorithm cycles through the neighborhood of the initial solution. If the difference between the current solution objective function and the previous solutions objective function is less than zero, the current solution is chosen as the best solution. If the difference between the current solution objective function and the previous solutions objective function is greater than or equal to zero, the current solution is accepted with the probability. The starting temperature T in the early runs of the algorithm is very high. After a fixed number of iterations, the temperature T is lowered by a pre-defined function to simulate a cooling rate. The algorithm stops when the temperature T reaches a value of zero, which indicates the system is "frozen" [2].

Since its inception, the basic simulated annealing algorithm and variants of it have been discussed in the context of solving the examination timetabling problem. Thompson and Dowsland propose three different variants to the basic simulated annealing algorithm to overcome the issue that decisions made in earlier phases of the algorithm may lead a disconnected solution space and missed optimum or near-optimum solutions [19]. The three variants include conducting an independent search for each part of the solution space by using different starting solutions, increasing the number of solutions in a neighborhood of solutions, penalizing undesirable solutions instead of eliminating them. The first variant proved to be successful especially in data sets that were disjointed. The second variant where the author compared Kempe chain annealing, which has a larger neighborhood of solutions, to basic simulated annealing also yielded superior results. The final proposed variant proved to be too cumbersome when choosing penalties. Chamait compared the performance of simulated annealing to Ant Colony optimization (a meta-heuristic used to solve combinatorial optimization problems) in the examination timetabling problem [20]. In terms of run time, the Ant Colony method resulted in shorter times for all trials. In terms of value of objective function, Ant Colony Optimization resulted in the lowest value, while the standard deviation of values was smaller for simulated annealing. Akinwale el.al compared the performance of simulated annealing to Genetic Algorithm on the course timetabling problem [21]. It is found that Genetic Algorithm outperformed simulated annealing in run time and ease of implementation. On the other hand, Simulated annealing utilized less computer resources, lines of code, and program volume (memory space).

E. Tabu Search

Tabu Search is a meta-heuristic based on the work proposed by Fred Glover designed to solve combinatorial optimization problems [22]. In the case where exhaustively searching through a solution space is not feasible, Tabu Search offers a way to search through a solution space efficiently. A limitation of other specialized strategies such as decent methods and hill climbing heuristics that are designed to solve combinatorial problems is that they yield local optimal solutions that often are not global optima. Tabu Search has the ability to work with these other problem solving strategies to guide them past the bounds of local optimality. The Tabu Search algorithm has been adapted over the years to solve the examination timetabling problem. A. Hertz explored the Tabu Search for large scale timetabling problems [23]. In this paper, the basic ingredients for Tabu Search were generalized to fit any assignment sub-problem including the timetabling problem. The TATI algorithm, which is an algorithm adapted from Tabu Search to specifically handle timetabling problems, was described in detail. TATI algorithm was successfully tested on the course timetabling problem. The dataset was obtained from the faculty of engineering and technology, Lautech, Nigeria. In this paper, three different configurations for the soft and hard constraints were tested. The configuration that yielded the best results differentiated between the soft and hard constraints by assigning a weight of 10 to all of the hard constraints, and a weight of 1 for all soft constraints.

F. Quadratic Assignment

One of the famous method that was used to solve combinatorial optimization problems is the quadratic assignment. The method was introduced in 1957 Martin Beckman and Tjallian C. Koopmans when trying to model a facilitation location problem [24].The Quadratic assignment problem (QAP) is a complex form of the linear assignment problem (LAP). The QAP is equivalence of the problem to LAP with certain additional constraints demonstrated. The objective of LAP is to assign i.e. each person to one and only one job to minimize the sum of each assignment cost. In addition to the cost matrix, the QAP includes a distance matrix like what was presented by Hanan and Kurtzberg in order to preserve consistency [25]. In a research done in 2015, Fadhilah Ahmad investigated a quadratic assignment approach for solving examination timetabling problem. The main objective aimed to reduce or in some situation to eliminate the level of conflicts in the examination timetabling [26]. The paper presents a framework of five phases computer based quadratic approach. In the first phase parameters been determined then constraint tables were generated. Thirdly, assignments of the parameters are done. Finally, in the last two phases, solving the constraint and obtaining an optimized solution for the examination problem.

TABLE I. COMPARISON OF SCHEDULING TECHNIQUES

#	Technique	Advantages	Disadvantages
1	Graph Coloring	• Best method for solving exam conflicts	• It does not schedule soft constraints • Takes long time to solve a problem
2	Mixed Integer Linear Programming	• Emphasizes the generation of flexible class timetable for students. • Less time consumed compared to the manual scheduling- • Less scheduling conflicts	• The outcomes of the solution are parameter dependent • As the number of the variables increases, the time for searching for the solution increases
3	Genetic Algorithm	• Flexibility in choosing sets of different solutions • Easy to implement and understand	• Has many lines of code • Occupies more computing resources
4	Simulated Annealing	• Work for any kind of optimization problem • Gives shorter code • Easy to understand • Short run time	• Produces lesser optimum solution compare to other methods
5	Tabu Search	• High quality solution • Low run time • It can work on large scheduling problems	• Formulating the problem is difficult • Computing resources is expensive
6	Quadratic Assignment Problem	• Reduces the cost of the assignment	• Very hard to implement • Complexity of grouping the process

G. Hybrid Approach

In other papers, researches have been investigating hybrid approach, depending on various methods that provide a feasible solution to exam timetabling. A research by Akhan and Guray done in 2013 for a university exam scheduling using hybrid approach by the implementation of using arrays to obtain performance in execution [27]. The formulated algorithm will run until a cut off condition exist. In order to schedule an exam to a specific time period, the algorithm will run to check if the time-slot is full, meaning that in a configuration screen (the user is allowed to select a period as empty to not place any exams). Another algorithm used in the paper is map coloring which is a type of graph coloring approach to solve different scheduling constraint. Another hybrid approach presented solutions of combinatorial optimization problems entitled in an Ant Colony optimization problem. The research was adopted by Micheal Eley and described how ant colonies find the shortest path between food sources and their nest in the Ant System [28]. The approach consists of n cycles and each cycle consists of m ant, constructing a feasible solution. Different approaches were also presented in the paper such Max-Min then finally benchmarked with other famous algorithms like graph coloring to test the performance of Ant Colony algorithm.

IV. RESULTS AND DISCUSSION

This section presents a framework of related research for examination scheduling. Different solutions techniques were adopted to serve a specific educational environment and solve its related scheduling problem. In fact, many researches shared similar objectives in solving the exam scheduling problem but differs in the way of formulating the variables and constraints and applying the solution based on the selected approach. Table 1 addresses the advantages and disadvantages of each method in order to tailor the focus of satisfying the main objectives of examination scheduling problem.

V. CONCLUSION

Examination timetabling is a common problem faced in various organizations and an important area to be studied. A number of researches have been undertaken in this area mainly focusing on modeling and formulating examination-timetabling problems. Depending on the nature of the scheduling problem, the objective may vary from research to another to find the most feasible solution. The widely-used solution approaches for the timetabling problem have been studied and analyzed thoroughly in this literature survey and they are compared, in order to provide directions for academicians and researchers for further work.

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