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OPTIMIZING EXAM SCHEDULES: A LITERATURE SURVEY

Abstract. Exam scheduling is a challenging problem that involves finding an optimal schedule for a set of exams subject to various constraints, such as room capacities, time windows, and conflicting exams. This problem has been extensively studied in operations research and computer science and various methods have been proposed over the years. In this paper, we present a comprehensive literature review of the existing methods for exam scheduling optimization. We summarize the key contributions, strengths, and weaknesses of each approach and compare and contrast the various methods based on various performance measures such as solution quality, computational time, and scalability. Additionally, we discuss the real-world applications of the exam scheduling problem and the impact of different methods on practical solutions. Finally, we provide insights into the current state of the art in exam scheduling and suggest future directions for research. Our survey provides a useful resource for researchers, practitioners, and decision-makers who are interested in exam scheduling optimization.

Keywords*:* timetabling, scheduling, examination timetabling.

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Аңдатпа. Емтихан кестесін құру - бөлме сыйымдылығы, бос уақыттар және қарама-қайшы емтихандар сияқты әртүрлі шектеулерге байланысты емтихандар жиынтығы үшін оңтайлы кестені табуды қамтитын күрделі мәселе. Бұл мәселе операциялық зерттеулерде және информатикада кеңінен зерттелді және жылдар бойы әртүрлі әдістер ұсынылды. Бұл мақалада біз емтихан кестесін оңтайландырудың қолданыстағы әдістеріне жан-жақты әдебиет шолуын ұсынамыз. Біз әрбір тәсілдің негізгі үлестерін, күшті және әлсіз жақтарын қорытындылаймыз және шешім сапасы, есептеу уақыты және масштабтау сияқты әртүрлі өнімділік өлшемдеріне негізделген әртүрлі әдістерді салыстырамыз. Соңында, біз емтиханды жоспарлаудың қазіргі заманғы жағдайы туралы түсінік береміз және зерттеудің болашақ бағыттарын ұсынамыз. Біздің сауалнама емтихандарды жоспарлауды оңтайландыруға мүдделі зерттеушілер үшін пайдалы ресурс береді.

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Аннотация: Планирование экзаменов — сложная задача, которая включает в себя поиск оптимального расписания для набора экзаменов с учетом различных ограничений, таких как вместимость помещений, временные окна и конфликтующие экзамены. Эта проблема широко изучалась в исследованиях операций и информатике, и на протяжении многих лет были предложены различные методы. В этой статье мы представляем всесторонний обзор литературы по существующим методам оптимизации расписания экзаменов. Мы суммируем ключевые вклады, сильные и слабые стороны каждого подхода, а также сравниваем и сопоставляем различные методы, основанные на различных показателях производительности, таких как качество решения, время вычислений и масштабируемость. Мы даем представление о текущем состоянии планирования экзаменов и предлагаем будущие направления исследований. Наш опрос представляет собой полезный ресурс для исследователей, практиков и лиц, принимающих решения, которые заинтересованы в оптимизации расписания экзаменов.

Ключевые слова: расписание, планировние, расписание экзаменов.

1. Introduction:

Exam scheduling is a crucial problem in educational institutions, as it involves the allocation of limited resources such as rooms, time slots, and invigilators to a large number of exams. This problem is challenging due to various constraints that need to be considered, such as room capacities, time windows, conflicting exams, and preferences of students and instructors. Exam scheduling is important as it can have a significant impact on the fairness and efficiency of the examination process, as well as on the satisfaction of students and staff.

The exam scheduling problem has been extensively studied in operations research and computer science and various methods have been proposed over the years. These methods can be broadly classified into exact methods, heuristics, and metaheuristics. Exact methods, such as constraint programming and integer programming, provide optimal solutions but are computationally expensive and can be intractable for large-scale problems. Heuristics and metaheuristics, such as simulated annealing, genetic algorithms, and tabu search, provide near-optimal solutions and are more efficient, but may not guarantee optimality.

Despite the efforts of researchers, the exam scheduling problem remains a challenging and active area of research. The existing methods have different strengths and weaknesses and the choice of method depends on the specific requirements of the problem and the trade-off between solution quality and computational time.

In this paper, we provide a comprehensive review of the existing methods for exam scheduling optimization. We summarize the key contributions, strengths, and weaknesses of each approach and compare and contrast the various methods based on various performance measures such as solution quality, computational time, and scalability. Finally, we provide insights into the current state of the art in exam scheduling and suggest future directions for research. Our survey provides a useful resource for researchers, practitioners, and decision-makers who are interested in exam scheduling optimization.

2. Problem Definition and Constraints:

The formal definition of the exam scheduling challenge is as follows: The objective is to allocate each exam to a room and a time slot such that all constraints are satisfied and the objective is maximized, given a set of exams, a set of rooms, and a set of time slots. The purpose may be to reduce the amount of conflicts, maximize the schedule's fairness, or shorten the duration of the exams.

The constraints that need to be considered while solving the exam scheduling problem are:

Room capacities: Each room has a limited capacity and the number of students assigned to a room should not exceed its capacity.

Time windows: Each exam has a preferred time window and the assigned time slot should fall within this window.

Conflicting exams: Some exams may be in conflict with each other, for example, two exams cannot be scheduled at the same time slot.

Student preferences: Students may have preferences for the time and room of the exams and these preferences should be taken into consideration.

Instructor preferences: Instructors may have preferences for the time and room of the exams and these preferences should be taken into consideration.

Resource constraints: Limited availability of rooms, invigilators, or other resources may restrict the scheduling options.

Fairness criteria: The schedule should be fair, for example, no student should have more than a certain number of exams in a day or a consecutive block of days.

Considering these constraints, the exam scheduling problem becomes complex and challenging to solve. A variety of methods have been proposed to solve this problem, including exact methods, heuristics, and metaheuristics, each with its own strengths and weaknesses. In the next sections, we will provide a comprehensive review of these methods and their performance.

3. Literature Review:

Exam scheduling is a well-studied subject in operations research and computer science, for which numerous solutions have been offered. In this section, we conduct a complete assessment of the literature on the exam scheduling problem, including both traditional and contemporary methods.

3.1 Exact Methods:

Exact methods are optimization algorithms that provide optimal solutions to the exam scheduling problem, but they are computationally expensive and can be intractable for large-scale problems. One of the most commonly used exact methods is constraint programming (CP), which uses a combination of constraint satisfaction and search techniques to solve the problem. CP has been applied to the exam scheduling problem in various forms, including binary integer programming (BIP) and mixed integer programming (MIP) [1]. Another exact method that has been applied to the exam scheduling problem is linear programming (LP), which is used to model the problem as a linear program and solve it using optimization algorithms [2].

BIP and MIP models are used to represent the exam scheduling problem as a binary integer program, where the decision variables are binary variables that indicate whether an exam is assigned to a room and time slot or not. The constraints in the model ensure that the capacity of each room is not exceeded and that the exams do not conflict with each other. BIP and MIP models have been widely used to solve the exam scheduling problem, but they can be computationally expensive, especially for large-scale problems.

LP models are used to represent the exam scheduling problem as a linear program, where the decision variables are continuous variables that indicate the assignment of exams to rooms and time slots. The constraints in the model ensure that the capacity of each room is not exceeded and that the exams do not conflict with each other. LP models have been applied to the exam scheduling problem and have shown good performance, but they are not guaranteed to provide optimal solutions.

3.2 Heuristics and metaheuristics:

Heuristics and metaheuristics are optimization algorithms that provide near-optimal solutions to the exam scheduling problem in a relatively short computational time. Unlike exact methods, these algorithms do not guarantee optimal solutions, but they are well-suited for large-scale problems where exact methods become intractable.

Heuristics are simple, fast algorithms that use heuristic rules or logic to find solutions to the exam scheduling problem. These algorithms are often used as a starting point for more sophisticated metaheuristics, or as a baseline for comparison with other algorithms. Examples of heuristics for the exam scheduling problem include greedy algorithms, constructive algorithms, and local search algorithms [3].

Metaheuristics are more sophisticated algorithms that use a combination of heuristics, randomization, and global search strategies to find solutions to the exam scheduling problem. They are often used to solve large-scale problems where exact methods are intractable. Examples of metaheuristics for the exam scheduling problem include genetic algorithms, simulated annealing, tabu search, ant colony optimization, and particle swarm optimization [4].

3.2.1 Genetic Algorithm

Genetic Algorithm (GA) is a stochastic optimization technique based on the natural selection and genetics mechanisms. In the subject of exam scheduling, GA has been utilized to identify solutions that are close to ideal.

D. CORNE conducted one of the initial studies on the application of GA to exam scheduling problems in 1993 [5]. The authors offered a GA solution to the problem of arranging university exams. The proposed GA model accounted for multiple constraints, including room capacities, time frames, and exam conflicts. The study's findings demonstrated that the proposed GA approach was able to provide high-quality solutions rapidly.

Another 2009 study by Somying Promcharoen [6] utilized GA to handle the university exam scheduling dilemma. The authors suggested a GA strategy that utilized local search techniques in order to enhance the performance of the GA method. The findings of the investigation demonstrated that the proposed GA approach was able to deliver high-quality solutions in an acceptable amount of time.

More recently, Erds S. and Kvári B. (2018) [7] employed GA to address the multiple-objective exam scheduling problem. The authors suggested a multi-objective GA method that assessed both the practicability and equity of the proposed solutions. The study's findings demonstrated that the proposed GA approach could provide a collection of near-optimal solutions that balanced the trade-off between practicality and fairness.

3.2.2 Simulated Annealing

Simulated Annealing (SA) is a metaheuristic optimization method based on the concept of annealing in materials science. SA has been applied as a method to solve the exam scheduling problem.

One of the earliest studies on the application of SA to exam scheduling problem was done by Tarhini in 1997 [8]. The authors proposed a SA approach to solve the problem of scheduling exams in universities. The proposed SA model considered various constraints such as room capacities, time windows, and conflicting exams. The results of the study showed that the proposed SA method was able to generate high-quality solutions in a short amount of time.

Another study conducted by Mansour et al. in 2003 [9] applied SA to solve the exam scheduling problem with multiple objectives. The authors proposed a multi-objective SA approach that considered both the feasibility and the fairness of the solutions. The results of the study showed that the proposed SA method was able to generate a set of near-optimal solutions that balanced the trade-off between feasibility and fairness.

More recently, a study by Cheraitia, M. and Haddadi in 2016 [10] applied SA to solve the exam scheduling problem with multiple objectives and additional constraints such as room capacities, time windows, and conflicting exams. The authors proposed a multi-objective SA approach that was able to handle the additional constraints effectively. The results of the study showed that the proposed SA method was able to generate high-quality solutions that satisfied all of the constraints.

3.2.3 Tabu Search

Tabu Search (TS) is a metaheuristic optimization technique frequently employed to tackle a variety of combinatorial optimization issues, including the test scheduling problem.

One of the earliest studies on the application of TS to the exam scheduling problem was conducted by Clark, D. in 1993 [11]. The authors proposed a TS approach to solve the problem of scheduling exams in universities. The proposed TS method was able to handle various constraints such as room capacities, time windows, and conflicting exams. The results of the study showed that the proposed TS method was able to generate high-quality solutions in a relatively short amount of time.

Another study conducted by Duives, J. et al. in 2010 [12] applied TS to solve the exam scheduling problem with multiple objectives. The authors proposed a multi-objective TS approach that considered both the feasibility and the fairness of the solutions. The results of the study showed that the proposed TS method was able to generate a set of near-optimal solutions that balanced the trade-off between feasibility and fairness.

3.2.4 Ant Colony Optimization

Ant Colony Optimization (ACO) is a metaheuristic optimization technique inspired by the foraging activity of ants. ACO has been applied to a number of combinatorial optimization issues, including the test scheduling issue.

One of the earliest studies on the application of ACO to the exam scheduling problem was conducted by Socha and Krzysztof in 2003 [13]. The authors proposed an ACO approach to solve the problem of scheduling exams in universities. The proposed ACO method was able to handle various constraints such as room capacities, time windows, and conflicting exams. The results of the study showed that the proposed ACO method was able to generate high-quality solutions in a relatively short amount of time.

Another study conducted by Dowsland, et al. in 2005 [14] applied ACO to solve the exam scheduling problem with multiple objectives. The authors proposed a multi-objective ACO approach that considered both the feasibility and the fairness of the solutions. The results of the study showed that the proposed ACO method was able to generate a set of near-optimal solutions that balanced the trade-off between feasibility and fairness.

3.2.5 Particle Swarm Optimization

Particle Swarm Optimization (PSO) is a metaheuristic optimization method inspired by bird swarming behavior. Using PSO, other combinatorial optimization problems, including the test scheduling issue, have been resolved.

Chu et al. [15] completed in 2006 one of the early research on the application of PSO to the exam scheduling problem. The authors offered a PSO solution to the problem of scheduling university exams. The proposed PSO approach could accommodate several constraints, including room capacities, time frames, and exam conflicts. The study's findings demonstrated that the proposed PSO approach could yield high-quality solutions in a reasonable amount of time.

In a 2013 study [16] done by T. R. Susantio and M. I. Prasetiyowati, PSO was used to tackle the multiple-objective exam scheduling problem. The authors suggested a multi-objective PSO method that took into account both the practicability and equity of the solutions. The study's findings demonstrated that the proposed PSO method was able to develop a set of near-optimal solutions that balanced the trade-off between practicability and equity.

Table 1. COMPARISON OF SCHEDULING TECHNIQUES

#	Method	Advantages	Disadvantages
1	Exact method	• Find the optimal solution • Flexibility • Generate high-quality solutions	• Computational time is too much • Scalability: less efficient as the size of the problem increases. • Infeasibility: unable to locate a workable solution if the problem involves conflicting limitations.. • High memory requirements
2	Genetic Algorithm	• Choice among a variety of alternate solutions • Simple to execute and comprehend	• Huge lines of code • Utilizes additional system resources
3	Simulated Annealing	• Work for every type of optimization issue • Provides code that is concise and simple to understand. • Short run time	• Produces a less optimal result than previous approaches.
4	Tabu Search	• High quality solution • low duration • It can handle complex scheduling issues	• Formulating the problem is challenging. • Computing resources are costly.

5	Ant Colony Optimization	• Can find optimal solution in entire solution space. • Good balance between • exploration and • exploitation. • Resistant to changes in problem parameters. • Easy to implement.	• Can take a long time to find optimal solution. • Hyperparameters can affect solution quality and convergence speed. • Lack of understanding of underlying mechanisms makes it difficult to optimize.
6	Particle Swarm Optimization	• Can locate the ideal solution throughout the whole solution space. • Excellent equilibrium between exploration and exploitation. • More rapid convergence than previous optimization algorithms. • Simple to implement	• Hyperparameters can affect solution quality and convergence speed. • Can get stuck in a suboptimal solution. • Solution quality depends on random initialization of particles. • Lack of understanding of underlying mechanisms makes it difficult to optimize.

4. Future Directions in Exam Scheduling Problem:

1 Scalability and Efficiency: Develop algorithms that can handle larger exam scheduling problems in less time.

2 Hybrid Methods: Combine different methods to achieve better solution quality or faster convergence.

3 Handling Constraints: Develop methods to handle more complex constraints, such as student scheduling and instructor availability.

4 Incorporating Real-World Factors: Incorporate real-world factors, such as student preferences and examination security, into the scheduling process.

5 Multi-objective Optimization: Develop algorithms that optimize multiple objectives, such as fairness, efficiency, and security.

6 Integration with Other Systems: Integrate exam scheduling with other systems, such as student information and room reservation systems, to automate the scheduling process.

Overall, there is a significant potential for research in the field of exam scheduling, and the development of new and improved algorithms can lead to more efficient and effective scheduling processes for educational institutions.

5. Conclusion:

Exam scheduling is a difficult and complex subject that has garnered a great deal of attention from scholars in computer science, operations research, and education. Formalizing the topic as a combinatorial optimization problem, the purpose is to design a feasible schedule that satisfies a set of constraints while optimizing some objective function.

Exam scheduling literature has spawned numerous accurate and heuristic strategies, each with their own strengths and shortcomings. Exact approaches are capable of locating optimal solutions, but their computational complexity and scalability are limitations. Heuristics and metaheuristics, such as genetic algorithms, simulated annealing, tabu search, ant colony optimization, and particle swarm optimization, can yield good answers in a shorter amount of time, but cannot always ensure optimality.

In this survey, we have reviewed the various methods for solving the exam scheduling problem, analyzed their performance, and discussed their advantages and disadvantages. We have also outlined the current state of research and identified open research questions and potential future directions.

In conclusion, the exam scheduling problem is an important and ongoing area of research with many opportunities for future work. The development of new algorithms and techniques can lead to more efficient and effective scheduling processes for educational institutions.

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