

Airport Scheduling: A Summary of Three Scenarios on the Application of Machine Learning and Genetic Algorithms

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Abstract. Airport scheduling has an important optimization value in air transportation, and its complexity and multiple constraints make it difficult for existing methods to deal with it comprehensively. This paper is a review paper, that systematically summarizes the application of genetic algorithms and machine learning in the scheduling of flights, the scheduling of airport resource allocation, and the scheduling of airport external resource allocation. Through the analysis of many studies, this paper summarizes the advantages and disadvantages of different algorithms in various scheduling scenarios and points out the advantages of genetic algorithms in dealing with complex multi-objective optimization problems. In addition, this paper explores the potential of combining machine learning with genetic algorithms to further enhance the effect of scheduling optimization. This paper provides an important reference for future research and helps the innovation and practical application of methods in the field of airport scheduling.

Keywords: Machine Learning, Genetic Algorithm, Scheduling Methods, Scheduling Scenarios.

1. Introduction

Airport scheduling is a crucial part of the modern air transportation system, and it is directly related to flight punctuality, passenger satisfaction, and airport operation efficiency. The development of air transportation plays a key role in economic development, where the impact of airport expansion on local economic development has been mainly analyzed in the literature [1]. However, these influences are also reflected in the demand for air traffic due to economic development, so the complexity and importance of airport scheduling is becoming more and more important in the light of the rapid development of the global economy and the expanding population, which leads to a continuous increase in the demand for air traffic. Efficient airport scheduling is important to alleviate the stagnation of flights and the accumulation of passengers. Through optimized scheduling, flight delays and congestion can be effectively reduced, thus optimizing resource use and overall operational efficiency. Therefore, the research and development of advanced airport scheduling algorithms is particularly important.

The importance of airport dispatching for airport resource management and operation is also introduced in detail [2]. There has been a lot of research on airport scheduling algorithms, which show significant advantages in improving scheduling efficiency and accuracy. Many studies show that optimization algorithms such as genetic algorithms, ant colony algorithms, particle swarm optimization, etc., perform well in solving complex airport scheduling problems. A large number of empirical studies in the literature have proved the feasibility and effectiveness of these algorithms in practical applications. Among them, the combination of genetic and machine learning algorithms has a significant effect. For example, this research mainly focuses on the scheduling analysis of genetic algorithms for refueling vehicles and ferry vehicles in the airport. Compared with direct flight scheduling, this scheduling direction fundamentally solves the problem of resource utilization. Because dispatching fuel tankers and ferries makes them more efficient, the result is that the landed aircraft can be equipped with the work of the next flight faster. Therefore, in some aspects, this scheduling strategy can also make some contributions to flight delays. At the same time, the efficient operation of the shuttle bus is also conducive to passengers leaving the airport faster, to avoid airport resources being occupied by passengers who have finished their travel. At the same time, there are already relevant literature on intelligent scheduling algorithms combined with machine learning

technology, which have stronger adaptability and accuracy in forecasting and decision-making, thus further improving the overall effect of airport scheduling. It can be seen that the algorithm combining sub direction genetic algorithm and machine learning for airport scheduling has a significant effect, but few articles focus on all the factors that can affect airport schedule.

This paper focuses on the application of genetic algorithms and machine learning in airport scheduling to provide an overview and summary and explore the role and limitations of genetic algorithms and machine learning in airport scheduling scenarios. Airport scheduling is a huge direction, and the research topic of this paper is to analyze the current utilization of airport resources and external airport resources and flight scheduling strategies. Achieving this goal requires a comprehensive review of the existing scheduling algorithms. A comprehensive review of existing scheduling algorithms is needed to achieve this goal. The strengths and weaknesses of the algorithms in each scenario are analyzed; this is used to determine the application scenarios of genetic algorithms and machine learning.

2. Algorithm overview

Genetic algorithms of an optimization algorithm based on natural selection and genetic mechanism is widely used to solve complex scheduling problems [3]. Its basic principle is derived from biological evolution, and by simulating the genetic and mutation processes of organisms, it continuously optimizes the solution to the problem. Genetic algorithms are excellent in complex optimization problems such as airport scheduling because of their powerful global search capability and adaptability. The core of genetic algorithms is to simulate the natural evolutionary process, through selection, crossover and mutation operations to optimize the individuals in the population iteratively.

The basic steps of genetic algorithm include the following: Firstly, the problem's solution is represented as a chromosome through encoding. The encoding is usually binary, real or symbolic. Next, an initial population of multiple chromosomes is randomly generated, and the diversity of the population is crucial for the algorithm's global search capability. Then, the fitness function is used to evaluate the strengths and weaknesses of each chromosome, and the chromosome with a higher fitness value indicates that its corresponding solution is closer to the optimal solution. Next, chromosomes are selected to participate in reproduction based on fitness value, and common selection methods include roulette selection, tournament selection and sorted selection. Subsequently, new chromosomes, i.e. zygotes, are generated through crossover operation, which simulates gene recombination in the biological genetic process, and common crossover methods include single-point crossover, multi-point crossover and uniform crossover. After the crossover operation, the chromosomes need to be mutated to introduce new genetic information to avoid the population falling into local optimization, and the common mutation methods include bit-flip and random mutation. Finally, the selection, crossover and mutation operations are carried out iteratively until the termination condition is met, which may be a predetermined fitness value or a certain number of iterations.

Genetic algorithm has strong global search ability and can effectively explore the solution space. It also has a wide range of adaptability and is suitable for various problems. In addition, the parallel processing ability of genetic algorithm can significantly improve the computing efficiency. Its robustness is also good, it is insensitive to the selection of initial conditions and parameters, and it can operate stably in different environments. These advantages make genetic algorithm very effective in optimizing and solving complex problems. However, the genetic algorithm also has some shortcomings, such as large computing resource consumption, complex parameter setting and slow convergence speed.

Machine learning is a technique that allows computers to learn patterns and regularities from data through algorithms and statistical models, to automate prediction and decision-making. Its main methods include supervised, unsupervised, semi-supervised, and reinforcement learning. Supervised learning uses labeled data for training and is commonly used for classification and regression tasks

such as image recognition and house price prediction. Unsupervised learning deals with unlabeled data and is commonly used for clustering and dimensionality reduction, such as customer segmentation and data visualization. Semi-supervised learning combines a small amount of labeled data with a large amount of unlabeled data to improve model efficiency and accuracy. Reinforcement learning obtains feedback by interacting with the environment and is commonly used in games and robot control.

Machine learning has many advantages. First, it can process large-scale and complex data sets and extract useful information and patterns from data through automated processes. Secondly, the machine learning model can be continuously improved and optimized. With the increase of data volume and algorithm improvement, its performance will gradually improve. In addition, machine learning has high flexibility and adaptability, and can be applied to various fields and scenarios, such as medical diagnosis, financial prediction, natural language processing and image recognition. At the same time, machine learning can also realize real-time analysis and prediction, and provide timely support for decision-making. Machine learning can significantly improve productivity and innovation capabilities through efficient data processing and analysis capabilities.

Although machine learning methods have many advantages, they also have some disadvantages. First, machine learning models rely on a large amount of high-quality data, and the data's availability and quality directly affects the model's performance. In the case of insufficient data or poor data quality, the model may not perform well. Second, machine learning models' training and debugging process is complex and requires a lot of computational resources and expertise, which may be a challenge for small businesses and individual researchers. In addition, machine learning models are often "black boxes" and it is difficult to explain their internal decision-making processes, which is a problem in certain application scenarios that require high interpretability (e.g., medical diagnosis and legal judgment). Finally, machine learning models may be biased and discriminatory. If the training data contains biases, the model may inherit these biases, leading to unfair decisions and results. Therefore, how to ensure the fairness of data and transparency of models is an important research direction.

3. Applications

The application of genetic algorithms in airport scheduling is summarized here. In order to explore the impact of the algorithm on airport scheduling, this paper categorizes airport scheduling into three scenarios, including flight scheduling, allocation of existing resources at the airport, and scheduling of available resources outside the airport. The scheduling focuses on the application of genetic algorithms and machine learning in these three scheduling scenarios, and whether the application produces satisfactory results.

The first focus is on the scheduling of flights, since flight scheduling has a decisive role in the allocation of airport resources. In this article, a multi-objective genetic algorithm is used to schedule flights [4]. The algorithm integrates multiple objectives and is not based on a single variable to find the best solution. Therefore, four hypotheses are set up to construct the model in this paper. In the construction of the model, one decision variable and several parameters are used to get the optimal parameters through the decision variable. The decision variable is set as the departure time of the first flight segment. Many time variables in the airport are set as the parameters, so that two decision problems are constructed. The optimal decision variable is obtained by solving the decision problem to respond to the optimization of the parameters. The decision model adjusts the unimplemented flights to compare with the flights actually implemented at the airport to get the effect of the important variables to reflect the effect of an optimal flight scheduling.

The same genetic algorithm is also used in scheduling airport resource allocation (such as shuttle bus, refueling truck). In relevant research, genetic algorithm is used to dispatch and allocate ferry vehicles and refueling vehicles, and multi-objective genetic algorithm is used to establish a decision-making model [5]. By optimizing the six decision variables, namely, the assignment and use status

of refueling vehicles and shuttle buses, as well as the boarding and refueling start time of flights, the main optimization goal is to achieve the vehicles with the minimum demand and minimize the start time of flight services. In addition, constraint conditions are added to limit the decision-making of the decision-making model, so that the scheduling model of the shuttle bus and refueling truck is obtained. Later, further inspection and certification are carried out according to the data obtained by the Capital International Airport. Finally, it is concluded that the cooperative scheduling of refueling truck and ferry bus with genetic algorithm has significant scheduling effect on the Capital International Airport.

Finally, scheduling the external resources of the airport (e.g. cabs, buses, etc.) can be scheduled using machine learning methods. A paper mainly analyzes the resource scheduling problem of machine learning for taxis. This paper proposes a mature decision-making model constructed according to eight different assumptions. At the same time, the eight assumptions are reasonable, mainly considering the cost, passenger volume, transportation distance, waiting time, charging standards, and economic profit and other factors. Determine the assumptions within the scope that can be investigated to build the decision-making model in this context. At the same time, this paper also considers a number of factors that may have an impact on taxi scheduling to establish variable relationships. Through the BP neural network of a single hidden layer, we can build a correlation model of the number of flights, passenger flow, parking lot passengers, parking lot taxis in a day, so that we can have enough data to further observe and analyze the scheduling strategy. Then, we can get the location that taxi drivers may go to and estimate the transportation distance by using the thermal imaging map, so that we can preliminarily estimate the economic profit according to the waiting time, transportation costs and charging standards, so that we can build a decision-making model for taxi dispatching within a day under the consideration of multiple variables. After the subsequent more detailed increase of variables, the factors of holidays and weather are considered to expand the universality of the decision-making model further. Through the increase of these variables, the taxi dispatching decision-making model of Chengdu Shuangliu Airport within one year was constructed, and a mature taxi dispatching model was finally perfected. The multi-dimensional decision model composed of multiple variables, such as passenger volume, taxi volume, weather, holidays, airport flight volume, economic profit, cost, and transportation distance, is comprehensively considered. Some of these variables have established an association model through machine learning, thus simplifying the complexity of the decision model.

4. Conclusion

Through this research, we deeply discussed the application of genetic algorithm and machine learning in flight and airport resource allocation scheduling. From three aspects of flight scheduling, airport internal resource scheduling and airport external resource scheduling, this paper comprehensively summarizes the developable points and advantages of the current airport scheduling field. It verifies its remarkable role in improving airport operation efficiency. With its powerful search and optimization capabilities, genetic algorithms can effectively solve complex scheduling problems and significantly reduce flight delays and resource waste. Machine learning can effectively establish variable relationships by virtue of its excellent memory ability and data receiving ability.

First of all, the application of genetic algorithms in flight scheduling shows their ability to quickly find the optimal solution. Through simulation and verification of actual data, it is found that genetic algorithm can quickly filter out the optimal or the best solution among a large number of scheduling schemes, thus ensuring that the flights can be operated efficiently according to the plan and reducing the delay phenomenon. This is of great significance in improving the overall operational efficiency and passenger satisfaction of airports.

Secondly, the genetic algorithm also performs well in airport resource allocation and scheduling. Reasonable allocation of airport resources is the key to ensure on-time flights and smooth operation. Genetic algorithm can optimize the resource allocation through its unique selection, crossover and mutation mechanisms to ensure that all kinds of resources (e.g., fuel trucks, ferries, etc.) are

reasonably and efficiently utilized. This not only reduces the possibility of resource conflict, but also improves the service capability and response speed of the airport.

Finally, in the airport external resource allocation scheduling, machine learning can through a large number of existing data to many difficult to establish a link between the variables to establish a link, so that more variables can be reflected in the decision-making model, so that the decision-making model is more reasonable. This ensures that the disembarked passengers can leave the airport quickly to avoid congestion at the airport exit and reduces the problem of the subsequent disembarked passengers not leaving the station normally and the ferries not being dispatched normally.

Overall, genetic algorithms and machine learning provide an efficient and reliable method for solving flight scheduling and airport resource allocation scheduling. The results of this study demonstrate the broad application prospects of genetic algorithms and machine learning in air transportation systems, and provide valuable experience and guidance for subsequent research and practice. In the future, combined with other advanced technologies, such as big data analysis, genetic algorithm and machine learning are expected further to enhance the intelligence and automation level of airport scheduling, thus contributing more to the sustainable development of air transportation industry.

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