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Research on the Allocation of Parking Resources under A-CDM Mechanism

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Abstract. *As the initial node of air transport, airport includes air traffic control, airport companies, airlines and other aviation operation support departments. The orderly combination of these departments constitutes the airport terminal operation system. With the gradual development of China's civil aviation industry, the aviation management system has been overwhelmed. The allocation of appropriate flights on the stand has a very important impact on both airlines and airports. Therefore, airport terminal operation unit of the system need to coordinate and cooperate with each other, such as air traffic control departments to integrate the airport run within the range of information and release to all aviation users, certainly can effectively improve the level of the entire airport security, efficiency and service quality, to improve the probability of a normal flight departure, reduce delays general economic costs. In order to solve the parking space allocation problem, a static parking space allocation model was established with the minimum travel distance of passengers as the optimization target, and the genetic algorithm was used to solve the optimization problem.*

Keywords: *A-CDM, airport gate assignment, minimum the total passengers walking distance, tabu search algorithm*

1. Introduction

Airport CDM has been deeply involved in the concept of air traffic management operation, and has become an important driving factor to improve the operational efficiency of air traffic management network and airport stakeholders. By 2019, ranked among the top ranking domestic airport of Beijing capital international airport, Shanghai Pudong international airport, Guangzhou Baiyun airport passenger throughput of 11 million person-time, marked the rapid development of civil

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aviation in our country at the same time, also for airport operations and the command of the resource scheduling has brought the huge challenge, so efficient airport management for the effective use of the existing system resources is becoming more and more important. Reasonable allocation of parking space can improve airport capacity, reduce flight delay rate and reduce the occurrence of accidents, which is the key factor of airport system capacity and service efficiency.

2. A-CDM Mechanism

With the rapid development of civil aviation transportation and the rapid growth of traffic volume, multi-terminal and multi-region management has become a trend in the development of civil aviation. However, this will make airport operation and security more complex. Seat allocation is a very important task in the daily operation of an airport, which is the core resource of the airport. Efficient and reasonable allocation scheme will not only bring great economic benefits to civil aviation transport. And to a certain extent can improve the safety of civil aviation transport. Scholars at home and abroad have conducted a lot of researches on models and algorithms for real-time airport parking station assignment [1-9]. According to the existing studies, the multi-terminal mode, flight wave, collaborative decision, time slot exchange fairness and the influence of these four factors should be considered in the real-time seat assignment algorithm.

Airport collaborative decision-making mechanism is one of the new concepts adopted by transport ministers of the European civil aviation conference in the European air traffic management strategy in 2000 [10]. Airport CDM is a concept aimed at improving air traffic flow and capacity management at airports by reducing delays, improving punctuality of events, optimizing the use of resources. Airport CDM allows airport participants to make the right decisions in collaboration with other airport participants by being aware of the limitations, current and expected status of other participants (airport operators, aircraft operators, ground handling, air traffic control). In order to ensure that high-quality decisions are made continuously [11], airport participants need to set goals. All airport CDM participants share the primary goal of maintaining a safe, smooth and efficient air traffic service for the benefit of passengers and cargo. To achieve this primary goal, aircraft operators, airports, ground handling, and air traffic controllers all have a number of specific supporting goals. The goal of the aircraft operator is to be able to perform the flight according to the schedule planned by the company. Flight delays can cause airlines to incur additional costs (extra fuel, missed connections). The goal of an airport is to maximize throughput and efficiency while fulfilling its operational plan. The goal of ground handling is to maximize the efficiency of resource management while ensuring service level agreements [12]. The best use of available resources depends in part on the accuracy of forecasts of inbound and outbound flights. The goal of atc is to achieve the optimal use of existing infrastructure (runways and taxiways) while ensuring safety. In order to measure the implementation effect of airport CDM objectives, a performance measurement method is introduced to evaluate the integrity of airport CDM.

3. Gate Assignment Problem

Parking space allocation refers to the allocation of appropriate parking space for inbound and outbound flights taking into account operating rules, aircraft type, parking space type, flight time and other factors. The seat allocation system is an important part of the airport information management system. The proper seat allocation directly affects the efficiency and passenger satisfaction of the airport. Due to the relative complexity of the domestic airport information system, most of the automatic allocation of flight space in the domestic information system is not fully automatic, but only semi-automatic. That is, the allocation scheme is given first, then manually processed, and the inappropriate allocation method is changed. However, the manual allocation method will often result in the allocation of some inorganic seats in the flight, and the allocation to the remote seats, and the transfer of passengers by way of shuttle bus. This has a serious impact on passenger satisfaction, as well as a waste of resources and additional costs.

The research on parking space allocation can be generally classified into the following types: the first type focuses on models and algorithms. Because we know that the parking space allocation problem is a np-hard problem, its time complexity increases exponentially with the increase of flight size. Therefore, a lot of literature is about which algorithm or hybrid algorithm can be used to reduce the running time of the model. Such as Mangoubi R S [1], Yah S Y, re-arrest -- C M [13], Yah S, Tang C [14], Zhu Shiqun, Zhu Jinfu [15], and so on, Wei Dongxuan [16], Yang Wendong [17], Feng Cheng [18], etc, are all on the basis of the basic allocation model is set up using heuristic algorithm or a combination of several algorithms to solve the model in order to reduce time and improve efficiency. The second type mainly focuses on model simulation. After the basic data are obtained, various types of simulation systems are set up to simulate the parking space allocation of the airport in real time using the simulation technology, mainly to solve the conflict control problem of the aircraft in the parking space. Cheng Y [19] proposed an AGAP simulation model based on rules and network technology. Yan S [20] et al. proposed a simulation model combining two similar heuristic algorithms of minimum total passenger walking distance.

In the study of the optimization goal, when taking the interests of passengers as the main object of consideration, it is most widely used to take the minimum travel distance of passengers and the minimum waiting time of passengers as the optimization goal. When the utilization rate of airport slots is taken as the main consideration, the optimization goal is to minimize the idle time of slots and the number of remote slots. In the previous studies, more and more scholars paid attention to the breakthrough in algorithm innovation, but in the choice of optimization goals often choose a single optimization goal. In the actual AGAP problem, the optimization goal should be multi-objective. If the optimization goal is only the minimum travel distance of passengers, some seats will be busy while others will be idle. If only the idle time is considered, the passenger satisfaction will be reduced.

4. Gate Assignment Problem Model

The goal of parking space allocation optimization is to allocate a given flight to different seats, so that there will be no conflicts between flights and passengers can walk the shortest distance [21-22]. Aircraft that cannot be allocated to a stand will be allocated to the apron. Since the distance from the entrance to the apron is much greater than that from other stands, flights should be allocated to the stand as far as possible. Only one aircraft (except the tarmac) is allowed to be assigned to all stands at the same time. Since different aircraft position problems can be decomposed into several identical aircraft position problems, this paper assumes that all available aircraft positions and required aircraft positions are the same. The mathematical model of parking space allocation is given below [23-25].

Define the following variables:

N: the planes assemble (arrive or leave);

M: the number of available seats at the airport;

n: the total number of planes;

m: total number of seats;

a_i: arrival time of flight I;

d_i: departure time of flight I;

W_{kl}: the distance from seat k to seat l;

f_{ij}: number of passengers from flight I to j;

g_i: seats assigned to aircraft I;

Two virtual stands are added: 0 represents the entrance or exit of the airport,m+ 1 represents the inorganic bit available when the aircraft is allocated to the apron; The binary variable y_{ik}= 1 means that flight I is allocated to entrance k; otherwise, it is 0; (I,j)y_{ik}= y_{jk}= 1(k≠ m+ 1) if and only if $(a_i-d_j)\times(a_j-d_i)< 0$.

The optimization goal is:

$$\text{Minimize}\sum_{i=1}^{n}\sum_{j=1}^{n}\sum_{k=1}^{m+1}\sum_{l=1}^{m+1} f_{ij}\times W_{kl}\times y_{ik}\times y_{il}+\sum_{i=1}^{n} f_{0i}\times W_{ogi}+\sum_{i=1}^{n} f_{i0}\times W_{gi0} \quad (1)$$

The constraint conditions are:

$$\sum_{k=1}^{m+1} y_{ik}= 1(\forall i,1\le i\le n) \quad (2)$$

$$a_i< d_i(\forall i,1\le i\le n) \quad (3)$$

$$y_{ik}\times yjk(d_j- a_i)(d_i- a_j)\le 0, \quad (4)$$

$$(\forall i,j,1\le i,j\le n,k\neq m+ 1) \quad (5)$$

$$y_{ik}\in\{0,1\}(\forall i,1\le i\le n,\forall k,1\le k\le m+ 1) \quad (6)$$

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5. Design of Airport Gate Assignment Genetic Algorithm

The operation of genetic algorithm needs tedious calculation from the beginning to the end, so we need to sort out the algorithm process. Genetic algorithm is mainly composed of the following steps:

(1) Firstly, according to the actual problem, determine the objective function and constraint conditions of the optimization problem, as well as the form of the solution;

(2) Establish an optimization model, that is, determine the objective function and its mathematical description;

(3) The coding method of chromosomes is given, that is, the individual genotype and search space are given;

(4) Establish the decoding method to realize the mutual conversion between genotype and phenotype;

(5) Give the evaluation method of individual fitness, and establish the conversion relationship between the objective function value and individual fitness;

(6) The specific operation method of genetic operators, that is, the detailed operation process of genetic operators including selection, crossover and variation is given;

(7) Determine the operation parameters of the genetic algorithm.

In this paper, a parking space allocation algorithm based on genetic algorithm is proposed. In order to avoid the rapid growth of the coding length with the increase of the number of flights, the real coding method is adopted. To simplify the description, the airport has 3 stands and 10 flights to be allocated. Assuming that flight 1 and flight 2 are allocated to stand 1,3, 4 and 5 to stand 2,6, 7 and 8 to stand 3, and 9 and 10 to stand on the tarmac, the genetic code is as follows:

1	2	0	3	4	5	0	6	7	8	0	9	10

Flights assigned to different stands are separated by 0, with each group representing a different stand. In addition, the method of proportion selection is used in the process of genetic algorithm execution.

The method of randomly generating population is adopted. Considering that in the actual situation, the distance from the entrance to the tarmac is much greater than that from the entrance to the tarmac, the primary task of the parking space allocation problem is to minimize the number of flights allocated to the tarmac, which can greatly accelerate the convergence speed of the algorithm. Therefore, this paper uses greedy algorithm to further optimize the initial population. The basic principle is as follows: after all the flights are sorted, the flights allocated to the tarmac are adjusted in turn, and each flight is allocated to the stand that is free and whose free start time is closest to the flight's entry time. If no such stand exists, the flight will remain on the tarmac.

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5.1 Design of Fitness Function

The objective function is directly adopted as the fitness function, and the differentiation degree of different objective function values is not big, which will lead to the slow convergence of the algorithm and affect the calculation time. Therefore, the idea of simulated annealing is introduced to design the fitness function as follows:

$$fitness=e^{value\times(-a)}\times 10^{n}$$

Value represents the target function Value, and n adjusts the interval of fitness function Value so that it is not too small. Coefficient a determines the compulsion of replication. The smaller a is, the greater the differentiation of fitness value is. The fitness function is opposite to the monotonicity of the target function. When the target function reaches the maximum value, the fitness function takes the minimum value.

5.2 Crossover Operator Design

At different stages of evolution, two situations occur when fitness values are selected in proportion. In the early stage of genetic evolution, there are usually some super-normal individuals, who are so competitive that they control the selection process and influence the algorithm to search for the global optimal solution. In the late stage of genetic evolution, the potential of continuous optimization is reduced due to the close convergence of the algorithm and the small difference in fitness of individuals in the population.

(1) Handle the change in the number of stands. If the number of stops in the daughter chromosome increases, then starting from the last crossing point and ending at the previous crossing point, look for the position with the code of 0. There must be such a point, where the code of this position is 0, and the code of this position is not 0 in the other daughter chromosome, so the codes of this position on the two chromosomes are interchanged. If the number is reduced, the number of stops must be increased for another daughter chromosome, which can be disposed of. This process is repeated until the number of slots does not change.

(2) To deal with the situation that the same flight occupies two stands. From the last intersection to the end of the previous one, look for the flight, replace the first location of the flight with the smallest one that is not currently present in the daughter chromosome, and repeat the process until each flight is assigned to a stand.

(3) To deal with the problem of time conflict between flights at the same terminal. According to constraint condition (4), each flight was adjusted. Flights that did not meet the constraint condition were allocated to the apron. Then greedy algorithm was used to optimize the flights to minimize the number of flights allocated to the apron.

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5.3 Mutation Operator

Two genes were randomly selected from chromosomes for exchange, and the flights assigned to each stand were sorted according to the time of entry into the stand. Each flight was adjusted according to the constraint condition (4), and the flights that did not meet the constraint condition were assigned to the apron. The algorithm process mentioned above is combined with the real-time flight allocation in the collaborative decision-making system of A-CDM airport to determine the set of parking space allocation and finally determine the corresponding parking space assignment scheme.

6. Conclusion

This paper studies the collaborative decision-making mechanism under the airport slots allocation model based on minimum passenger walking distance, through the establishment of walking with the minimum distance as the optimization goal, and the constraint conditions of slots distribution model was established, by combining genetic algorithm and characteristics, as well as the current CDM in some airports to realize information sharing, on the basis of the model was reasonable algorithm design, can fully consider slots real-time allocation and to maximize the airlines flight, in order to optimize the slots at the allocation of resources, improve the capacity of the airport scene, reduce the number of conflicts and flight delays the time to lay the foundation.

In this article, mainly study the establishment of the model, the model of a full feasibility study, it remains to be continue to verify, are considered in the model under the certain time, considering the delay of the flight time slot optimized, gate position is assigned a real-time dynamic process, not only by Atc, airports, airlines and the influence of the controllable factors such as the unit also is limited by the weather and other natural conditions, therefore, for the gate position distribution needs further research.

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