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Research on Civil Aviation Ground Regulation based on GA Algorithm

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Abstract

In recent years, the civil aviation transportation industry is developing rapidly. The airport has become an indispensable facility for passenger travel and cargo transportation. With the continuous increase of airport throughput, traffic congestion often occurs during flight peak hours and bad weather, resulting in large-area flight delays and long-time ground waiting of aircraft, especially those flights that have entered the taxiway after launch, resulting in high aviation fuel loss with the operation of APU (auxiliary power unit). Therefore, the management of flight delay has become an effective means to improve the competitiveness of air transportation enterprises. This paper studies the number of aircraft taking off and landing and the law of time difference on each runway of the airport. Taking the time difference as the independent variable, through fitting the data, this paper establishes the relationship model between the take-off and landing difference and the airport operation efficiency, completes the model hypothesis, model establishment and stability analysis, tests the goodness of fit of the actual flight data of the airport, takes the test results as the model input for simulation, and the results are consistent with the actual departure process. Finally, through the analysis of departure flight data, this paper uses the method of delaying the number of flights in peak hours in batches to improve the algorithm and improve the utilization of taxiway and runway, so as to reduce the waiting time and dwell time of flights. Through the simulation of the improved model, the results show that the improved algorithm is practical and effective, and provides an effective reference value for solving the problem of airport ground traffic congestion.

Keywords

GA (Genetic Algorithm); For Ground Scheduling System of Inbound and Outbound; Flight Waiting Model.

1. Introduction

With the continuous development of economic globalization and trade, in recent years, air travel has gradually developed into an important means of transportation for people to travel. Since the growth rate hit a low of 4.7% in 2008, the national civil aviation passenger throughput has been growing rapidly. In the 10-year period from 2009 to 2018, the growth rate was more than 10% in other years except for 9.5% in 2012. However, in 2019, the growth rate dropped sharply to 6.9%, 3.3 percentage points lower than the previous year. In 2019, the national civil aviation passenger throughput was 1.35 billion, 3.3 times that of 405 million in 2008. Therefore, the safety of air travel has attracted more and more attention from people from all walks of life. Airport ground operation scheduling is a key link in flight. An excellent airport ground operation scheduling can not only improve the operation efficiency of the airport, but also accurately control the time when the aircraft leaves the apron, plan the aircraft downtime and ensure the safety of the aircraft in the process of operation. Therefore, airport ground operation scheduling has attracted extensive attention.

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In 2010, China's overall punctuality rate was 75.8%. The essence of this problem is the imbalance between the capacity and demand of the airport. When the capacity is far less than the demand, it will cause traffic congestion and the aircraft cannot land. The emergence of such situations has greatly increased the potential safety hazards of flight. Therefore, optimizing the airport ground operation scheduling is the key measure to ensure flight safety.

2. Selection and Implementation of Algorithm

2.1 GA Algorithm Overview

Genetic algorithm (GA) originated from the computer simulation of biological systems. It is a random global search and optimization method developed by imitating the biological evolution mechanism of nature, and draws lessons from Darwin's evolution theory and Mendel's genetic theory. Its essence is an efficient, parallel and global search method, which can automatically acquire and accumulate knowledge about the search space in the search process, and adaptively control the search process to obtain the best solution.

Mathematical point of view: in the process of solving practical problems, we will find that many problems are non convex, that is, there are often many local optimal solutions in the global scope, so how to find the global optimal solution in the global scope is an important problem of the optimization problem. Genetic algorithm can skillfully solve the problem. It does not need the internal complex mechanism, and we can regard it as a black box, Constantly looking for potential solutions and finding the global optimal solution adaptively through certain criteria. When solving more complex combinatorial optimization problems, compared with some conventional optimization algorithms, it can usually obtain better optimization results faster.

2.2 Implementation of GA Algorithm

Implementation of GA algorithm chromosome encoding and decoding:

The genes of each individual in the initial population can be generated by evenly distributed random numbers, for example, in an interval $x \in [a, b]$ In order to find the optimal solution, the coding length of chromosome and the accuracy requirements of X are very important. Assuming that the length of chromosome to be coded is n and the required accuracy dimension is m digits after the decimal point, the relationship between chromosome coding length and accuracy is as follows:

$$2^{n-1} \leq (b-a)\,10^{m} \leq 2^{n}-1$$

Under the relevant accuracy requirements, the coding length n of chromosome can be determined according to the above inequality, and then the coding of independent variable {x can be realized:

000...000=0

000...001=1

000...010=2

...

111...111=$2^n - 1$

Under the relevant accuracy requirements, the coding length n of chromosome can be determined according to the above inequality, so as to realize the coding of independent variable X: when solving the value of individual adaptive function, the chromosome coding needs to be decoded. For a binary string with length N, the decoded x value is:

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$$x = a + \frac{b-a}{2^n - 1}\sum_{k=1}^{n} b_k 2^{k-1}$$

Among them $b_1, b_2, \ldots b_n$ is coding number (0 or 1) on the k-th bit (from right to left) of an individual's binary coding can realize the transformation between understanding space and gene space elements in the above definition of encoding and decoding.

Fitness function: the selection of fitness function directly affects the convergence speed of genetic algorithm and whether it can find the optimal solution. Because genetic algorithm basically does not use external information in evolutionary search, it only uses the fitness function as the basis and uses the fitness of each individual of the population to search Because the complexity of fitness function is the main component of the complexity of genetic algorithm, the design of fitness function should be as simple as possible to minimize the time complexity of calculation. There are many construction methods, such as selecting the reciprocal of the system objective function as the fitness function of genetic algorithm.

Operation steps of genetic algorithm:

1) Determine the value range of fitness function, accuracy and chromosome coding length.

2) Initialization operation: chromosome coding, establishment of population number, crossover and mutation probability, etc.

3) Initialize population: randomly generate the first generation population.

4) Use the fitness function to evaluate the population and judge whether it meets the stop condition. If so, stop and output the optimal solution; Otherwise, continue the operation.

5) Select, cross and mutate the population to get the next generation population. Go back to step 4.

Based on the aircraft, the specific operations are as follows:

① Chromosome coding

The coding method based on operation is adopted. The chromosome is composed of the sequence of all operations. Each gene represents an operation. All operations of the same aircraft are represented by the same aircraft serial number. The arrangement and combination of all aircraft serial numbers are taken as the chromosome. The position of the aircraft serial number in the individual represents the ground sequence of the aircraft. For example, the chromosome of a 3 * 3 scale example can be [213121233], in which the first gene 2 is the first occurrence of J2, representing the first process of J2, and on the ground of M1, i.e. o2m1,1; The second gene 1 is the first appearance of J1, on the ground of M1, that is, operation o1m1,1; Similarly, gene 3 is operation o3m2, 1; The fourth gene 1 is operation o1m2, 2; The fifth gene 2 is o2m3, 2, followed by operation o1m3, 3, o2m2, 3, o3m1, 2, o3m3, 3.

② Chromosome coding

Because the optimization performance and search efficiency of genetic algorithm are strongly dependent on the initial population, Neh heuristic rules are introduced to form the initial population individual of aircraft, and the remaining initial population of genetic algorithm is generated by random generation.

③ Calculate fitness value

The reciprocal of the system objective function is selected as the fitness function of the improved genetic algorithm, is:

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$$u(\theta)=\frac{1}{f(\theta)}=\frac{1}{C_{max}}=\frac{1}{\sum_{i=1}^{n}\sum_{j=1}^{n_i}(S_{i,j}^{m_k}+P_{i,j}^{m_k})}\quad m_k\in M$$

④ Chromosome coding

Selection: wheel selection. The selection probability of the individual is determined according to the proportion of fitness value of each chromosome. For a given population of size n, the selection probability of the ith individual is:

$$P_s(i)=\frac{f_i}{\sum_{i=1}^{N}f_i},\ i=1,2,\cdots N$$

1) FI is the fitness value of the ith individual in the group, and Σ Ni = 1fi is the sum of the fitness values of the group. It is obvious that individuals with high fitness function value have greater selection probability.

2) Crossover: randomly select two individuals from the population according to the crossover probability as the parent, and select the first and last backtracking node for each individual as the intersection according to the location information of the backtracking aircraft (for the case where the number of backtracking aircraft is less than or equal to 1, randomly select two or one aircraft as the intersection). Firstly, the parts before and after the intersection point in the male parent are cross copied, and then the genes not contained in the intersection part are supplemented according to the order of the original aircraft in the other male parent, which can not only retain the relative position of the backtracking point, but also maintain the diversity of the population on the basis of the backtracking point.

3) Mutation: according to the mutation probability, first select the aircraft with backtracking as the mutation individual, use the exchange of adjacent individuals to realize the mutation operation, and then randomly select the remaining mutation individuals and use the method of random insertion for mutation.

3. Model Analysis and Prediction

3.1 Data Sources

The data comes from the annual data of aircraft flying between domestic airports from October 2019 to October 2020.

For the terminal airport cargo aircraft ground scheduling problem with limited waiting time in the buffer zone, an appropriate scheduling method is constructed. For the small-scale scheduling problem, a branch search algorithm is constructed to obtain its exact solution. For medium and large-scale scheduling problems, through the recursive backtracking position information and constraint transmission of branch search algorithm, repair the ground start time of aircraft, design the corresponding crossover operator and mutation operator, propose an improved genetic algorithm (GA) to solve, and complete the scheduling of all aircraft after iterative evolution. Finally, simulation experiments and performance analysis verify the effectiveness and practicability of the proposed algorithm to solve this kind of scheduling problem.

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3.2 Model Analysis

It can be seen that the average value of the improved GA algorithm tends to be the optimal value from the first generation of GA to the second generation of GA, and when we compare it with the improved GA algorithm, the average value of the improved GA algorithm tends to be the optimal value from the first generation of GA to the second generation of GA, the convergence effect is also better.

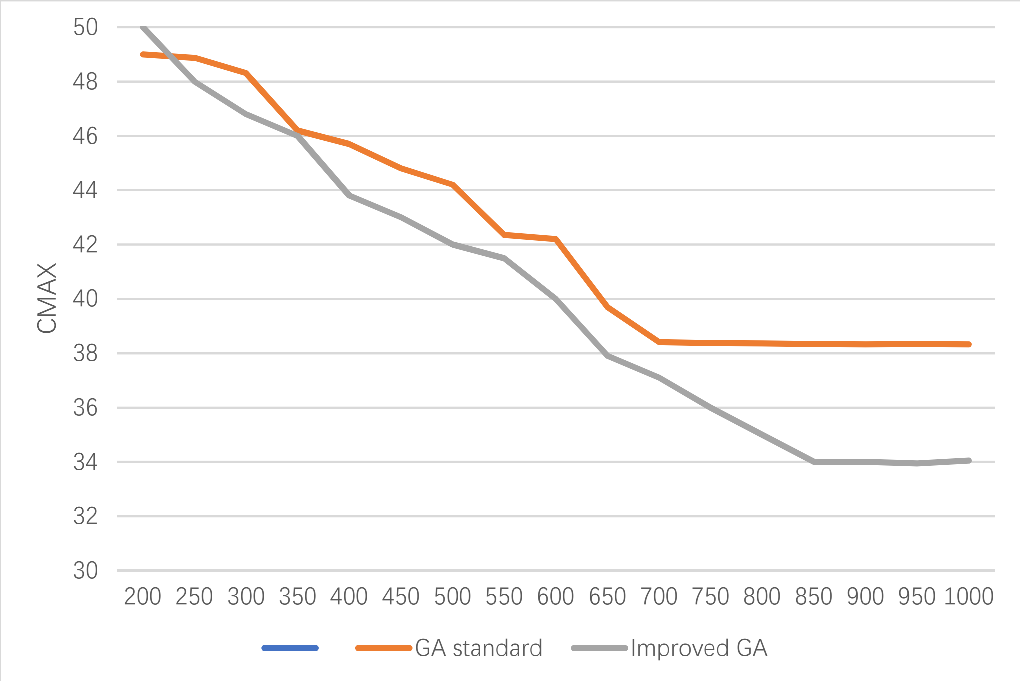

Figure 1. average convergence of standard GA algorithm and improved GA algorithm

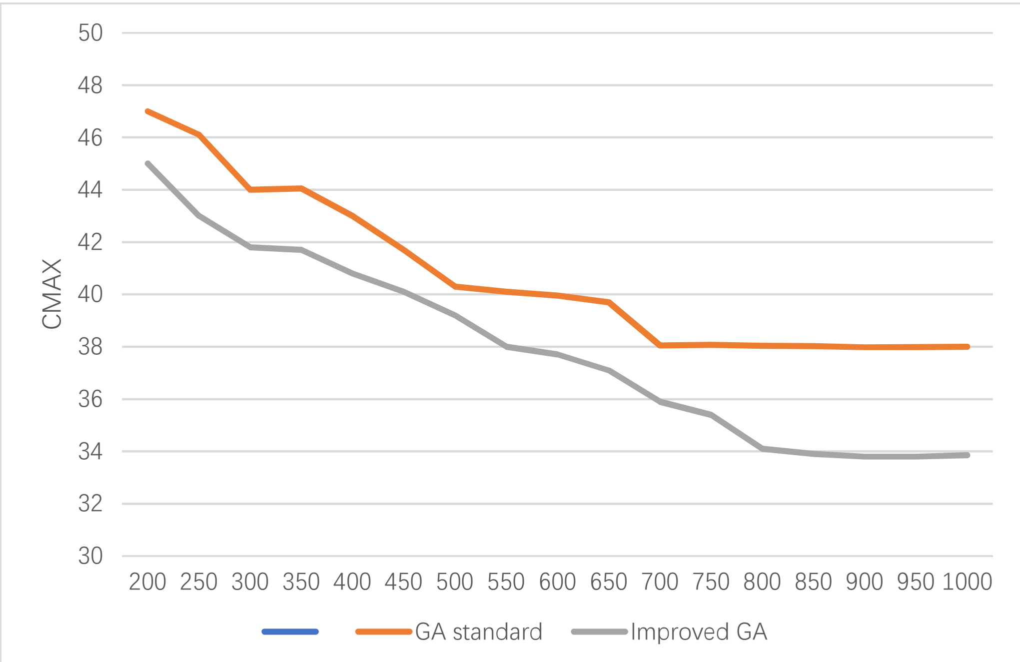

Figure 2. optimal value convergence of standard GA algorithm and improved GA algorithm

During the experiment, we found that when the number of aircraft is large, the time constraints are more strict, the scheduling results change less, the scheduling results are relatively stable, and the data tend to be stable. When the aircraft flow in and out of the port is small, the constraints on aircraft landing are poor, the data are relatively loose, the scheduling results change greatly, which has a great impact on the results, the data are unstable, and there are large errors.

During the experiment, there is no obvious difference between the branch algorithm and the genetic algorithm. However, when the number of aircraft and other constraints increase, the running time of the branch algorithm increases significantly, and it is prone to certain errors. The data obtained by the genetic algorithm is more stable. During the experiment, the running time of the standard GA algorithm is shorter than that of the improved GA algorithm, but the data obtained by the improved GA algorithm is closer to the original data, The results are more accurate.

4. Conclusion

In order to ensure the orderly landing and take-off of aircraft for the scheduling problem of civil aviation airport, this paper studies the number of aircraft taking off and landing and the law of time difference on each runway of the airport, takes the time difference as the independent variable, and establishes a mathematical model of the relationship between the take-off and landing difference and the operation efficiency of the airport. The model provides a reference for civil aviation ground scheduling from the mathematical level. In the aspect of algorithm, we use the mature GA (genetic algorithm), design the algorithm factor through the backtracking point information in branch search, improve the genetic algorithm within the allowable range, and verify the effectiveness of the algorithm through stable results.

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