Research Article

An Improved Genetic Algorithm-Based Traffic Scheduling Model for Airport Terminal Areas

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This paper takes the airport terminal area as the main research content and combines genetic algorithm with airport terminal area analysis theory to analyze and study the traffic scheduling in the airport terminal area. Based on the study of traditional traffic scheduling techniques and key techniques of genetic algorithms, this paper participates in the actual project of genetic algorithm-based traffic scheduling, analyzes the requirements of the project, focuses on the design and implementation of the traffic scheduling algorithm module in the genetic algorithm-based traffic scheduling system, and conducts further research on the pathfinding by constraints submodule. In this paper, the flight approach and departure sequencing problem and runway allocation problem are the main research objects. The dynamic optimal scheduling model of flight approach and departure is established by considering the interests and demands of airlines and airports, and a new scheduling algorithm is proposed. In this paper, a brief introduction to the airport terminal area is given, and the feasibility of the approach/departure optimal scheduling is introduced from the perspective of airlines with a long-range parallel two-runway airport as the research background. Secondly, through the analysis of the flight approach and departure process and the study of the approach and departure cooperative optimization strategy, a single-runway flight approach and departure traffic scheduling model under the joint sequencing strategy is established with the optimization objective of minimizing the total flight delay time, and the model is solved by using the sliding time window algorithm. Then, based on the single-runway scheduling model, a multirunway multiobjective flight optimal scheduling model is established with the objectives of minimizing total delay time, increasing runway throughput per unit time and fairness of flight delay time allocation, and a dynamic algorithm (STW-GA) combining sliding time window algorithm and dual-structured chromosome genetic algorithm is proposed to solve the model.

1. Introduction

With the rapid development of China’s economy, the scale of the civil aviation industry is expanding; although the level of protection of all parties is constantly improving, the huge transport demand still brings many problems of unbalanced and uncoordinated development to the civil aviation industry, the use of airspace structure is becoming increasingly complex and diversified, and simple analysis and rough planning are no longer able to meet the requirements of safety and efficiency [1]. In addition, the root cause of ATC problems in flight delays is unreasonable airspace structure and inadequate overall airspace planning, so more accurate forecasting and long-term planning are fundamen-
in busy terminal areas is also increasing [3]. The main influencing factor of air traffic network congestion is the “bottleneck” effect caused by the capacity constraints of airports, terminal areas, and route intersections, and the terminal area, as one of the subsystems of the ATC system, is in a sense the most complex subsystem in terms of operational status. The airspace has a complex route structure, limited airspace resources, flight flow, and control difficulties, which become the bottleneck of the whole airspace efficiency [4]. Airspace planning is an important element in the field of airspace design and management and is an important method to improve airspace operational efficiency and air traffic service quality. The main influencing factor of air traffic network congestion is the “bottleneck” effect caused by the capacity constraints of airports, terminal areas, and route intersections. As one of the subsystems of the air traffic control system, the terminal area is, in a sense, one of the most complex subsystems; this airspace has complex characteristics such as complex route structure, limited airspace resources, and difficulty in-flight flow and control, which has become a bottleneck for improving the efficiency of the entire airspace. The research on how to reasonably plan the airspace of new airports in busy terminal areas is an important means to solve the effective allocation of airspace resources and alleviate the pressure on airspace, which is of great significance to improve the airspace management capacity of terminal areas in China. Therefore, this paper starts from the perspective of terminal area airspace planning, predicts the number of takeoffs and landings of airports in the busy terminal area and the distribution of flight traffic OD in the terminal area, establishes a terminal area route network optimization model based on the layout of waypoints, and ensures that the terminal area airspace can provide safe and efficient services for users.

Traffic scheduling is the problem of optimizing resource allocation for complex data flows in a cloud data center when sharing network resources and is directly related to the network transmission performance of applications with differentiated performance requirements in cloud data centers. Therefore, traffic scheduling has been the focus of industry and academia. To improve the convergence performance of the genetic algorithm, researchers apply various complex network models to the population structure design of the genetic algorithm and analyze how different population structures affect the performance of the genetic algorithm. With the explosive growth of cloud data center tenants and applications, cloud data center applications show significant differentiation in performance requirements. For example, some applications (e.g., online sales, web search, securities trading, and other services) have very small data traffic, typically a few kb to a few hundred kb [5]. These small chunks of data streams are very sensitive to latency during network transmission, and often a very small transmission delay can result in a large loss of revenue. Some other applications (e.g., data analysis, storage backup, virtual machine migration, and other services) generally have very large data traffic. These applications have little requirement for transmission latency, but because their data traffic is generally very large, they need to occupy a large amount of bandwidth in the cloud data center to achieve network transmission. In practical application, the genetic algorithm does not have high requirements on the model of the optimization problem, and it also has good adaptability to the ambiguity of data when solving. It has been well applied in real life and is an efficient global search. The optimal algorithm has the advantages of strong applicability, strong robustness, and high efficiency. On the other hand, the lack of effective isolation of different application data streams in cloud data centers makes these data streams with different performance requirements must compete for the same network resources frequently, thus posing a great challenge to cloud data center traffic management.

As a typical representative of the search algorithm that simulates the superiority and inferiority in nature, the genetic algorithm is fundamentally similar to a complex system; this system consists of a large number of individuals, and the individuals in the system interact with each other, thus having a large impact on the nature of the system; in other words, the population structure of the genetic algorithm has a significant impact on the transmission of genetic information in the population. The population structure of a genetic algorithm can adjust the propagation of genetic information in the population, thus having a significant impact on the convergence performance of the genetic algorithm [6]. To improve the convergence performance of genetic algorithms, researchers have applied various complex network models to the design of population structures of genetic algorithms and analyzed how different population structures affect the performance of genetic algorithms. The researchers classified these population topologies into two types: stationary and kinematic structures. For genetic algorithms that simulate natural evolutionary processes, the stationary structure does not reflect the changing interactions between individuals in the population, so it can limit the performance improvement of genetic algorithms [7]. The study of the kinematic structure is divided into two main categories: one is to adopt the corresponding adaptive scheme for the genetic algorithm and improve the structure according to the existing network model, and the other is to improve the original network structure according to the individuals in the population. In a sense, the real world can be seen as a relatively complex self-organizing complex network, and if the computational process of genetic algorithms can be designed according to the evolutionary process of self-organizing dynamic networks in the real world, the individuals in genetic algorithms can interact with each other like a biological population in nature. A genetic algorithm is a heuristic algorithm based on the genetic evolution mechanism of the natural population, which is widely used in global optimization search. It is different from the traditional search method. It randomly searches the target space by simulating the biological evolution process in nature. Moreover, the theory of complex networks can open new directions for the study of genetic algorithm performance improvement, so genetic algorithms can be analyzed and designed from the perspective of complex networks. However, few existing studies combine complex networks with genetic algorithm performance improvement, and the study
of genetic algorithm analysis and design based on complex network theory has significant research significance for genetic algorithm performance improvement. Complex network theory has been widely used in virtual communities, transportation systems, disaster spreading, and other fields.

2. Related Works

As an important area connecting the two sides of the airspace, the terminal area airspace has been studied in many developed countries. Mc Conkey firstly planned the airway network from two different perspectives of aircraft flight and control to meet the needs of both airspace users and studied the airway network in the terminal area and transition area by comparing the structure of the airway network studied the airway network in the terminal area and transition area by comparing the structure of the airway network under terminal area and normal flight [8]. In 2001, the "National Airspace System Operation Development Plan 2001-2010" was released to solve the problems of route congestion and airport congestion caused by various reasons and proposed measures to improve the security capacity of airport terminal areas by using ground-air data link and regional navigation. In 2007, the FAA found that airspace is another important factor, in addition to runways, limiting the capacity of airports, and explored the effect of increasing or improving air traffic control procedures and redesigning airspace structures on improving airport capacity [9]. Dual Serhan incorporates airline and passenger delay costs into an integrated airport ground and terminal airspace traffic management system, and Stavros Sidiropoulos constructs a framework for dynamic approach and departure routes to a multiairport terminal area, which leads to a significant improvement in the efficiency of the multiairport terminal area system [10]. In 2009, Hui Zhang established a terminal area Voronoi finite element profile model based on flight segments and combined traffic forecasting with route network optimization for sector classification, and proposed a "flight segment" theory for the characteristics of terminal area flight paths. In the same year, Rui Zhou proposed the "flight segment" theory for the characteristics of the terminal area flight path. In the same year, Rui Zhou conducted an in-depth and systematic study on the optimization of terminal airspace structure, proposed a terminal airspace route dynamic management model based on the principle of economic optimality, and established an evaluation system to evaluate the operational capacity and status of the route network. 2014, Li Yinfei combined the analysis of the factors affecting terminal area capacity, established three types of terminal airspace resource allocation strategies to improve the guarantee capacity of the terminal area, which are runway operation mode adjustment, route structure optimization, and traffic flow optimization, and established a terminal area airspace resource allocation strategy evaluation model. Previous studies on terminal area airspace focused on traffic flow prediction, airport capacity assessment, flight approach and departure sequencing, etc., but less research was conducted on the overall planning of airspace in busy terminal areas.

The early (the early 1990s) traffic scheduling technology used in router-based core networks was Native IP. Native IP changed the path of service traffic by simply adjusting the routing weights/attributes of the interior gateway protocol (IGP) or by issuing access control list (ACL) policies on the router side. The ACL policy was issued at the router side, in order to change the path of service traffic and realize traffic scheduling. Fewer studies related to the aspect of airport scheduling for traffic scheduling algorithms are mostly focused on the study of heuristic algorithms. To minimize the delay cost, Xiaohang Cheng solves the single-runway entry scheduling problem by the essence adaptive genetic algorithm and optimizes the entry sequence of flights and the entry moment. To reduce the total flight delay time and cumulative landing time, a backtracking and swapping-based flight approach sequencing model is proposed [11]. The model effectively utilizes the spare time slots by the backtracking method and then determines the flight exchange rules by the cumulative landing factor and the delay factor. And the optimal values of the backtracking factor and weights are calculated through several simulations [12]. With the research objective of reducing the total flight delay time and increasing the airport capacity, the fusion backtracking algorithm is proposed based on the location-constrained exchange algorithm and the airflow control model.

The genetic algorithm was first proposed by Professor J. Holland in 1975 in his monograph “Adaptation in Nature and Artificial Systems,” which is a class of optimization algorithms that simulate natural selection and meritocracy in nature [13]. Genetic algorithms have no high requirements for the model of optimization problems in real-life applications, they also have good adaptability to the ambiguity of data in solving them, and they are well used in real life as an efficient global optimization-seeking algorithm with the advantages of high applicability, robustness, and efficiency. Well-adapted in real-life applications, it is an efficient global optimization-seeking algorithm with the advantages of high applicability, robustness, and efficiency. In practical applications, the standard genetic algorithm has many defects in maintaining population diversity, convergence accuracy, and convergence speed, which limit the development and application of genetic algorithms. Therefore, researchers have improved genetic algorithms in terms of parameter improvement and optimization, scheme adjustment, hybrid genetic algorithms, and improved neighborhood topology [14]. In terms of improvement and optimization of parameters and adjustment of the scheme, a new improved genetic algorithm is proposed, whose fitness function can change with individual states, while the variation operation is adjusted in the genetic algorithm, and it is experimentally found that the performance of the improved genetic algorithm is significantly improved, which makes the efficiency of solving complex problems significantly improved. To deal with optimization problems with large dimensions, an improved genetic algorithm is proposed. The improved genetic algorithm improves the strategy in selecting the initial population and adopts adaptive processing for the assignment of individuals, uses three individual assignment schemes, and applies the new strategy in selecting the initial population. It is found that the improved genetic algorithm
greatly improves the convergence speed of the algorithm and effectively improves the solution performance of the genetic algorithm. The operation operators of the genetic algorithm were optimally adjusted, the crossover and mutation operations in the genetic algorithm were adaptively processed, while the corresponding formulas were reasonably adjusted, and the elite retention strategy was optimized with a more reasonable and effective scheme. It is found that the improved genetic algorithm greatly reduces the production cost while effectively reducing the optimization time. In the research of combining with other algorithms, the standard genetic algorithm is combined with the particle swarm algorithm, and the improved algorithm carries out special retention for the elite individuals, and the particle swarm algorithm further optimizes the processing of the elite individuals, and the experiments find that the combination of the two algorithms effectively improves the performance of the algorithm. In recent years, with the popularity of the Internet and the rapid development of artificial intelligence algorithms, its application areas are also more and more extensive, in which the aerospace path planning problem can also be solved by artificial intelligence algorithms. A genetic algorithm is a common method for production scheduling problems. In many cases, the mathematical models established for production scheduling problems are difficult to solve accurately. After some simplifications in time, the solution can be solved, and the solution results are too different from the actual because of too much simplification. A genetic algorithm is an effective tool for solving complex scheduling problems. Genetic algorithms are characterized by strong robustness and outstanding global search capability and perform well in performing problem-solving [15]. Intelligent optimal collision avoidance techniques formed using genetic algorithms are used to solve the path planning problems, and the optimal fitness function is obtained by finding the optimal path points. An aircraft motion model is incorporated into the path planning for spaceflight, which can roughly evaluate the aircraft motion under the influence of external conditions.

3. Research on Airport Terminal Area Traffic Scheduling Model Based on Improved Genetic Algorithm

3.1. Improved Genetic Algorithm Design. A genetic algorithm is a heuristic algorithm based on the mechanism of the genetic evolution of the natural population, which is widely used with global optimization search. It differs from traditional search methods by simulating the biological evolution process in nature and performing a stochastic search of the target space. The genetic algorithm simulates the genetic phenomena of selection, crossover, and mutation in the process of natural selection and natural inheritance in Darwinian biological evolution, retains some candidate chromosomes in each iteration, selects the best performing chromosomes from these chromosomes according to certain indicators, uses selection, crossover, and mutation to combine these chromosomes again to produce a new generation of chromosomes, and repeats until a chromosome is found that meets the target. The core idea is survival of the fittest, i.e., the better solutions are retained and passed on to the next generation, and the worse ones are eliminated [16]. Genetic algorithms provide a general framework for solving optimization problems for complex systems, which does not depend on the specific domain of the problem and is robust to the type of problem, so the method is widely used in various disciplines. For example, in function optimization: for some nonlinear, multimodel, multiojective function optimization problems, which are difficult to solve by other optimization methods, genetic algorithms do facilitate better results. A genetic algorithm is a common method for production scheduling problems. In many cases, the mathematical model established for production scheduling problems is difficult to solve accurately, and even after some simplification, the solution can be solved too far from the actual result due to too much simplification. A genetic algorithm is an effective tool for solving complex scheduling problems.

3.1.1. Coding. The primary problem of applying a genetic algorithm is coding, which is the conversion of text, numbers, or other objects into a computer-recognizable language according to specified guidelines. The design of coding directly affects the successful operation of the algorithm, as well as the design of crossover operations, mutation operations, selection operations, and the evolutionary efficiency of the algorithm in genetic algorithms. The encoding of the genetic algorithm is to establish the mapping relationship between the genotype space of the expression space domain, as shown in Figure 1. Decoding, on the other hand, is the inverse process of encoding, converting computer language into human-understandable text. The topology management module inputs the topology information into the module, the policy management module also takes the policy conditions as the input of the module, and the traffic scheduling algorithm module selects one or more paths according to the traffic scheduling algorithm after acquiring the input information. The path planned by the traffic scheduling algorithm is the path that conforms to the policy and costs as little as possible. If no path that conforms to the policy is found, suboptimal pathfinding or priority preemption is performed as needed. This module mainly includes submodules of pathfinding according to constraints, multipath pathfinding, and priority preemption.

Through the analysis of the multirunway flight scheduling problem, it is known that the solution of the flight scheduling model is the optimal flight scheduling sequence and the corresponding approach and departure runways of the flights. Therefore, considering this feature of the solution of the flight scheduling model, this paper adopts a dual structure coding method in the coding of chromosomes. The first structure is the flight information, which represents the queuing sequence of flights, and the second structure is the runway information, which represents the takeoff and departure runways of corresponding flights. Since the simulation information of the arithmetic example in this paper is based on parallel dual runways, the traditional numerical coding method is used in this paper, with 0 and 1
representing the two runways, respectively. But for the flight sequence chromosome, if the binary encoding is used to encode, it will generate meaningless encoding after the selection, crossover, and mutation operation regrets, which causes encoding mismatch and leads to the algorithm cannot continue to solve. Similarly, the same problem occurs if the original flight sequence number is encoded directly. Therefore, in this paper, GreenStreet codes are used to encode the flight sequence chromosomes in the first layer to ensure that no meaningless chromosomes are generated after the evolutionary operation and to reduce the complexity and difficulty of the algorithm.

3.1.2. Fitness Function. Genetic algorithms are heuristic algorithms, an intuitive or empirically constructed algorithm that does not rely on external information to validate the results during the search but rather calculates the fitness of feasible solutions as an important basis for evaluating the merit of chromosomes by including a fitness function in the algorithm. Also, the magnitude of chromosome fitness is used as an important basis for the probability of chromosomes being selected in the selection operation. Chromosomes with large fitness can be inherited to the next generation with greater probability, and conversely, chromosomes with small fitness lose their competitive advantage and have low selection probability. Limited by the planned, controlled, and fluctuating characteristics of traffic demand, empirical methods can only simply reflect the static mapping relationship between traffic flow parameters under certain operating scenarios and lack of in-depth exploration of the macrodynamic evolution of traffic flow under different congestion levels. The database of its influence mechanism.

Therefore, the correct construction of the fitness function directly affects the convergence result of the genetic algorithm and its convergence speed. And in general, the fitness function can be obtained directly by the transformation of the objective function. If the solution objective is a maximization problem, the fitness function is \( \text{Fitness}(f(x_1)) = f(x_1) \), and if the solution objective is a minimization problem, the fitness function is \( \text{Fitness}(f(x_1)) = f(x_1) \). However, since the model constructed in this paper is the objective minimization problem, and the selection operation in this paper is the choice of roulette wheel selection, the probability cannot be negative, so this paper adopts the bounds construction method and takes the inverse of the objective function as the fitness function for solving the minimization problem. And to prevent the denominator from being 0, a constant 1 is added to the denominator. In summary, the fitness function in the genetic algorithm is

\[
\text{Fitness}(f(x_1)) = \frac{f(x_1)}{\sqrt{f(x_1) \cdot 1}}.
\]

3.1.3. Selection. The selection operation involves replicating chromosomes from a contemporary population into the next generation population with probability proportional to fitness. That is, chromosomes with higher fitness are better adapted to their environment and have a greater chance of replication. To make the optimal solution well preserved, this paper performs the selection operation using the best-preserved selection method. The roulette wheel selection method is used to select and preserve the individuals with higher fitness function values in the current population.
And particle algorithm (LD-MPSO) is used to solve the model. Ining, not only need to assign ous chapter, although it is dynamic, for multirunway schedul-
cannot be changed once the encoding is successful [17]. be added at any time, and the traditional genetic algorithm delay classi
based on airport priority is constructed considering the delay time, and a multiairport coordinated release model is established to minimize the total 
under an airport is newly added. A dual objective function on airport priority in the terminal area of multiple airports ficated and computationally ine
}[18]. Waypoints are the intersection of multiple flight paths, which can easily cause conflicts when multiple aircraft enter or breakaway, and determine the safety of air operation, and the spatial location of waypoints directly determines the operation cost of the flight path network, so the problem of flight path network optimization usually starts from the study of waypoint layout optimization. The waypoint layout problem is a mathematical problem to determine the optimization objectives, make them meet the established constraints, establish the corresponding optimization model, design a reasonable and effective algorithm to dynamically adjust the spatial geographic coordinates of waypoints, and finally optimize each optimization objective of the waypoint network. Another purpose of designing the double-crossing operator genetic algorithm is to accelerate the convergence speed of the algorithm; through the data statistics, the change curve of the sum of squares of the cost of each flight delay is shown in Figure 4. By analyzing the characteristics of the airway network in the terminal area, the problem of location selection of the new airport and the optimization of the airway network are transformed into the optimization of the waypoint layout, which is abstracted into the network topology structure composed of points and lines. Then a multiojective optimization model that considers both economy and safety is established, with the constraints of not generating new intersections and selecting in characteristic regions.

Realistic problems can be expressed by the mathematical models developed, but the reality is often so intricate that the actual state cannot be fully reduced. The air-ground traffic network in the terminal area, as a special traffic network sys-
step 1, Output the initialization queue with the first w aircraft of the FCFS algorithm as the initial time window

Step 2. Based on the flight information in the time window, a two-layer structured chromosome coding is used to encode and generate the primitive population

Step 3. Calculate the fitness of individuals within the population

Step 4. Selection, crossover, and mutation operations are performed on chromosomes to generate a new generation of populations

Step 5. Determine if the genetic algorithm termination condition is satisfied; if so, continue to Step 6, and if not, skip Step 3

Step 6. Determine whether the time window reaches the right boundary; if it does, the final scheduling result is output, if there are still flights after the window, the optimization window is moved backward by s steps, and the remaining w-s aircraft in the previous window with the newly added s aircraft generates a new window consisting of w aircraft, jumping to Step 2. The flow chart of the algorithm is shown in Figure 3

3.2. Airport Terminal Area Traffic Scheduling Modeling. The strength of the terminal area route network structure affects whether the terminal area airspace can be operated safely and efficiently and whether the cost is reasonable. Waypoints are the connection points of various flight segments in the route network, and their spatial layout is the key to the topological characteristics of the route network [18]. Waypoints are the intersection of multiple flight paths, which can easily cause conflicts when multiple aircraft enter or breakaway, and determine the safety of air operation, and the spatial location of waypoints directly determines the operation cost of the flight path network, so the problem of flight path network optimization usually starts from the study of waypoint layout optimization. The waypoint layout problem is a mathematical problem to determine the optimization objectives, make them meet the established constraints, establish the corresponding optimization model, design a reasonable and effective algorithm to dynamically adjust the spatial geographic coordinates of waypoints, and finally optimize each optimization objective of the waypoint network. Another purpose of designing the double-crossing operator genetic algorithm is to accelerate the convergence speed of the algorithm; through the data statistics, the change curve of the sum of squares of the cost of each flight delay is shown in Figure 4. By analyzing the characteristics of the airway network in the terminal area, the problem of location selection of the new airport and the optimization of the airway network are transformed into the optimization of the waypoint layout, which is abstracted into the network topology structure composed of points and lines. Then a mutliobjective optimization model that considers both economy and safety is established, with the constraints of not generating new intersections and selecting in characteristic regions.

Realistic problems can be expressed by the mathematical models developed, but the reality is often so intricate that the actual state cannot be fully reduced. The air-ground traffic network in the terminal area, as a special traffic network system that conveys flight flows, has nodes including airports, waypoints, and handover points. In this paper, as a theoretical study, to simplify the actual problem, reasonable assumptions are made to translate the important features of the research object into the mathematical language to describe it. Therefore, this paper uses the abstraction $G = (A, B, N)$ of the topology of the airway network to represent the airway network in the terminal area of the study. With the rapid development of my country's economy, the scale
of the civil aviation industry has continued to expand; although the level of support for all parties has continued to improve, the huge transportation demand still brings many problems of unbalanced and uncoordinated development to the civil aviation industry, and the use of airspace structure is becoming increasingly complex and diversified. With the increasing complexity and diversity, simple analysis and extensive planning can no longer meet the requirements of safety and efficiency. A indicates the set of airport points and boundary points in the terminal airway network that needs to be constructed, and since the boundary points have the same characteristics as the airport points, which both generate and absorb traffic, the boundary points and airport points are regarded as immovable points; B indicates the set of waypoints in the terminal area, as the object of optimization in this paper, has movability; N denotes the set of flight segments in the route network.
\[
\min d = \sum_{i=1}^{n} \sum_{j=1}^{m} f_{ij}d_{ij} + \int f_{ij}.
\] (2)

In the terminal area route network optimization model established in this paper, the following premise assumptions are made: (1) all inbound and outbound flights in the terminal area fly according to the route structure, without considering the flight situation outside the route structure; (2) all aircraft fly at the same speed and uniform speed in the center of the route, without considering the overtaking and changing altitude layer situation, and without considering the type and performance differences; (3) since the research content of this thesis is terminal area route network planning, the scope is the approach and departure route network, so the route network can be seen as two-dimensional to study. (4) Aircraft are treated as an unconditional straightsline flight between node pairs, and the cost of the route network depends on the cost of each route. (5) To avoid the model solution from getting upside down in the planning and not being able to arrive at an optimal solution, each waypoint is allowed to search in a two-dimensional square space centered at its original position, with the range of square sides being 30 km. For the terminal area waypoint layout problem, the model can be described as follows: with the initial route network \( G = (A, B) \) and the flight traffic distribution of each node known, adjust \( n \) waypoint locations in a given region to satisfy the maximum economy and safety of the route network and the best airline mobility and passenger experience. According to the above definition, the objective function of this mathematical model can be expressed as

\[
\begin{aligned}
\min d &= \sum_{i=1}^{n} \sum_{j=1}^{m} f_{ij}d_{ij} \\
\min e &= \frac{f_{1f_{2}}}{v} \sin \frac{1}{2} \\
\min \theta &= \int_{j}^{\gamma} \theta_{ij}
\end{aligned}
\] (3)

The traffic scheduling algorithm module is the core of the traffic scheduling system and is the focus of this paper. The topology management module inputs the topology information into this module, the policy management module takes the policy conditions as input to this module as well, and the traffic scheduling algorithm module selects one or more paths according to the traffic scheduling algorithm after obtaining the input information. The path planned by the traffic scheduling algorithm is the path that conforms to the policy and costs as little as possible, and if a path that conforms to the policy cannot be found, then suboptimal pathfinding or priority preemption is performed on demand [19]. The main submodules under this module are pathfinding by constraint, multiple pathfinding, and priority preemption. Traffic scheduling is the problem of optimal resource allocation for complex data flows in cloud data centers when sharing network resources and is directly related to the network transmission performance of applications with differentiated performance requirements in cloud data centers. The main algorithm of pathfinding by constraint is a multiconstraint multiojective pathfinding algorithm, which is a pathfinding algorithm under multiple constraints, where the multiple constraints include delay, jitter, packet loss rate, and bandwidth. The purpose of multiple pathfinding is to find multiple alternative paths between the source nodes to the destination node in the network to meet the user’s selection needs for different paths. Priority preemption is to release the link resources occupied by low-priority service applications to plan paths for high-priority service applications when the paths cannot be computed by the multiconstraint multiobjective routing algorithm, and the system allows priority preemption. The overall design of the traffic scheduling algorithm is first described below. The demand for mandatory nodes, mandatory links, disabled nodes, and disabled links occurs in the actual network. The traffic scheduling algorithm first determines whether the required or disabled node links are needed, then performs pathfinding by constraint, and when the path planning by constraint fails and path preemption is allowed, priority preemption is performed to preempt the link resources occupied by the low-priority service flow. Figure 5 shows the overall flow design of the traffic scheduling algorithm. A waypoint is the intersection of multiple routes. When multiple aircraft enter or break free, it is easy to cause conflict, which determines the safety of air operations, and the spatial position of the waypoint directly determines what the route network is. Therefore, the route network optimization problem usually starts from the route network. Start with research on layout optimization.

4. Analysis of Results

4.1. Improved Genetic Algorithm System Analysis. Although the genetic algorithm has strong global searchability, the local searchability of the method is very poor, for the weak local searchability of the genetic algorithm “persistent problem,” affecting the accuracy of the final search results of the algorithm, and the reactive optimization problem is nonlinear. In this paper, we introduce a nonlinear programming function, which has a strong local searchability in dealing with the nonlinear problem with constraints to find the minimum value. First, we use a mathematical multivariate function to perform a simple test of the improvement effect of the improved genetic algorithm proposed in this paper, and since \( f(x) \) is a multivariate function in mathematics, we can calculate the minimum value of the also function as 2. Taking \( f(x) \) as the objective function, we use the simple genetic algorithm with the improved genetic algorithm proposed in this paper to find the minimum value of this function as follows.

\[
f(x) = \frac{\sin x_1 \sin x_2 \sin x_3 \sin x_4}{\sin 5x_1 \sin 5x_2 \sin 5x_3 \sin 5x_4}
\] (4)

The process of the improved genetic algorithm is somewhat different from that of the simple genetic algorithm. Its
basic process first requires calculating the initial trend by PQ decomposition method, encoding the problem variables using a hybrid approach, and then calculating the fitness value of each individual in the population and secondly using the improved genetic algorithm to perform genetic operations to generate the new generation of individuals, in which the minon function is used to perform a nonlinear search for the optimum whenever the number of genetic generations is an integer multiple of 10 until the termination condition is satisfied to stop the genetic iteration process and output the optimal solution at this time as the global optimal solution. The genetic algorithm iteration diagram is shown in Figure 6.

The empirical traffic flow basic diagram effectively portrays the correlations of traffic flow parameters under real traffic demand and the characteristics of network supply and demand dynamics in the terminal area. However, limited by the planned, controlled, and fluctuating characteristics of traffic demand, the empirical method can only simply reflect the static mapping relationships among traffic flow parameters under certain operation scenarios and lacks the data basis to deeply explore the macroscopic dynamic evolution of traffic flow and its influence mechanism under different congestion levels. Given this, this section relies on the constructed traffic flow simulation platform in the terminal area and adopts the manual adjustment of parameters to reveal the spatial and temporal characteristics of the approach and departure traffic flow and its evolution law, analyze the sensitivity of the traffic flow phase threshold to the traffic flow operational parameters, and provide a theoretical basis for the design of the approach and departure air-ground integrated real-time control method. Under the simulation parameter environment, the traffic flow ratio of each approach and departure point is kept constant, and the traffic scenarios under the independent operation of the approach and departure field are designed in incremental steps of 0.1 vehicles/minute, and the duration of each scenario is 8 hours of continuous service request [20]. Based on the constructed CTM platform, we simulate the evolutionary trajectory of the macroscopic basic diagram of inbound/departure traffic flow under different scenarios, to reveal the characteristic patterns of traffic flow congestion evolution in the terminal area. For the genetic algorithm that simulates the natural evolution process, the static state structure cannot reflect the changing interaction relationship between the individuals in the population, so it will limit the performance improvement of the genetic algorithm. The research on the kinematic structure is mainly divided into two categories: one is to use the corresponding adaptive scheme for genetic algorithm and improve the structure according to the existing network model and the other is to use the original network structure according to the situation of the individuals in the population make improvements. According to the general transportation flow congestion evolution characteristics, combined with the critical traffic demand and demand change trend, three states of traffic congestion evolution in the terminal area are classified: (a) formation state: traffic demand continues to grow and is smaller than the critical demand, network throughput grows linearly with traffic demand, and traffic flow has a congestion formation trend but operates stably; (b) accumulation state: traffic demand reaches and exceeds its critical, network throughput grows linearly with traffic demand, and traffic flow has a congestion formation trend but operates stably; (b) cumulative state: traffic demand reaches and exceeds its threshold, network throughput tends to saturate and decreases to some extent, and traffic flow congestion keeps increasing; and (c) dissipation state: traffic demand in the airspace gradually decreases, and traffic flow shows slow or rapid dissipation depending on the degree of network congestion. To deal with the large dimension of the optimization problem, an improved genetic algorithm is proposed. The improved genetic algorithm improves the strategy when selecting the initial population and adopts

Figure 5: Flow scheduling algorithm overall flow design diagram.
adaptive processing for the allocation of individuals. Three individual allocation schemes are used, and a new strategy is applied when selecting the initial population.

$$C(t_1) = \min \int_{mc} \int_{f_1} c_{\text{f}} \sin \left( t_{df} - t_{ec} \right).$$ (5)

The FCFS algorithm, traditional genetic algorithm, segmented genetic algorithm, and STW-GA algorithm are compiled using PYTHON3 and solved by simulation with the algorithm examples. The results demonstrate that both the traditional genetic algorithm and STW-GA algorithm can significantly reduce the total delay time and increase the runway throughput efficiency compared with the FCFS algorithm, and the delay time is more equitably distributed. The STW-GA algorithm is also dynamic, feasible, and efficient. Traffic scheduling is a very important issue in cloud data centers and has been a challenge. The current traffic scheduling schemes in cloud data centers go to two extremes. Information agnostic schemes have a wide range of applicability and good deployability; however, they have very limited effectiveness in optimizing the performance of network transport. While information-aware traffic scheduling solutions achieve excellent network performance, they severely neglect the scope of the solution itself, and most information-aware traffic scheduling solutions require custom switches, making them not only very limited in scope but also difficult to deploy in current cloud data centers.

4.2. Airport Terminal Area Traffic Scheduling Implementation. By analyzing the characteristics of the airway network in the terminal area, the problem of siting new airports with airway network optimization is transformed into the problem of airway point layout optimization, which is abstracted into a network topology composed of points and lines [21]. Then a multiobjective optimization model that considers economy and safety is established, with the constraints of not generating new intersections and selecting in the characteristic area. Afterward, an example analysis is conducted to process the airspace data within the terminal area of Shanghai, traffic data preprocessing, and position transformation coordination, and the differential evolutionary algorithm solution procedure is written using the MATLAB software, resulting in 19 waypoint locations being optimized, which proves the practical significance and feasibility of considering the location of the new airport site from the perspective of optimal route network in the terminal area (see Figure 7 for the clustering effect).

Based on the complex dynamic characteristics of traffic flow in the terminal area, the air-ground traffic flow congestion management solution for tactical operation is built from the perspectives of both traffic flow and controllers, covering “volume”-coordinated control of approach and departure launch rates, “sequence”-multisector approach traffic flow rate cooperative control, and “trace”-sector traffic flow horizontal trajectory management under multiple constraints, three major space-time overlapping functional modules, respectively, using air-ground meta cell network microsimulation platform, and terminal area airspace. The effectiveness of the solution is verified by using three methods: a macroscopic simulation platform for air-ground meta cell networks, a microscopic fast simulation platform for terminal area airspace, and a “human-in-the-loop” real-time simulation experiment. Genetic algorithm provides a general framework for solving complex system optimization problems; it does not depend on the specific field of the problem and has strong robustness to the types of problems, so the method is widely used in various disciplines. At the stage when the trajectory-based operation has not yet been carried...
out, this solution can enrich and enhance the tactical/real-time level of the terminal area congestion mitigation methods and means for the external uncertain environment, thus improving the control capability and the safety and efficiency of traffic flow operation under congestion. It should be noted that the sector traffic flow “sequencing” control in this chapter only considers the first-come-first-served strategy based on the sector flow rate, and further attempts can be made to integrate with mature sequencing methods to generate more optimal and reasonable arrival times for sector exit point control. At the same time, the horizontal trajectory system can be extended to the network version and fused with the “volume” and “sequence” control modules to form a complete terminal area congestion decongestion system, and the joint operation experiment of multiple sectors in the terminal area can be designed for comprehensive verification. In addition, the horizontal trajectory management tool based on the inter-aircraft concept provides a strong reference for the four-dimensional trajectory planning in real-time under certain performance optimization objectives (fairness, economy, and efficiency) to support the development of performance-based higher-order air traffic management.

\[
U_j(x_i, x_j) = \max_{ij} U_i(x_{i-j}, x_{i+j}).
\]  

For the problem of cooperative release based on airport priority in the terminal area of multiple airports under the addition of new airports, a dual objective function is established to minimize the total delay cost and total delay time of flights, a cooperative release model based on airport priority under consideration of delay classification is constructed, a multiobjective linear decreasing particle algorithm (LD-MPSO) is used to solve the model, and then an arithmetic example under the addition of new airports in the terminal area is. The simulation analysis is carried out to introduce

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through analysis and comparison, so as to provide a theoretical method and scientific basis for constructing a unified cooperative release mechanism in the multi-airport terminal area. The comparison of the route network optimization results is shown in Figure 8.

5. Conclusion

Along with the rapid development of China’s economy, the development of the civil aviation industry has also ushered in unprecedented opportunities and challenges. On the one hand, the number of flights has been increasing. On the one hand, the number of airports is increasing, and the civil aviation industry is thriving. On the other hand, however, airline congestion is becoming increasingly serious, and if not properly addressed, it will certainly hinder the progress of the aviation industry. The problem of flight sequencing in the terminal area has always been a key and difficult issue for research in the field of aviation control; especially in this era of rapid economic development, the phenomenon of congestion in the terminal area is extremely serious. With the development of the global air transport industry and the increasing number of aircraft, the flight sequencing problem has been categorized as an NP-hard problem. Genetic algorithms have advantages such as high global search capability and potential concurrency in solving such problems but also possess some disadvantages. By reading and studying the literature related to solving flight sequencing problems with genetic algorithms, it is found that simply setting the sequencing goal to the shortest total flight landing time is an oversimplified goal and the practicality of the sequencing results is not high. For the disadvantages of genetic algorithms such as instability and prematureness, an adaptive genetic algorithm is used to deal with it. At the same time, the convergence speed of the algorithm can be improved. The implementation of the terminal area flight scheduling system is carried out through the platform support provided by the national ATC scenario simulation system, and the improved sorting algorithm is applied to it. Through the analysis and comparison of the sorting results, the algorithm improvement is proved to be effective and achieves the research objectives.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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