Research Article

Intelligent Management of Air Traffic Flow Based on Intelligent Motion Coordinate Data Model

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To adapt to the intelligent management of traffic flow in modern aviation, this study improves the algorithm according to the data exercise method and establishes the mathematical model and vector model of intelligent motion coordinates. Moreover, according to the simulation test method, this study analyzes the six-degree-of-freedom equation of motion in the coordinate system of the civil aviation aircraft and uses the simulation method to regard the civil aviation as a rigid body with a certain mass and mass distribution. In addition, this study builds an intelligent model based on the demand analysis, and according to the actual demand, this study combines the simulation method to analyze the structure of the intelligent management model of air traffic flow. Finally, this study uses the experimental analysis method to verify the effect of the model proposed in this study and combines the experimental research to verify that the model proposed in this study has a certain effect.

1. Introduction

Air traffic flow management (ATFM) is to take appropriate measures in advance or at the right time when the air traffic flow is approaching or reach the available capacity of air traffic control to ensure that the air traffic flows into or through the corresponding area to maximize the airspace [1]. It is an important part of air traffic management (ATM). Its main purpose is to safely and effectively use the existing airspace, air traffic management services, and airport facilities and to provide aircraft operators with timely and accurate information, so as to plan and implement an economical air transportation to forecast flight information as accurately as possible and minimize delays. At present, with the continuous economic growth, the demand for civil aviation from all walks of life is increasing, and the civil aviation transportation volume also maintains a very high growth rate [2]. As air traffic continues to increase, air traffic is becoming more and more congested. In particular, in areas with dense air traffic, air delays are gradually increasing, and the load on controllers is gradually increasing. Flight delays caused by excessive traffic not only put tremendous pressure on the control department but also seriously affected the interests of airlines. An effective way to solve this problem while maintaining existing resources is to forecast air traffic flow. Scientific and accurate flow forecasting is not only an effective guarantee for the continuous and smooth air traffic flow but also an important basis for ATFM departments at all levels to make decisions and development strategies. Control departments and airlines deploy and optimize in advance according to the forecast results, avoid areas with congested air traffic, reduce delays, reduce the pressure on control departments, and improve airlines’ operational efficiency [3].

Air traffic flow management includes methods of predicting, analyzing, planning, organizing, processing, adjusting, configuring air traffic flow and any work carried out in this way, and ensuring the safe, orderly, and expedited flow of air traffic, the total amount of air traffic handled in a certain time period, a waypoint, or a designated airspace is commensurate with the total capacity of the air traffic control system. In particular, the flight plan prediction tool is used to predict the traffic flow of the target route or area, and scientific methods are taken to replan, organize, and process the air traffic flow.
according to the predicted scenario, to ensure that the traffic of the target route or area is reasonably redistributed, so that in the process of safe, orderly, and accelerated flow of air traffic, the total air traffic flow that can be handled by the air traffic control system to which the target route or area belongs within a certain period of time is adapted to its total capacity to prevent and correct at the airport. In the terminal area, route, sector, area, and other airspaces, the phenomenon of excessive concentration of flight flow and exceeding the prescribed limit occurs. The principles of implementing ATFM are based on advance flow management (also known as strategic flow management) and preflight flow management (also known as tactical flow management), supplemented by real-time flow control (also known as dynamic flow management), mainly based on ground deployment, supplemented by air deployment.

The construction needs to further give play to the role of air transportation in promoting the development of the national economy, to effectively realize the value of airspace resources, and to give full play to its social benefits, and it is also an inherent requirement for the development of air transportation. Moreover, the construction of air traffic flow management system in China’s civil aviation is a strategic need to respond to the global integration of air traffic management and to improve the competitiveness of air traffic services in the future, and it is also a requirement for improving air traffic services.

The organizational structure of this study is as follows: the first part summarizes and analyzes the status quo, finds problems, and proposes the research content of this study. The second part analyzes the research status of the research topic of this study and summarizes the relevant literature. The third part is the algorithm of this study. The improvement part mainly improves the spatial data model and provides the algorithm basis for the subsequent model construction. The fourth part is the research focus of this study, which is the construction of the civil aviation air traffic flow management model. The fifth part is the foundation of the fourth part. The experimental research is carried out on the above. The conclusion part is to summarize the research content of this study and make an outlook.

This article combines the spatial data model for air traffic flow management of civil aviation, constructs an intelligent management model, and designs experiments to verify the model, which provides a reference for subsequent air traffic flow management of civil aviation.

The main contributions of this study are as follows: 1. constructing a spatial data model to make the simulation of civil aviation air traffic flow management process more realistic; 2. avoiding the shortcomings of traditional civil aviation air traffic flow management methods through algorithm improvement; and 3. civil aviation air traffic flow in complex situations. Traffic management provides a theoretical reference.

2. Related Work

Although the system did not clearly and systematically propose a time-based flow management strategy for this system at the beginning, the fine management of each aircraft has entered the industry’s field of vision. The follow-up research of air traffic flow management strategy has been put forward continuously. Literature [4] proposed the concept of flow management based on time measurement and, based on this, proposed a distributed time arrangement method based on time measurement, aiming at a certain key point, or the measurement point converted the trailing interval value and divided it into one-hour period and allocated it to the aircraft and used TMA to conduct a five-month test in Philadelphia. Literature [5] proposed the details of trajectory estimation in flow management based on time measurement. Only accurate trajectory estimation can accurately time control aircraft memory; otherwise, blind time scheduling will cause additional traffic delays and control operation load. Track estimation is mainly used for time measurement based on the estimation of past point time. Literature [6] puts forward the concept of important freezing area branching in time-based flow management to ensure the feasibility of the sequencing system in actual operation. In [7], a dynamic time window management method was proposed in view of the uncertainty of multiple-center traffic management advisory system (multiple-center traffic management advisor, McTMA), considering the maneuverability of aircraft in the air. It is not a single definite time but a flexible time window to constrain the aircraft’s overtime time, which enhances the flexibility and operability of the strategy. At the same time, they also stipulate the adjustment rules for overlapping time windows and the buffer between time windows, etc. [8]. Literature [9] provides the use of time-based traffic management strategies to conduct more extensive experimental research on time-based traffic management strategies in the McTMA system. Literature [10] proposed the principle and operation process of a traffic management strategy based on time measurement instead of a trailing interval traffic management strategy. The traffic flow management strategy based on time measurement is completely distinguished from trailing interval management. Literature [11] gave a new strategy and a way of coordinating the trailing interval strategy. The strategy based on time measurement can use the passed trailing interval as a restriction condition to adjust the upstream flight queue to form a distributed flow management.

Literature [12] studied the problem of regional air traffic flow control, using queuing theory, combined with the characteristics of regional control, established a regional flow control model, reasonably selected control periods and control intervals, maximized use of airspace resources, and reduced flights. Delays ensure the safety and smooth flow of air traffic. Literature [13] studied the modeling of regional air traffic control, combined queuing theory with regional flow control, and used mathematical modeling to conduct a preliminary calculation of the flow control strategy in the Xi’an control zone. In the literature [14], in the research of air traffic flow management in the terminal area, preliminary explorations were made on flight sequencing systems and aviation information systems. Literature [15] studied the flow management system and proposed the concept and modeling method of the strategic and tactical flow management models. It has a certain introduction to the airway
flow management model, terminal area flow management model, and airport flow management model and preliminary research. In the literature [16], in the research on the air traffic flow management model and algorithm in the terminal area, he proposed to use the heuristic greedy algorithm to carry out the mathematical modeling of the flow management method and at the same time use the concept of the system to solve the problems. Literature [17] proposed to use the Markov chain to solve related problems. At the same time, it proposed the mathematical model of airport capacity and the factors affecting airport capacity and carried out dynamic route planning. Literature [18] used the numerical value to quantify the speed of each stage of the aircraft, the safety interval of the aircraft, and the time of the runway occupation, proposed a probability model for calculating the runway capacity and solved the corresponding runway capacity curve. In the literature [19], in the research on the key technology of cooperative flow management in the airport terminal area, the calculation method of the dynamic limit of the airport capacity and the conversion between the arrival and departure capacity are proposed, and the runway capacity curve and genetic algorithm are used to calculate the arrival and departure port with the least delay cost. Capacity, on the basis of the research on single airport traffic management, further related research on multi-airport collaborative traffic management technology. Literature [20] introduced airspace capacity prediction and evaluation and airport capacity evaluation models in the research on key technologies of flow management and proposed solutions for ground holding strategies, air rerouting strategies, and airspace dynamic management.

It can be seen from the above research that the traditional civil aviation air traffic flow management mostly stays in the single-factor simulation stage, and there are still some deficiencies in the simulation of the civil aviation traffic flow management process under various complex situations. Intelligent management model is designed and tested to verify the model, to provide a reference for subsequent civil aviation air traffic flow management.

3. Air Traffic Flow Management Algorithm of Civil Aviation Based on Spatial Data Model

3.1. Coordinate System Transformation. The earth’s surface can be approximately regarded as an inertial reference frame for the mechanical processes occurring in a small range and short time. The problem of civil aviation movement belongs to this kind of mechanical process. Therefore, when studying civil aviation dynamics, the earth is always used as the reference frame. Then, it takes the ground coordinate system \( E \xi \eta \zeta \) as the stationary coordinate system of civil aviation movement. The origin \( E \) of the ground coordinate system can be taken as any certain point on the ground, the sea surface, or the sea. The \( E \xi \) axis is kept horizontal, and the main course of civil aviation is usually taken as the positive direction of the \( E \) axis. The \( E \xi \) axis and \( E \eta \) axis are perpendicular to each other in the horizontal plane, and the positive direction of the axis can be optional. The \( E \xi \) axis is perpendicular to the \( E \xi \eta \) coordinate plane, and its positive direction points to the center of the earth. \( OZ \) forms a right-handed rectangular coordinate system. The north-east depth coordinate system is used here, as shown in Figure 1. The main symbols in the geodetic coordinate system are shown in Table 1.

Although the ground coordinate system is an inertial reference system, it is not convenient to use in many cases. For example, when studying the interaction force between civil aviation and the surrounding fluid, it is difficult to express with ground coordinate system parameters because the hydrodynamic force is determined by the relative motion of the civil aviation aircraft and the fluid. For another example, the moment of inertia of a civil aviation aircraft is represented by a fixed coordinate system parameter, which also becomes very complicated in form. Therefore, in addition to the ground coordinate system, other coordinate systems need to be established. The most commonly used is the coordinate system established on the civil aircraft, called the motion coordinate system or the civil aircraft coordinate system (as shown in Figure 1). Because the motion coordinate system is fixed on the civil aviation aircraft and moves in any form with the civil aviation aircraft, it cannot be regarded as an inertial system except when it is stationary and moving in a straight line at a uniform speed.

Since the civil aircraft coordinate system has angular velocity to the ground, it is not an inertial reference system. In this coordinate system, Newton’s second law of dynamics does not hold. Therefore, when modeling motion, you should first establish the motion equation in the static coordinate system, then convert the parameters into the components of the dynamic coordinate to express, and finally get the motion equation corresponding to the dynamic coordinate system. In the motion coordinate system, the \( OX \) axis is generally taken to point to the civil aviation section in the longitudinal section. The \( OY \) axis is perpendicular to the longitudinal section, pointing to the starboard side, and parallel to the waterplane. The \( OZ \) axis is in the longitudinal midsection, pointing in the direction of the bottom of the aircraft, and perpendicular to the waterline. The main symbols in the motion coordinate system are shown in Table 2.

The position and attitude of any point in the sky of civil aviation can be determined by the coordinate value \((\xi, \eta, \zeta, \phi, \theta, \psi)\). Moreover, these three attitude angles are called roll angle \( \phi \), pitch angle \( \theta \), and yaw angle \( \psi \), respectively, which are defined as follows.

The roll angle \( \phi \) is the angle between the XOZ plane and the vertical plane \( xo \xi \) passing through the \( OX \) axis.

According to the transformation relationship of the three-axis rotations based on the coordinate base transformation in the literature, the transformation relationship between the civil aircraft coordinate system and the ground coordinate system \( \phi \) can be obtained as follows:
In the formula, the conversion matrix is $S$. To maintain the one-to-one correspondence between $S$ and $\varphi$, $\psi$, and $\theta$, the range of the three corners can be limited to

$$
\begin{bmatrix}
\xi \\
\eta \\
\zeta \\
\end{bmatrix} = S 
\begin{bmatrix}
x \\
y \\
z \\
\end{bmatrix}.
$$

(2)

In the motion control of civil aviation, it is often necessary to convert the angular velocity between the two coordinate systems. The relationship of the angular velocity of rotation in the two coordinate systems can be expressed by the following formula:

$$
\begin{bmatrix}
p \\
q \\
r \\
\end{bmatrix} = 
\begin{pmatrix}
1 & 0 & -\sin \theta \\
0 & \cos \varphi & \cos \theta \sin \varphi \\
0 & -\sin \varphi & \cos \theta \cos \varphi \\
\end{pmatrix}
\begin{bmatrix}
\dot{\varphi} \\
\dot{\theta} \\
\dot{\psi} \\
\end{bmatrix}.
$$

(3)

Its inverse transformation is as follows:

$$
\begin{bmatrix}
\dot{\varphi} \\
\dot{\theta} \\
\dot{\psi} \\
\end{bmatrix} = 
\begin{pmatrix}
\sin \varphi \tan \theta & \cos \varphi \tan \theta \\
0 & \cos \varphi & -\sin \varphi \\
0 & \sin \varphi \cos \theta & \cos \varphi \cos \theta \\
\end{pmatrix}
\begin{bmatrix}
p \\
q \\
r \\
\end{bmatrix}.
$$

(4)

Civil aviation performs six degrees of movement in space under the action of external force and external moment. Using the basic principles of dynamics, the six-degree-of-freedom motion equation of civil aviation in the civil aviation aircraft coordinate system can be derived. In the analysis, civil aviation is regarded as a rigid body with a certain mass and mass distribution.

After the motion coordinate system OXYZ is established, the components of each relevant vector on the three coordinate axes OX, OY, and OZ are as follows.

The center of gravity coordinates is as follows:

$$
R_G = \{x_G, y_G, z_G\}.
$$

(5)

The moment of inertia matrix is as follows:

$$
I = 
\begin{pmatrix}
I_x & I_{xy} & I_{xz} \\
I_{yx} & I_y & I_{yz} \\
I_{zx} & I_{zy} & I_z \\
\end{pmatrix}.
$$

(6)

Taking the geometric center of civil aviation as the coordinate origin, the motion coordinate system is established, and the coordinate axis can be approximated as the principal axis of inertia, and the product of inertia is zero.

Therefore, the general equation for the translational motion of civil aviation along the three-axis direction of the civil aviation aircraft coordinate system is as follows:

$$
\begin{align*}
\dot{u} - vr + wq - x_G(q^2 + r^2) + y_G(pq - r) + z_G(pr + \dot{q}) &= F_x, \\
\dot{v} - wp + ur - y_G(r^2 + p^2) + z_G(qr - \dot{p}) + x_G(qp + r) &= F_y, \\
\dot{w} - uq + vp - z_G(p^2 + q^2) + x_G(rq - \dot{q}) + y_G(rq + \dot{p}) &= F_z.
\end{align*}
$$

(7)

3.2. Vector Model. The forward-looking radar is used to simulate the detection of obstacles in the air. In the process of virtual simulation of civil aviation forward-looking radar, it is mainly used to provide information for civil aviation to avoid obstacles. The purpose of simulation is to use digital methods to simulate the movement of forward-looking radar with civil aviation. Its main concern is whether there are obstacles within the field of view of the forward-looking radar and does not care about the specific nature of the obstacles.

In the formula, $F_x, F_y, F_z$ are the resultant force (N) of various external forces acting on civil aviation; $K$, $M$, and $N$ are the moments ($N \cdot m$) relative to the origin of the coordinate acting on civil aviation. Among the various equipment equipped with civil aviation, forward-looking radar is one of the indispensable important detection equipment. The forward-looking radar is mainly used for environmental perception. When navigating in civil aviation, you will encounter various obstacles in the air. With the forward-looking radar, it can have the ability to avoid obstacles and ensure the safety of civil aviation.

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The method of forward-looking radar processing obstacle information is to use the method based on raster icon. Moreover, this method is first proposed by Carnegie Mellon University for obstacle avoidance. The field of view of the forward-looking radar is planned as a two-dimensional grid array, and each grid is filled to indicate whether there is an obstacle detected in the grid, as shown in Figure 2.

Since the forward-looking radar is installed on the civil aviation body, the description of its relatively fixed earth coordinate system changes with the change in the civil aviation attitude and path. We assume that \((x_c, y_c, z_c)\) is the centroid of civil aviation, \((x_s, y_s, z_s)\) is the coordinates of the forward-looking radar installation point, and \(l_{cs}\) is the distance from the forward-looking radar installation point to the centroid of civil aviation. \((x_c, y_c, z_c)\) and \((x_s, y_s, z_s)\) are the coordinates defined in the civil aircraft coordinate system (motion coordinate system), where \((x_c, y_c, z_c) = (0, 0, 0)\) and \((x_s, y_s, z_s) = (l_{cs}, 0, 0)\). Then, the field of view of the civil aviation forward-looking radar is as follows:

\[
\begin{align*}
\frac{|y_{bs}|}{\sqrt{x_{bs}^2 + y_{bs}^2}} & \leq \sin \frac{\alpha_s}{2} \\
\sqrt{x_{bs}^2 + y_{bs}^2 + z_{bs}^2} & \leq R_v \\
\frac{|z_{bs}|}{\sqrt{x_{bs}^2 + y_{bs}^2}} & \leq \sin \frac{\beta_s}{2}
\end{align*}
\]

(8)

Among them, \((x_{bs}, y_{bs}, z_{bs})\) can be expressed as follows:

\[
\begin{align*}
x_{bs} &= x'_{obs} - x_s, \\
y_{bs} &= y'_{obs} - y_s, \\
z_{bs} &= z'_{obs} - z_s.
\end{align*}
\]

(9)

In the formula, \((x'_{obs}, y'_{obs}, z'_{obs})\) is the coordinate of the obstacle in the civil aircraft coordinate system \(ox'_{y'_{z'}}\).

This traditional method establishes a forward-looking radar field of view and a mathematical model of obstacles and then calculates the positional relationship between the radar beam straight line AB and the obstacle based on the knowledge of spatial solid geometry, thereby judging whether the beam detects the target. Although this method can accurately calculate the distance between the detected target point and the starting point (transmitting point) of the forward-looking radar beam, this method has great limitations. This method has the following three deficiencies:

(1) The mathematical model of the forward-looking radar field of view is greatly affected by the attitude of civil aviation. For the 6-degree-of-freedom motion of civil aviation, the change in attitude will make the established mathematical model of the forward-looking radar field of view have certain limitations.

(2) The geometric shape of the airborne entities is diverse, and more of them are irregular shapes. For objects with complex shapes, mathematical models are difficult or impossible to describe. Therefore, the spatial target modeling method based on mathematical models can only establish typical, regular, or simplified obstacle models.

(3) Due to the complexity of motion in civil aviation, the spatial mathematical description of a large number of radar beams will become very complicated with complex civil aviation motion. This makes it very difficult to determine the spatial geometric relationship between the radar field of view and the aerial entity by solving the intersection information of the beam and the obstacle.

The advantage of establishing the radar sight vector model is that it is simple to establish and easy to calculate. The disadvantage is that it is greatly affected by the attitude of civil aviation and has a limited scope of application. It is only suitable for civil aviation without heeling and trimming. Therefore, this article uses the coordinates of the radar boundary vector points to describe the range of its field of view. As can be seen from Figures 2 and 3, the boundary
vector points are as follows: \( o \) point, \( P_1 \) point, \( P_2 \) point, \( P_3 \) point, and \( P_4 \) point. Among them, the coordinate of point \( o \) is known as \( (x_o, y_o, z_o) \), which can be obtained using the characteristic parameters of the radar field of view and the coordinates of point \( o \). The coordinates of the other four boundary vector points are as follows:

\[
\begin{align*}
  x_i &= R \sin \alpha_i \cos \beta_i + x_o, \\
  y_i &= R \cos \alpha_i \cos \beta_i + y_o, \\
  z_i &= R \sin \beta_i + z_o, \\
  i &= 1, 2, 3, 4.
\end{align*}
\]

Among them, there are as follows:

\[
\begin{align*}
  \alpha_1 &= -\frac{\alpha}{2} \quad \beta_1 = \frac{\beta}{2}, \\
  \alpha_2 &= -\frac{\alpha}{2} \quad \beta_2 = \frac{\beta}{2}, \\
  \alpha_3 &= -\frac{\alpha}{2} \quad \beta_3 = \frac{\beta}{2}, \\
  \alpha_4 &= -\frac{\alpha}{2} \quad \beta_4 = \frac{\beta}{2}.
\end{align*}
\]

In this way, using the five-point coordinates of \( o \) point, \( P_1 \) point, \( P_2 \) point, \( P_3 \) point, and \( P_4 \) point, a closed solid sector can be determined in the three-dimensional space, and this sector is the field of view of the forward-looking radar. When detecting a space target point, it only needs to detect whether the target point coordinates fall within the three-dimensional sector, and then, it can be judged that there is an obstacle-free target in the visual field of the forward-looking radar. Since the forward-looking radar is installed in the nose and wax of civil aviation, it can do complex sports with civil aviation. Under normal circumstances, air entities are fixed in the geodetic coordinate system.

This subject proposes a five-point method to describe the field of view of the forward-looking radar and establish a vector model of the field of view of the forward-looking radar. These five points are \( o \) point, \( P_1 \) point, \( P_2 \) point, \( P_3 \) point, and \( P_4 \) point, as shown in Figure 3.

4. Air Traffic Flow Management of Civil Aviation Model Based on Spatial Data Model

4.1. Civil Aviation Air Traffic Mode. The main influencing factors of air traffic flow management of civil aviation based on the spatial data model are as follows: frozen area, airport and airspace capacity, the difference in traffic flow within the management range, the mutual influence of adjacent airports, priority considerations, minimum separation standards, etc.

For traffic management personnel, the aircraft overtime is constantly adjusted, which increases the workload and management difficulty. Moreover, it is difficult for aircraft to meet the ever-changing overtime requirements. The frozen zone is shown in Figure 3, which is the flight range at a certain time interval before reaching the measurement point, and the overtime time of the aircraft entering this range will not be adjusted after planning. The aircraft passes through this point at the required time, and the aircraft entering the frozen zone affects subsequent flights by certain restrictions when planning the overall flight sequence.

Outside the frozen zone inside the area, after the aircraft taking off takes off according to the scheduled departure
sequence, if the planned overtime time is changed, the aircraft does not need to adjust the overtime time for the time being. After entering the frozen area, the time passed is determined and adjusted according to the time after freezing, as shown in Figure 4.

For the split strategy, it is usually applied to airspace units (including runways) such as key nodes and crossing routes. Figure 5 is a schematic diagram of a shunt node. Point B1 is the crossing waypoint, and point A1 is the terminal area junction. Both can be used as key nodes to allocate time slots from aircraft converging in the direction of D1 and C2 using the shunt strategy. Then, the time is reversed, and the time sequence of the corresponding aircraft passing A1, B1, C2, and D1 is announced, as shown in Figure 6.

For the central strategy, it is usually applied to airspace units such as sectors or terminal areas, as shown in Figure 7. The most significant difference between the central type and the split type is that as a space area, there are multiple handover points for sectors, etc., which can receive multiple aircraft at the same time, and each handover point needs to meet the time axis distribution under restricted conditions. In the optimization process, the conditions of all handover points must be considered uniformly, and the global optimal solution must be sought.

4.2. Civil Aviation Air Traffic Flow Management. The air traffic flow management of civil aviation based on the spatial data model considers the maneuverability of the aircraft. The performance of the aircraft and the distance from the target node can determine the fluctuation range of the aircraft, as shown in Figure 8.

5. Air Traffic Flow Management of Civil Aviation Based on Spatial Data Model

To adapt to the intelligent management of traffic flow in modern aviation, this study applies the intelligent motion coordinate data model to intelligent aviation management and establishes its mathematical model and vector model. Moreover, this study analyzes the modeling method to obtain a vector model suitable for the intelligent management of modern aviation and derives the six-degree-of-freedom equation of motion of civil aviation in the coordinate system using the basic principles of dynamics. In the analysis, this study regards civil aviation as a rigid body with a certain mass and mass distribution.

On the basis of the above research, the system proposed in this study is simulated, and the actual effect of the air traffic flow management model of civil aviation based on the spatial data model is explored. The system is simulated by MATLAB, the aviation data are obtained from the network, the simulation dynamic graph is collected in the platform simulation, and the dynamicsimulation diagram is shown in Figure 9.

Through the simulation study of the spatial data model in Figure 9, it is shown that the model in this study can run the air traffic flow management process stably, and the next simulation operation is carried out on this basis.

Using the collected civil aviation data as input, the data simulation is carried out through the platform, and this study simulates the real-time traffic dynamic management of all several fields and obtains the result shown in Figure 10.

It can be seen from Figure 10 that the system model proposed in this study can visually display the nodes of the civil aviation traffic process, so the data simulation analysis...
Figure 4: Control type of freezing zone.

Figure 5: Schematic diagram of split node.

Figure 6: Split time distribution mode.
The simulation analysis shows that the air traffic flow management model of civil aviation based on the spatial data model performs well in the simulation, so the model in this study can be used to verify the effect in practice.
Figure 9: Time series of air traffic flow management of civil aviation based on spatial data model. (a) Time 1. (b) Time 2. (c) Time 3.

Figure 10: Dynamic simulation of civil aviation airport traffic. (a) Time 1. (b) Time 2. (c) Time 3.
6. Conclusion

The functions of the flow management system include the introduction and processing of dynamic information such as air traffic control radar, navigation telegram, and flight information; aircraft position and flight plan display based on integrated trajectory; air traffic flow statistics, display and prediction; arrival and departure and flight sequence display control at important points; and management of flow control events. Information transmission is a basic function of the flow management application system, and it is necessary and urgent to study the information transmission problem in the air traffic flow management application system. This article combines the spatial data model for air traffic flow management of civil aviation, constructs an intelligent management model, and designs experiments to verify the model to provide a reference for subsequent air traffic flow management of civil aviation. The simulation analysis shows that the air traffic flow management model of civil aviation proposed in this study based on the spatial data model performs well in the simulation, so the model proposed in this study can be used to verify the effect in practice.

Air traffic management, as a tactical strategy of flow management, will eventually be deployed by the controller in actual work, and the new strategy will increase the coordination time of the controller due to the need to release the point sequence time for each aircraft. The mechanism to adapt to this requirement has yet to be practiced, and factors such as controller deployment capabilities and weather, route, and aircraft characteristics may have different degrees of impact on the actual control process. How to model these complex factors needs to be further explored.

Data Availability

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

Table 3: Simulation results of air traffic flow management model of civil aviation based on spatial data model.

| No. | Simulation effect | No. | Simulation effect | No. | Simulation effect |
|-----|------------------|-----|------------------|-----|------------------|
| 1   | 83.31            | 14  | 88.78            | 27  | 93.60            |
| 2   | 83.77            | 15  | 81.75            | 28  | 85.18            |
| 3   | 86.65            | 16  | 84.07            | 29  | 81.43            |
| 4   | 84.56            | 17  | 86.44            | 30  | 80.78            |
| 5   | 91.52            | 18  | 88.74            | 31  | 84.54            |
| 6   | 81.64            | 19  | 84.27            | 32  | 80.67            |
| 7   | 79.44            | 20  | 85.50            | 33  | 88.73            |
| 8   | 88.88            | 21  | 91.87            | 34  | 92.92            |
| 9   | 83.21            | 22  | 93.09            | 35  | 83.55            |
| 10  | 88.76            | 23  | 79.62            | 36  | 84.49            |
| 11  | 93.22            | 24  | 81.06            | 37  | 83.10            |
| 12  | 89.24            | 25  | 79.79            | 38  | 93.44            |
| 13  | 87.59            | 26  | 92.76            | 39  | 79.58            |

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 study.

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