ISSN: 2664-9640

Research on Early Warning Method of Aircraft Taxiing Conflict Based on Controller Command Information

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Abstract

As the airport gets busier, the flight area is prone to accidents and incidents such as aircraft taxiing conflicts on the ground. In this regard, this article implements early warning of conflicts of different types and levels before the aircraft starts taxiing, and feeds back the detection results to the controller in advance. By analyzing the actual ADS-B historical data of the aircraft on the airport surface, the taxi conflict detection method is designed according to the characteristics of the three taxi conflicts. Based on the taxi instructions issued by the air traffic controller to the aircraft operating on the airport surface, the probability of conflict is obtained. , The result proves that the method of detecting head-to-head conflict, rear-end collision and cross conflict between aircrafts on the ground is accurate.

Keywords

ADS-B, taxi conflict, detection, multi-level early warning

1. Introduction

In recent years, with the rapid increase in the number of flights, the airport flight area has become increasingly busy, which directly affects the safety and efficiency of the airport, and can easily lead to taxi conflict accidents and incidents in the airport flight area. Therefore, how to operate the safety of the airport flight area through science and technology has become a problem that needs to be solved urgently.In terms of related theoretical research, there are mainly the following: Some improve the ability of airport operation and dispatch by optimizing the flight area dispatching [1, 2, 3]. Some improve the taxi trajectory to realize the conflict-free operation of the aircraft on the airport scene [4, 5, 6]. Some can achieve the purpose of reducing delays by improving the taxi time of the aircraft [7, 8, 9]. However, the current aircraft taxiing conflict detection needs to be based on the real-time position of the aircraft [10]. Although early warning is achieved to a certain extent, the correctness of the instruction is not verified when the controller issues the instruction to achieve early warning. Decision support needs to be strengthened.Therefore, this paper proposes a targeted approach for detecting aircraft taxiing conflicts on the ground. By analyzing the ADS-B historical data of the aircraft in actual operation of the airport scene, the taxi speed range of the aircraft on different positions on the taxiway is obtained, and the conflict detection algorithm is proposed to obtain the probability of conflict between the aircraft, which can be realized in advance for different types of aircraft before taxiing. Level of conflict warning.

2. Description of the problem of aircraft taxiing conflicts on the ground

2.1. Introduction to taxi conflict types

The surface taxiing of the aircraft is completed by radio communication between the controller and the pilot. After receiving the command from the controller, the pilot uses ground reference objects or ground signs to strictly follow the route in the command. The three types of potential aircraft taxiing conflicts during taxiing on the taxiway are shown in Figure 1:

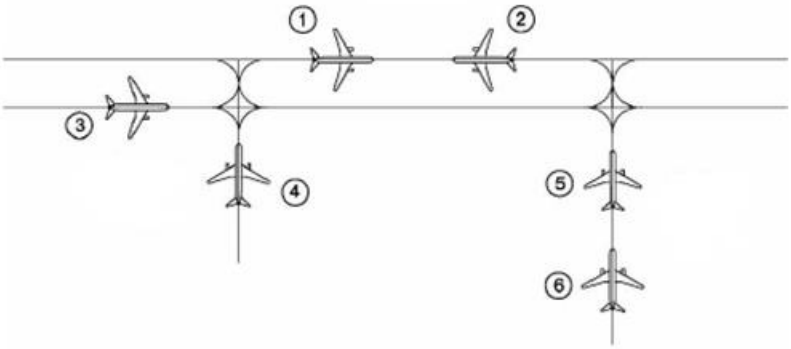

Figure 1:Schematic diagram of the three potential taxi conflicts during the taxiing process

(1)Head-to-head conflict

When two or more aircraft taxi opposite each other on the same section of the taxiway and there is no other intersection on the taxiway for them to taxi out, a confrontation conflict will occur. As shown in Figure 2 for the two planes 1 and 2.

(2)Cross conflict

When two planes cross their original taxi routes and have already met at the same taxiway intersection and the safety interval is not met at this time, a cross conflict may occur. As shown in Figure 2 for the two planes 3 and 4.

(3)Rear-end conflict

The taxiing routes of two aircrafts include the same straight taxiway, and when taxiing in the same direction on this taxiway, a rear-end collision may occur when the taxiing interval between the two aircraft is less than the specified minimum safe interval at a certain moment. As shown in Figure 2 for the two aircrafts 5 and 6.

2.2. Airplane taxi rules

During the actual taxiing of the aircraft, the aircraft must meet certain rules of motion, the main rules include:

(1)When the aircraft is taxiing on the scene, the taxiing route is uniquely determined and in a single direction. It must be taxied along the path specified by the control instruction. However, the flight crew can adjust the taxiing state according to the taxiway parameters (turning point, intersection, straight taxiway length, etc.) (startup) , Acceleration, constant speed, deceleration, stop, turn).

(2)All aircraft taxiing on the scene should maintain at least the specified safe separation. When two or more aircraft follow up taxiing, the aircraft behind is not allowed to exceed the aircraft in front, and the minimum separation between the two aircraft is not allowed to be less than 50. m.

(3)The aircraft is reasonably taxiing within the designated taxi speed range, and the taxi speed of the aircraft on the scene is not allowed to exceed 50 km/h.

Therefore, the problem to be solved in this article can be described as: how to provide a method for detecting aircraft taxiing conflicts based on the control command information, ensuring that the minimum distance between aircrafts is not less than 50 m, and the taxi speed is not more than 50 km/h.

ISSN: 2664-9640

3. Detection method of aircraft taxiing conflict on the ground

3.1. Assumptions

Due to the complexity of the aircraft taxiing in the airport flight area, in order to objectively reflect the essence of the aircraft taxiing process, but also facilitate discussion and processing, the assumption of completeness of information is introduced here, that is, before the aircraft taxis, including the aircraft flight plan, Basic information such as the model of the aircraft and the time when taxiing begins is complete, determined and known.

3.2. Data preprocessing

Define P_i andP_j as the set of planes to be planned, i and j represent different planes, $i \in N^*$. According to the CAD general plan of the target airport marking line, the length of each section of the taxiway is obtained, which is defined as L_k, $k \in$taxiway number.

According to the historical ADS-B data of an airport, the 24-digit ICAO address code, taxi speed, heading angle, geographic coordinates and other information of all planes operating at the airport can be obtained. By limiting the taxiway geographic location coordinate area, the python tool can obtain the taxi speed of all aircraft passing this taxiway, and calculate the speed interval of each taxiway 95% confidence interval, we can define this taxi speed interval asΔV_k, $k \in$taxiway number.

Define t_{si} as the time when aircraft i starts taxiing at the starting taxi point, and the subscript s is the starting taxi point of aircraft i; among them, the taxiing time for the departing aircraft is equal to the sliding time from the taxiway of the parking bay in the control order, and the subscript s is the starting taxiing point of the aircraft i. The time for the aircraft to start taxiing is equal to the time it takes to exit the runway and enter the fast exit lane.

Define T as the minimum safe time interval threshold between aircrafts. This article T consists of three parts:

$$T=T_{bc}+T_r+T_w \tag{1}$$

In formula (1), if the aircraft is taxiing at a maximum taxi speed of 50km/h on the ground and the minimum distance between aircraft taxiing on the ground cannot exceed 50m, the calculation will be converted into the aircraft's lowest taxi speed. The wake time interval T_w=3.6 s. At the same time, according to NASA's related research on airport surface collision parameters, the driver's reaction time T_r =2 s, and the aircraft's braking coordination time T_{bc} =1.2 s. Thus, T=3.6+2+1.2=6.8s.

Through the speed interval obtained above, the time interval required for the aircraft to taxi to each node can be calculated:

$$\Delta tP_i=\frac{L_k}{\Delta V_k} \tag{2}$$

In formula (2), ΔtP_i is the taxi time interval for the aircraft P_i to reach any node of the taxiway; ΔtP_j can be obtained in the same way;

$$\Delta tp_{ij}=(\Delta tP_i+ t_{si})-(\Delta tP_j + t_{sj}) \tag{3}$$

In formula (3), Δtp_{ij} is the time interval difference between the aircraft i and j arriving at any public node of the taxiway, and $t_{ij}p_{min}$ is defined as the lower limit of this interval, and $t_{ij}p_{max}$ is the upper limit of this interval.

3.3. Aircraft taxiing conflict detection and early warning algorithm

The corresponding aircraft taxiing conflict detection process is shown in Figure 2:

ISSN: 2664-9640

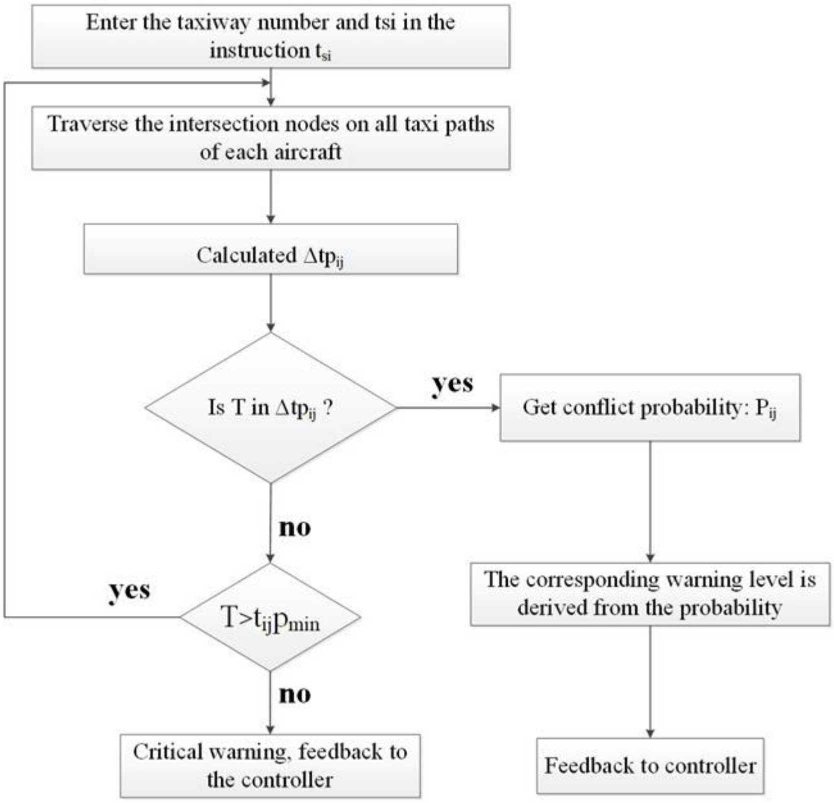

Figure 2: The flow chart of the airport taxiway conflict detection and early warning algorithm

Multi-level conflict early warning is set according to the probability. Multi-level early warning is more humane and can provide controllers with multiple ways to take measures. Among them, if the conflict probability is 0-30%, then a low-level early warning is given. The controller does not need to modify the issued instruction route, and can follow this area; if the conflict probability is 31%-70%, then an intermediate early warning is given. At the same time, it is necessary to pay attention to the taxiing dynamics of the aircraft at any time and modify the command route if necessary. At the same time, it can remind the pilot where a conflict may occur; if the conflict probability is 70%-100%, an advanced early warning is required and the controller needs Focus on this area, and the issued instructions must be modified according to the current operating conditions of the airport's flight area.

4. Experimental verification and results of aircraft taxiing conflict detection

According to actual airport surveys, when an aircraft leaves the runway and enters the taxiway, it may taxi with the aircraft. If the taxi speed is too fast, a rear-end collision may occur. Near the intersection of the taxiway, there may be encounters with other aircrafts, intersecting or confronting conflicts. When entering the designated parking space, there may be a confrontational conflict with the aircraft preparing to depart from the port.

Therefore, for the three types of conflicts, three sets of aircraft taxiing processes are artificially set, and conflict detection is performed on them. According to the input aircraft taxiing path and the start time of taxiing, different conflict probabilities and warning levels are obtained. The specific conditions are as follows:

In view of the conflict between aircraft taxiing, two real routing instructions with 24-bit aircraft address codes 78142A and 780FDF are selected. The real taxiing paths of the two aircrafts are shown in Figure 3. Shown:

ISSN: 2664-9640

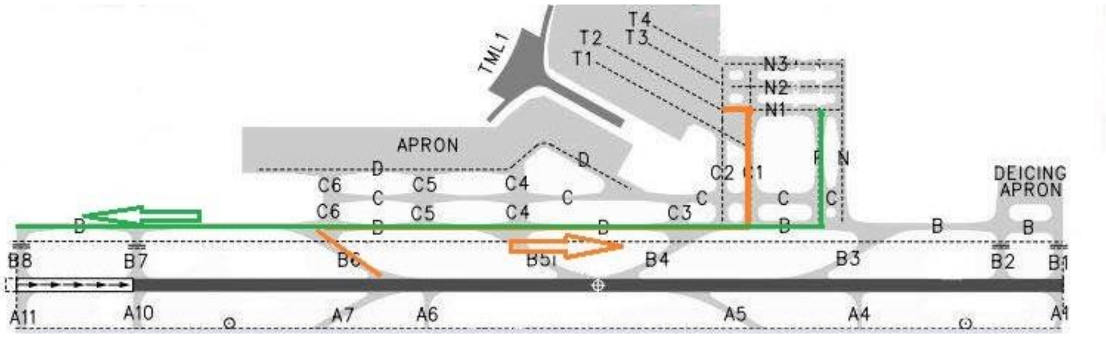
Figure 3: Real taxi path diagram of 78142A and 780FDF aircraft

It can be clearly seen from the above figure that the area where a confrontation conflict may occur is section B (area C3 to C6). The real time difference between the real routing instructions to reach the conflict area is used to verify the deduction process of this method. The results of verifying this conflict are shown in Table 1:

Table 1: Verification conflict

Taxi start time difference between aircraft	Real warning level	Conflict probability	Experimental verification warning level
0s	intermediate-level warning	32.90%	intermediate-level warning
5s	intermediate-level warning	40.09%	intermediate-level warning
10s	intermediate-level warning	47.28%	intermediate-level warning
15s	intermediate-level warning	47.28%	intermediate-level warning
20s	intermediate-level warning	61.66%	intermediate-level warning
25s	intermediate-level warning	50.71%	intermediate-level warning
30s	intermediate-level warning	50.24%	intermediate-level warning
35s	intermediate-level warning	57.79%	intermediate-level warning
40s	intermediate-level warning	65.33%	intermediate-level warning
45s	intermediate-level warning	47.64%	intermediate-level warning
50s	intermediate-level warning	40.10%	intermediate-level warning
55s	intermediate-level warning	32.55%	intermediate-level warning
60s	Low-level warning	25.01%	Low-level warning
65s	Low-level warning	17.46%	Low-level warning
70s	Low-level warning	22.92%	Low-level warning
75s	intermediate-level warning	31.82%	intermediate-level warning
80s	intermediate-level warning	40.71%	intermediate-level warning
85s	intermediate-level warning	49.61%	intermediate-level warning
90s	intermediate-level warning	58.51%	intermediate-level warning
95s	intermediate-level warning	67.40%	intermediate-level warning
100s	high-level warning	76.30%	high-level warning

In this method experiment, 20 simulated two aircraft start taxi time differences were selected. From the results of the above table, we can see that the conflicting areas that may occur between the two aircrafts belong to the actual alarm level and the conflict warning verified by this method experiment. The levels are all the same, so it is verified that the correct rate of the aircraft taxiing on the ground is 100%.

In the same way, for the aircraft taxiing cross conflict, the actual time difference between the two real routing instructions of 7808B7 and 780FDF to reach the conflict area is selected to verify the deduction process of this method, and 20 simulated two aircraft start taxi time differences are selected. The results show that in the cross-conflict area that may occur between two aircraft, when the difference in the taxiing time between the aircraft is 40s, the true warning level is high-level warning, and the conflict warning level verified by the experiment of this method is medium-level warning, but All the remaining true alarm levels are consistent with the conflict warning levels verified by the experiment of this method, and the accuracy rate of the cross-collision verification of the aircraft taxiing on the ground is 95%.

In the same way, for the collision of aircraft taxiing and rear-end collision, the real time difference between two 780D33 and 78142A real routing instructions to reach the conflict area is selected to verify the deduction process of this method, and 20 simulated two aircraft start taxi time differences are selected. The results show that in the possible rear-end collision area between two aircraft, when the difference in the taxiing time between the aircraft is 35s, the real alarm level is advanced early warning, and the conflict early warning level verified by the experiment of this method is intermediate early warning, but All the remaining true alarm levels are consistent with the conflict warning levels verified by the experiment of this method, so the correct rate of verifying that the aircraft is taxiing on the ground is 95%.

The results of the above three sets of experiments show that the actual alarm level is basically the same as the conflict early warning level verified by the experiment of this method, and the correct rate of the early warning of the three conflict experiments has reached more than 95%. Although in the verification of cross conflicts and rear-end collisions, there are situations where the early warning level does not reach the relevant early warning level, but the early warning level also reaches the level where the controller needs to modify the instructions, which can effectively avoid the occurrence of aircraft taxiing conflicts. Therefore, this method is considered to be accurate in detecting the three types of taxiing conflicts among aircraft.

5. Conclusion

This article proposes an early warning method for aircraft ground taxiing conflicts based on the command information of the controller, aiming at how to improve the safety of ground operations in the airport flight area, and how to use auxiliary facilities and equipment to improve the supervision and guarantee work in the process of ground control. The experimental results prove that the method of detecting the taxiing conflicts between aircrafts in this paper is accurate.

In general, the research in this article can play a role in supporting the controller's order and decision-making, can effectively improve the safety guarantee ability of airport operation, and can effectively help the current airport operation and dispatching to be safer and more efficient.

Acknowledgements

Supported by Boyin Foundation Project of Civil Aviation University of China(20200618034) the Fundamental Research Funds for the Central Universities (3122019047).

ISSN: 2664-9640

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