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TAXIING ROUTE PLANNING BASED ON AIRPORT HOTSPOTS

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Abstract

The Airport hotspot is the taxiing conflict occurs between aircraft. We identify those airport hotspots, evaluate the hotspot risk and then optimize the aircraft taxiing route correspondingly. By processing and analyzing historical surface surveillance data with node-route model, hotspots are optimized by using mechanism of taxi selection, and an optimization model of aircraft taxiing route based on time-space distribution of hotspots is proposed as well as its restrictions. A simulation to verify above optimization model is conducted. .

1 General Introduction

As the rapid development of air transportation, the ever larger ground maneuvering area induced complex taxiway and runway construction. The more the taxiway and runway intersections, the more probability of the aircraft ground movement conflicts. ICAO defines airport hotspot as the area where has more potential risk of collision or invasion of runway in the region of ground of the airport operation so far in running history[1]. These hotspot regions are likely to happen between aircraft and vehicles gliding conflicts, resulting in flight delays, making airline transportation industry suffer from tremendous loss. Therefore, it is significant to find a method to improve the operational efficiency of the whole airport system, solving conflict of airport resources by optimization of taxi route planning.

In 2004, ground traffic signal control technique integrated into A-SMGCS collision detection model, in order to better control the airport ground conflict coming up. Changyou Liu has considered typical rules of conflict restriction and secure isolation, establishing an optimizing model of airport conflict-free taxiing route[3]. Wei Zhang converts airport taxiing route to Petri net, and explores the optimizing taxiing route regulation. In 2010 and 2011, Xinping Zhu designed a corresponding controller algorithm to resolve head of taxiing routes conflicts[4]. But these researches are just in allusion to optimizing routes and liberation of conflicts in ground operation, not mentioning airport ground conflict hotspot area avoiding issue[5].

This paper analyzes the space-time distribution characteristics in airport ground conflict hotspots, coming up with an optimizing method of aircraft taxiing route based on the characteristic of conflict hotspot area. This method effectively alleviates the potential conflicts and other three typical ground taxiing route conflicts in airport ground hotspot area, guaranteeing the safety and efficiency of operation by making the time of all aircraft taxiing time and waiting time the shortest, and the goal of planning aircraft glide path with the least number of turning times[6].

The research concerned about:

- Setup the assessment model of conflict probability at airport surface intersection
- Alleviate the potential conflicts of ground hotspots area, and avoid it, meanwhile, improve the utilization efficiency of taxi resources.
- Avoid three kinds of typical taxiing conflicts (adversary, intersection, tracing conflict)

- Route optimization shall provide alternative route for flight according to the actual operation requirement.
- The optimized taxiing route can make the total taxiing time of all flights is more minimum, meanwhile, the number of turns and waiting time of planning taxiing route also should be as less as possible.

2 The Establishment of Airport Ground Model

2.1 Ground Node-route Model

The Node-route model is used to describe the composition of the airfield ground transportation system, in other words, it adopts hierarchical modeling way to establish the network model of ground traffic system. However, the intersection is a single node in node-route model, it can't describe the really movements in intersection area. so it's difficult to optimize a more accurate aircraft taxiway. Therefore, the author uses virtual node and practical node to detailing intersection road shown as figure First of all, abstracting intersection area to virtual node V1, then according to the intersection of taxi routes, further describing the actual node N1,N2,N3,N4 and the curves taxiing roads among nodes above. Considering aircraft occupies runway shortly and the taxiing speed of aircraft in airport apron is slow, the improved node = the intersection among runway, out-of-runway, taxiing lines in airport apron in road model will still be described as single node.

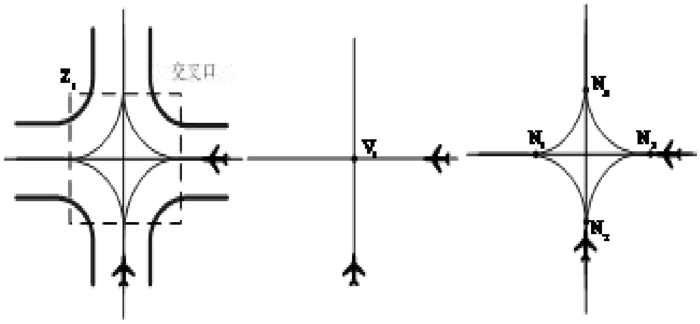

Fig.1. Modified Node-route Model

Obviously, airfield ground transportation system node-section from abstraction (shown in figure 2), virtual nodes represent taxiway intersection, out-of-mouth-runway, deicing area and so on. The actual nodes represent the nodes in every position of entrance or departure in the area. And section-road describes the straight line in taxiway, and curve way, runway, out-of-mouth-way, contact way in taxiway intersection. Therefore, airport traffic system can abstract to a directed graph G=(E,V,W) E is the sets of corresponding sides of each taxiing way in ground transportation system, V is the set of nodes among each adjacent sides, W is the set of the weights of sliding roads.

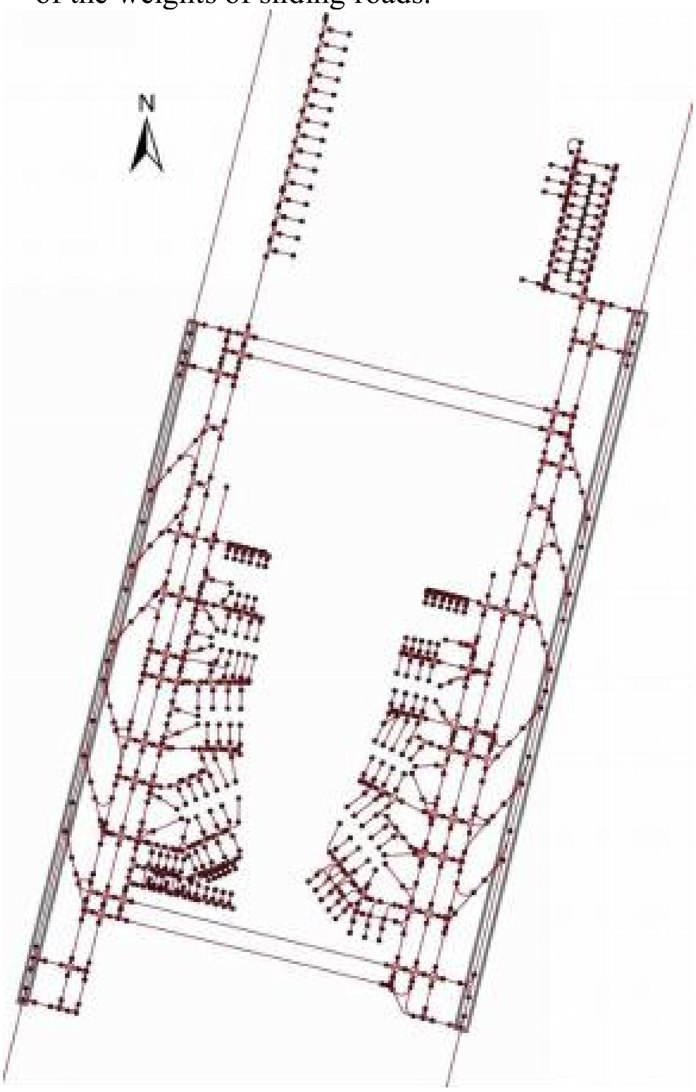

Fig.2. Airport Node-route Model Application

After investigate the SSR radar history data in an airport, a software developed to analysis the ground aircraft movement track, and then the ground taxiing situation have been researched.

The taxiway using law was given by the aircraft ground waiting frequency, waiting time, taxiing time and speed. Then the methods of modified Node-route model have been setup[2]. Considering actual operation control, streamlined improved Node-route model, and improve the efficiency of operations. The comprehensive weight assignment algorithm has been designed for both the physical characteristics of the airport and practical mode of operation to improve the accuracy and practicability.

2.2 Assessment Model of Conflict Probability at Airport Surface Intersection

Based on the historical surface surveillance radar data and the airport modeling technology, a network model of historical surface operating data was established, the airport model was streamlined and taxiway comprehensive weights were distributed combined with the actual operating law of taxiway, according to the comprehensive weights, the sections of airport model were divided into two levels.

In case of those sections with smaller comprehensive weights, design a static conflict detection model main about consideration for spatial and temporal overlap. Got the entry and departure times of aircraft which taxied through the taxiing units; and then analyzed any two planes taxied through the same taxiing unit , detected static collision based on judging whether they had time overlap , their heading-offset and distance threshold value was passed or not.

In case of those sections with bigger comprehensive weights, design a static conflict detection model based on the probability of collision. Calculate the probability of collision on them combined the state of aircraft features, detected static collision based on judging whether the probability threshold value was passed or not.

Set the interval velocity v_{span}, the current velocity v_{now}. In this paper, $[v_{now} - v_{span}, v_{now} + v_{span}]$ in the uniform distribution to describe the next moment airport aircraft ground speed. When $v_{now} - v_{span} < 0$, the uniform distribution of the lower limit value for a speed of 0. Aircraft constant speed, uniformly accelerated and uniform deceleration three ideal motion state of conflict probability have been analysis, and the constant speed aircraft conflict probability changing under different v_{span} values was described below.

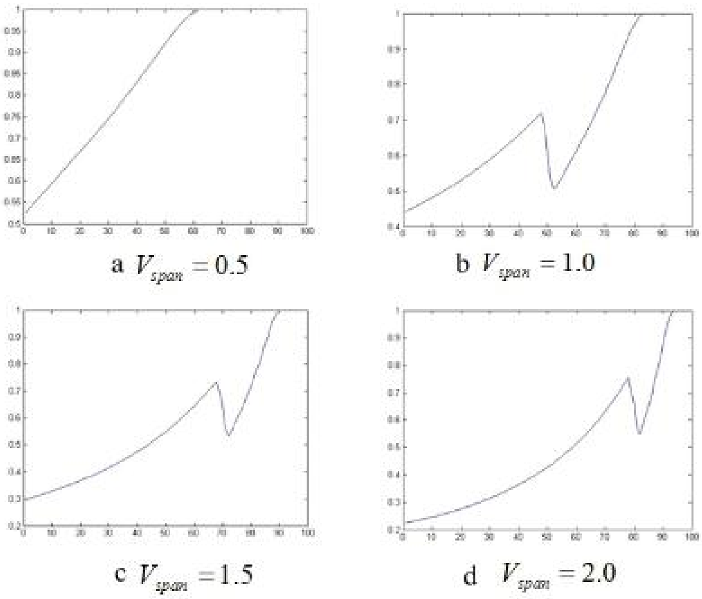

Fig.3. Two Constant Speed Aircraft Conflict Probability Changing under Different v_{span} Values

2.3 Characteristics of Time and Space Distribution in Conflict Hotspot Area

By research the historically data from an airport in middle-of-south region, it is found that the larger volume of traffic during certain period of time, the more potential conflict in operation, the aircraft will slow down, observe environment, even stop to wait when crossing intersection. In this case, the number of hotspots is detected to be more. Whereas less the hotspots, the shorter of time in conflict. Meanwhile, the potential taxiing conflicts produced by airport ground are not only relative with model of airport operation, as well as shows significant differences in temporal and spatial distribution characteristics. The hotspots areas are more likely to appear in the intersection of taxiways and runways, taxiway and taxiway.

From the spatiotemporal distributions statistics of two hotspots area from 02L runway surface between 06:00-15:00, it's obvious to see that between 12:00-15:00, HS01 hotspot area has the highest risk level with a total of three times dangerous conflict and a total of six flights in conflict with each other. The dangerous level of hotspot area is lower in the other time. During 09:00-15:00, two times dangerous conflicts happened in HS02, at this time HS02 is marked as hotspot area. During 06:00-09:00, no conflict occurs in HS02, meanwhile, it's not a hotspot. Flights can regularly access this area without waiting and avoidance. Spatiotemporal distributional characteristics of hotspot area are shown as figure 4. The deep red area represents that the conflicts are more and duration is longer in HS01 hotspot area in this period of time. Pink red represents that the conflicts are less or duration is shorter in HS02 hotspot area.

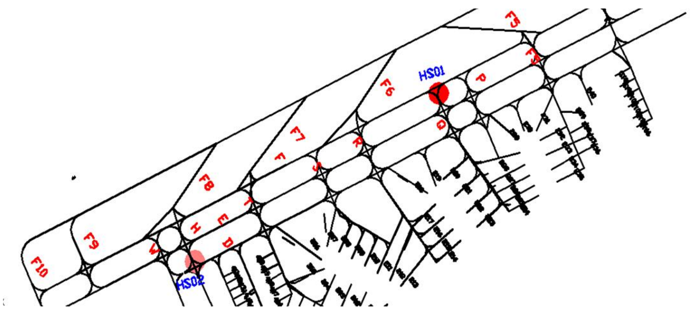

Fig.4. The Spatiotemporal Distributions of Hotspots on Runway 02L During 12:00-15:00

3 Simulation results of Taxiing-route Optimization Based on Temporally-spatially Distributional Characteristics of Hotspots

After studied the taxiing route planning methods and the collision avoidance mechanism as mentioned above[7][8], the surface topology is abstracted and modeled as node-route model by using theory of directed graph, and the values of each node-route section including operation rules and geographic information are assigned. Then, the modeling process for runway, taxiway and apron is illustrated as well as the motion model of taxiing aircraft, and the feasibility and reliability for the aforementioned models is justified.

By processing and analyzing historical surface surveillance data of a given aerodrome with node-route model, the characteristics of taxiing aircraft's speed variation and taxiway operation rules are obtained, and meanwhile an algorithm to identify aerodrome surface hotspot is proposed. Moreover, the time-space distribution and the cause for those identified hotspots are analyzed. To determine the risk level for the identified hotspots, the standard for categorizing hotspot by risk level is established as well.

The aircraft taxiing routes along part of those identified hotspots are optimized for instance, by using mechanism of taxi selection and avoidance at hotspots, and an optimization model of aircraft taxiing route based on time-space distribution of hotspots is proposed as well as its restrictions. A simulation to verify above optimization model is conducted with operational data of aircraft taxiing along the hotspots during a period of time. Simulation results show that the total taxiing time for those selected aircraft is reduced by 238 seconds by using the proposed optimization model, and the hotspots are effectively avoided during taxiing. Therefore, the risk level of hotspots is decreased, which is significant to the aerodrome operation efficiency and safety.

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