International Civil Aviation Organization

Eleventh Meeting of the Air Traffic Management Sub-Group (ATM/SG/11) of APANPIRG

Singapore, 2 – 6 October 2023

Agenda Item 5: ATM Systems (Modernization, Seamless ATM, CNS, ATFM)

RUNWAY SAFETY WARNING SYSTEM BASED ON SENSOR NETWORK AND INTELLIGENT VIDEO SURVEILLANCE IN PREVENTION OF RUNWAY INCURSIONS

(Presented by China)

SUMMARY

This paper presents the application of runway safety warning system based on sensor network and intelligent video surveillance to prevent runway incursions. A runway incursion warning system suitable for the characteristics of small and medium-sized airports in China and runway taxiing configurations has been developed by integrating various technologies related to the prevention of runway incursions, such as multi-sensor data network, video intelligent monitoring and detection, real-time target identification, tracking and positioning, and runway status lighting system. With an accuracy rate of runway safety warning reaching more than 95%, the system has been successfully tested and applied in numerous small and medium-sized airports, meeting the requirements of the aerodrome control tower for safe operation of runways.

1. INTRODUCTION

1.1 According to ICAO Doc 9870 *Manual on the Prevention of Runway Incursions*, the common factors that can result in runway incursions involve air traffic control, communications between controllers and pilots, pilots, airside vehicle drivers and environment.

1.2 The research on runway incursion prevention and the application analysis of targeted measures home and abroad have shown that improving the aerodrome surface surveillance capability, enhancing situational awareness of controllers/pilots/vehicle drivers and strengthening the building of warning systems for runway incursions are effective technological means to prevent runway incursions.

1.3 China has long been committed to the research and application of runway incursion prevention technologies, including surface surveillance, consistent situational awareness, and runway incursion monitoring and warning technologies.

1.4 A variety of surface surveillance sensors, such as multilateration system and surface movement radar, commonly used in large-sized airports, provide controllers with visual or audible alarm functions, which can effectively enhance the situational awareness of controllers. However, they are not widely applied in small and medium-sized airports due to high costs.

1.5 A runway safety warning system based on sensor network and intelligent video surveillance was developed in order to solve the problem about the unavailability of low-cost runway incursion prevention technology in small and medium-sized civil aviation airports.

2. DISCUSSION

Application Analysis of Runway Incursion Prevention Technology

2.1 The runway incursions can be prevented on various aspects, including improving the surface surveillance capability of airport, enhancing the situational awareness of controllers, and providing controllers, pilots and vehicle drivers with consistent situational awareness and direct runway incursion warning. There are some mature technologies available home and abroad. The following table provides a comparative analysis of the characteristics and costs of these technologies.

	Function	Advantages	Disadvantages	Cost
Surface movement radar	A non-collaborative sensor that can monitor targets such as aircraft and vehicles	Independence from transponder, and high positioning accuracy	Lack of target identification information, and possibility of false targets	Multi-runway airport: About CNY 20 million Single-runway airport: About CNY 10 million
Multilateration system	A collaborative sensor that can monitor targets such as aircraft and vehicles	High positioning accuracy and high data reliability	Each target to be provided with a transponder	Large airports: About CNY 10 million Small airports: About CNY 4-5 million
ADS-B	A collaborative sensor that can monitor targets such as aircraft and vehicles	High positioning accuracy, low cost and easy deployment	No guarantee for the accuracy and integrity of positioning data because their relevance to airborne equipment	About CNY 2 million
On-board beacon	Send vehicle positioning data automatically to provide vehicle locations for multilateration	Low cost and easy deployment	Only vehicles can be located	CNY 10,000/Nr.

	Function	Advantages	Disadvantages	Cost
	system and ADS-B system			
A-SMGCS	Provide controllers and pilots with surface situation and warning	Multiple functions such as surface targets' traffic dynamics, conflict alarm and route guidance	A complicated system that requires coordination of multiple sources of surveillance data	Large airports: About CNY 10 million Small and medium-sized airports: About CNY 5-6 million
Electronic flight strip	Record commands and flight status	A simple system with command logic alarm function	For controllers only	Large airports: About CNY 3-4 million Small airports: About CNY 2 million
Stop bars	An alert to pilots and vehicle drivers	Alert pilots and vehicle drivers directly	Human error may appear due to manual control by controllers	Single-runway airport: About CNY 20 million
Runway guard lights	Alert pilots and vehicle drivers that a runway is ahead	Alert pilots and vehicle drivers directly	No runway security alert	
Runway status lights	Alert pilots and vehicle drivers to runway security	Alert pilots and vehicle drivers directly; automatic operation instead of manual operation	A complicated system that relies on the surface monitoring system to provide traffic situation data	
Regional multi-sensor network	Multi-type sensors for access monitoring at entrances and exits of aircraft and vehicles	Triggered detection, multi-source data fusion and accurate detection results	Only object access is detectable, and manual intervention is required to determine if the access is an intrusion	Not more than CNY 2 million
Video surveillance at key points	Key points such as video surveillance crossings and	Multiple types of intrusions such as aircraft, vehicles	Small area under surveillance due to the impacts by meteorological	About CNY 1 million

	Function	Advantages	Disadvantages	Cost
	waiting-line locations	and personnel are detectable	conditions such as low visibility	
Panoramic intelligent video surveillance	Monitor the traffic dynamics of the whole surface, identify and track moving targets, and provide controllers with runway incursion warning	Detect various types of intrusions in an intelligent manner and provide controllers with advisory warning information	Low detection accuracy under some specific meteorological conditions	Not more than CNY 2 million

2.2 At present, the means of acquiring aerodrome surface traffic dynamics, such as surface movement radar and multilateration system, are priced at tens of millions of CNY. To install the equipment of these costly means in operating airports is also challenging, so their application is greatly limited. Most importantly, these means have the following inherent defects:

a) Existing non-collaborative surveillance means such as surface movement radar are severely affected by buildings, ground clutter and weather;

b) Existing collaborative surveillance means such as ADS-B require the airborne secondary surveillance radar transponders to acquire the identification of aircraft rather than surface vehicles;

c) It is challenging to meet the requirements for aerodrome surface safety if preventing surface collisions depends solely on controllers controlling the navigational aid lights, because it is a complicated operation that is prone to violating the applicable ATC regulations.

2.3 It is therefore necessary to develop a cost-effective runway intrusion prevention system that is suitable for small and medium-sized airports, enabling the airports to support the safe, orderly and rapid movement of aircraft and related vehicles under complicated circumstances, and achieving the goal of maintaining the airports' safety.

2.4 A runway safety warning system based on sensor network has been developed and put into use, by leveraging the wireless sensor network technology, flexible sensor layout, and multi-sensor information fusion technology. By examining the principles of runway occupancy identification and incursion inspection, a runway incursion warning detection logic for small and medium-sized airports has been designed, and the corresponding auxiliary decision-making system for runway use has been developed. They can provide controllers with key information, such as runway status alert, service status alert of linking taxiway and exit taxiway, momentary alerts for aircraft entering/exiting the key locations of runway, and runway incursion warning.

2.5 To ensure that the wireless sensor network covers the whole aerodrome protection area, multiple groups of sensors are evenly distributed at the geometric endpoints of the aerodrome protection area. Each group consists of a receiver and a transmitter. If a sensor is activated by a moving object (e.g. aircraft, vehicle or person) after an appropriate network form is selected for data transmission, the moving object's instantaneous state as it passes through the monitored area will be obtained and the corresponding sensing data will be transmitted to the central server through wireless network. Multi-

sensors are used to simultaneously identify several characteristics of a target by means of infrared sensor, millimeter-wave radar sensor, and laser intrusion detector for area-specific target detection, in order to ensure the reliability of runway incursion detection. Multiple sensors are used to gather target detection information from multiple directions. By the fusion of data from many sensors, the potential runway incursion occurrences are automatically identified, determined and alerted in accordance with the runway incursion identification logic, and controllers are provided with the relevant information. The component modules of the system are inexpensive, highly reliable, and stable. Different airports can configure the system flexibly according to their own characteristics and actual requirements.

2.6 This paper, by studying the theory and operation of runway status lighting systems, examining the management and operation standards on runway status lighting systems, and referring to the methods and management procedures for installing runway status lighting systems in China's airports, proposes the *Technical Configuration and Operation Standards for Runway Status Lighting System to Prevent Runway Incursions*, which provides construction concepts and schemes for safe runway status lights in China's airports.

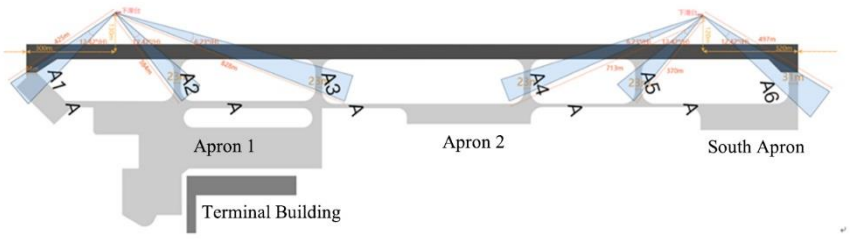
2.7 Based on the concept of video surveillance in key areas, a set of technologies for runway safety warning based on intelligent video surveillance has been proposed, and its system prototype has been developed, by studying the different types of runway incursion occurrences and their identification logic, and leveraging the positioning data space calculation technology, and video image intelligent target identification and tracking technology, and using multi-sensor source data fusion method. The system integrates the data from ATC automation system, ADS-B and vehicle beacon, and monitors the safe operation status between aircraft and runway, aircraft, vehicle and runway, vehicle and aircraft, personnel and runway, personnel and aircraft, other moving objects and runways, and other moving objects and aircraft in real time. Once the risk of incursion is identified, the system provides tower controllers with real-time and efficient information to make decisions on runway incursions. In addition, if any intrusion risk of vehicles, personnel and other moving objects is found, the system automatically pushes the alert to relevant departments of the airport immediately, and provides the corresponding warning plan of runway status lighting system, which helps speed up the disposal of incursions, greatly shorten the tower's response time to incursions, improve the efficiency of addressing the incursion risk, reduce runway operation risks and enhance runway safety.

2.8 The image and video data of the runway protection area is captured by different types of cameras installed in the aerodrome protection area. The Mask R-CNN model and KCF technology are used to process the real-time video data, capture and rapidly track all the moving objects (aircraft or vehicles) within the aerodrome protection area in the video. After the objects are identified and classified in real time, the controllers are alerted timely to potential runway incursions through the preset runway incursion warning logic. The transfer learning method is designed to improve the learning efficiency of the models in the system. The experimental results show that the detection and tracking accuracy of the models in the system can reach about 95%, allowing for efficient identification and tracking of aerodrome surface targets, accurate prediction of runway incursions and prompt alerting.

2.9 The runway safety warning systems, both based on sensor network and intelligent video surveillance, share technical features such as compact structure, low cost and easy installation and use. They are mainly applied to small and medium-sized airports, and their technical verification and promotion have been carried out as follows:

a) The runway safety warning system based on sensor network has been put into use at Harbin Taiping International Airport of China, and it has been operating normally and performing significant functions;

b) The runway safety warning system based on intelligent video surveillance has been designed and established, and based on the data from Quanzhou Jinjiang International Airport of China, the camera layout, as well as the accuracy test of real-time video recognition and tracking have been completed;



c) The two systems have the characteristics of low cost, excellent scalability, high reliability and good stability, and their continuous testing has revealed that their overall functions run well.

3. ACTION BY THE MEETING

3.1 The meeting is invited to:

a) note the information contained in this paper;

b) Consider convene relevant workshop led by ICAO to encourage members to share experiences and lessons learned from implementing new technologies for runway incursions at their airports.

c) Discuss any relevant matters as appropriate.

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