Recent Advances for Smart Air Traffic Management: An Overview

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Abstract. With the development of the civil aviation industry, the pressure carried by the air traffic management (ATM) system, which is the core of civil aviation operations, is also gradually increasing, and therefore, it is necessary to use the power of various emerging information technologies to build a smart air traffic management system, thereby improving operational efficiency while ensuring safe operation of air traffic management. In recent years, the research of smart air traffic management has become a hot topic in academic circles, supported by industry guidance units such as the Civil Aviation Administration and the Air Traffic Management Bureau, and scholars at home and abroad have conducted relevant explorations on smart air traffic management. The paper comprehensively analyzes the research results of smart air traffic management in recent years, and for cloud computing, big data, artificial intelligence, Internet of Things (IoT), mobile Internet, five most important emerging information technologies, the research progress of combining with smart air traffic management is analyzed, meanwhile, proposed the shortcomings of the existing research and the suggested research directions for the next step, provide reference for further research on smart air traffic management.

Keywords: Smart ATM · Cloud computing · Big data · Artificial intelligence · IoT · Mobile Internet

1 Introduction

Since 2009, US President Barack Obama has proposed the concept of "Smart Earth" for the first time at a round table with business leaders. The concept of "smart" has taken root in all walks of life and has become more and more popular with the continuous development of new generation of information technology, the civil aviation industry is no exception, put forward the development concept of "smart civil aviation". Taking it as an extension, in 2018, the Civil Aviation Administration of China put forward the "four enhancements of air traffic management" strategic objectives of "enhancing security, enhancing efficiency, enhancing smartness, and enhancing coordination," which focus on making up shortcomings and improving capabilities from aspects such as production safety, guaranteed operation, and construction developing [1]. Among them, "enhancing smartness" is an important foundation and necessary path to achieve the objectives of "enhancing security, enhancing

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efficiency, and enhancing coordination." And because of the importance of smart air traffic management for the future development of air traffic management system, at home and abroad, a lot of research has been proposed for this field, based on recent research results in the field of smart air traffic management at home and abroad, the paper will comb the concept and connotation and application and expansion of smart air traffic management and discuss the development trend and priority of future research in the field of smart air traffic management.

2 Concept and Connotation of Smart ATM

With the development of the new generation of information technology and the continuous expansion of the concept of "smart," the concept of smart air traffic management came into being. Wenxian and Xinping [2] proposed the concept of smart air traffic management earlier, they believe that the smart air traffic management system is a novel air traffic management system fully incorporating new generation of information technologies, in which sensors are equipped and universally connected, forming the "Internet of things for ATM" and contributing to the real-time surveillance and control for air traffic. The heterogeneous information from "Internet of things for ATM" is fused and processed through advanced computer platform. Then, the processed information is provided to every domain application platform, fulfilling more precise and more dynamic air traffic management. The concept basically applies the relevant fusion concept in the smart earth and depicts the basic logical framework of the smart air traffic management.

Jidong [3] strengthens the importance of Internet and artificial intelligence technology in the connotation of smart air traffic management, and he believes that in the smart air traffic management system, smart refers to the use of Internet technology to give management equipment some abilities of artificial intelligence, so that it can make its own judgment quickly and accurately, with certain mechanical smartness. This connotation also highlights an important feature of the smart air traffic management, which is to improve the production efficiency and diversity of assistant decision-making of air traffic controller through technical means [4] and reduce the amount of labor for them.

Hongyu et al. [5] proposed a concept of smart air traffic management and designed the overall framework of smart air traffic management system including sensing layer, network layer, platform layer, application layer, and visualization layer (Fig. 1). The sensing layer obtains information, the network layer transmits information, and the platform layer implements information storage, information exchange, information processing, etc., and the application layer covers control command, airspace management, air traffic flow management, flight service, low-altitude/general aviation, unmanned aircraft air traffic management, etc., and the visual layer provides efficient and intelligent interaction. Flexible and scalable basic platform and air traffic management applications can be realized through layered principles.

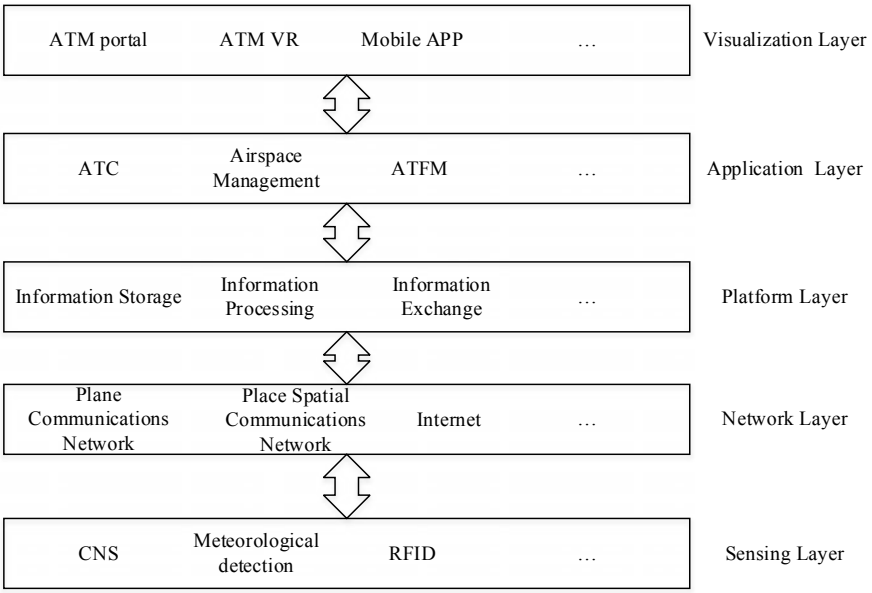

Fig. 1. Architecture of intellectualized air traffic management

3 Application and Expansion of Smart ATM

The development and implementation of smart air traffic management are inseparable from the maturity and application of a new generation of information technology. Scholars at home and abroad have conducted the research and exploration which combined air traffic management with representative technologies of a new generation of information technologies such as cloud computing, big data, artificial intelligence, Internet of Things, and mobile Internet.

3.1 Cloud Computing

Yun [6] analyzed four types of shortcomings of the current situation of data storage, processing, and analysis in air traffic management, and discussed the potential applications and advantages of using cloud computing in the management and processing of air traffic management data, and accordingly proposed improved optimization solution based on cloud computing infrastructure. She thought that data management solutions based on cloud computing can greatly improve the reliability and security of information systems in air traffic management and reduce the complexity and repeatability of data management.

Yunfei et al. [7] applied cloud computing to civil aviation collaborative decision-making system, they designed the system algorithms based on cloud computing topology, and carried out comparative algorithms analysis. Then, the optimal algorithm was used to complete the preliminary overall design and simulation test of the cloud

computing platform of system, which proved the feasibility and advancement of using cloud computing in air traffic management information systems.

Yuan [8] summarized the application experience of using cloud computing technology in the construction of air traffic management information systems at home and abroad. Analyses in the new generation of air traffic management information systems architecture based on cloud computing technology, air traffic management cloud computing verification project, air traffic flow management system based on cloud computing were focused on. And by setting up an air traffic flow management prototype system based on cloud computing technology, the feasibility of constructing an air traffic management system in the form of cloud was verified.

3.2 Big Data

With the development of information technology, big data technology has been widely used in the field of air traffic management as a trend of the current information industry. Chen and Fan [9] have combed the research progress of big data using the USA's air traffic management which has more developed civil aviation industry. Currently, the USA has achieved certain results in the System Wide Information Management (SWIM), the FAA operation and performance data system, the US National Flight Data Center, the enhanced traffic management system (ETMS), and other aspects. Overall, a big data application management model in air traffic management for statistical analysis, collaborative operation, and planning decision has been formed. The storage and hierarchical management of related data are becoming more and more standardized, and the secondary development and efficient use of data have become a hierarchy that is worth learning from.

Jingwei et al. [10] discussed the construction path of air traffic management big data based on information fusion. They proposed the basic idea of constructing China's air traffic management big data to build a national core database, establish an interactive interaction mechanism, and provide analytical and evaluation data products, by fully integrating and mining the data to optimize China's air traffic management information systems.

Ziqi [11] believed that the current application of big data in the field of air traffic safety management is still in its infancy, but it has achieved certain applications and breakthroughs in promoting the transformation of safety management mode, safety hazard investigation, operational risk warning, and unsafe incident investigation and case study.

Yongjie and Hui [12] integrated the previous research results and proposed a four-layer architecture of air traffic management big data based on the data, technology, platform, and application from the perspective of the application of the air traffic management network information system. Meanwhile, in terms of coordination, security, efficiency, and management, the application direction and development trend of air traffic management big data were given.

3.3 Artificial Intelligence

Xiaohong et al. [13] proposed the composition and implementation method of the artificial intelligence assistant decision-making system for air traffic management from the reality. The system aimed at solving different problems of air traffic management at all levels based on the prediction of flight conflict, the resolution of flight conflict, and the intelligent management of flight flow so as to finally realize the full application of artificial intelligence in air traffic management.

Yabin [14] believed that artificial intelligence technology can be applied to air traffic flow management assistant decision-making and flight conflict detection and detachment assistant decision-making, thus forming an artificial intelligence assistant system for air traffic management.

Tiansheng [15] believed that Automatic Dependent Surveillance Broadcast (ADS-B) can be regarded as a special artificial intelligence technology. Compared with other technologies, ADS-B provides a more accurate supervision method, enabling air traffic controllers can control air traffic management information systems as a whole and enhance the safety of air traffic, effectively solve congestion and re-push problems, improve the air traffic operating environment, and ensure flight safety.

3.4 Internet of Things (IoT)

Xinping [16] proposed a new air traffic management system based on IoT technology. The core of the project is to use the Internet of Things to improve the perception ability of air traffic in a more efficient and intelligent way and to enhance the interaction ability between air traffic controllers and pilots through various data links, thereby improving the level of air traffic management.

Yudong [17] analyzed the application prospects of using IoT technology in air traffic management collaborative decision-making system, airborne interval assistant system, and flight queue management.

Rui [18] and Yuanwei [19] proposed that the two key technologies of smart air traffic management are radio frequency identification (RFID) technology and wireless sensors network, by use of the two key technologies to realize surface operations, airspace operations, collaborative air traffic flow, runway safety, and equipment status management.

3.5 Mobile Internet

As a representative application software of the era of mobile Internet, WeChat has attracted applications from all walks of life since its introduction of Mini Program, due to its high feasibility of technology and application. Duan and Xie [1] developed the "Smart Management of Air Traffic Management Projects" system with the help of WeChat Mini Program tool. The system can realize the effects of mobilization, informationization, intelligence, velocity, and visualization of the project management system of East China Air Traffic Management Bureau of CAAC. It can be said that the use of mobile Internet has improved the intelligent level of air traffic management.

4 Suggestions for Follow-up Research

Based on the results of previous research, it can be seen that scholars at home and abroad have made useful explorations of smart air traffic management from the perspective of the combination of air traffic management and a new generation of information technology. Cloud computing, big data, artificial intelligence, Internet of Things, and mobile Internet technologies all have obtained a relatively rich application, but there are still some shortcomings in the existing research.

In the aspect of combining the research of smart air traffic management with cloud computing and big data technology, the existing research focuses on solving the storage optimization problem of large amounts of data, and the business application is a little limited. As the potential value of the air traffic management data continues to increase, it is recommended to carry out in-depth research of intelligent data processing of air traffic management. By studying the technologies of acquisition, processing, transmission, interaction, and intelligent mining of various air traffic management data, the capability promotion of the value of air traffic management data to the operation of air traffic management is further enhanced.

In the aspect of combining the research of smart air traffic management with artificial intelligence technology, the existing research has proposed to apply it to air traffic flow management assistant decision-making and flight conflict detection and detachment assistant decision-making. It also proposed the idea of developing auxiliary decision-making system. It is suggested that the follow-up study can further expand the scope of application on this basis and carry out more exploration in intelligent conflict management, intelligent air traffic flow management [20], intelligent planning management, and intelligent entry and exit sorting, and intelligent airport operation. At the same time, there have been many runway incursions in recent years. The hidden problem of information deviation in ground–air interaction needs to be solved urgently. For the important role of ground–air interaction talks in air traffic management, artificial intelligence technology can be introduced to study the applications of some important operation process such as voice read-back of air traffic controllers. What is more worthy of expectation is that, until the application of future artificial intelligence and other technologies in air traffic management is mature and reliable, we can completely use the robots with the ability of air traffic management, planning, reasoning, and action to complete the air traffic management business. It will bring about tremendous changes in the development of the entire air traffic management.

5 Conclusion

The importance of smart air traffic management for the future development of air traffic management has reached a general consensus. Researches have also been carried out in this field, and rich research results have been obtained. Combining the research results in the field of smart air traffic management at home and abroad, the paper combs the concept and connotation of smart air traffic management and analyzes the application expansion of smart air traffic management for five most important emerging information technologies (cloud computing, big data, artificial intelligence, Internet of

Things, and mobile Internet). And the development trend and priority of future research on smart air traffic management are discussed in view of the shortcomings of the existing research, which provides a reference for the further research of the subsequent smart air traffic management.

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