

Research of Air Traffic Control Technology on Patent Analysis

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Abstract: With the rapid development of the global civil aviation transportation industry, the role of air traffic control is becoming more and more important in order to effectively prevent the collision between aircraft and aircraft, aircraft and obstacles, and maintain and accelerate the air traffic order. A research method based on patent analysis is proposed to study air traffic control technology to understand the development of air traffic control technology. The development of air traffic control technology is discussed from three angles: global patent application trend, application area and patent master technology composition, the development trend and technology distribution of relevant patent applications is analyzed, and the main development direction of air traffic control technology is investigated. According to the analysis, the technical development trend and characteristics in the field of air traffic control technology in the future can be grasped, and the results can provide reference to the development of air traffic control technology in the future.

1. Introduction

With the rapid development of global economy and science and technology, civil aviation has played an increasingly prominent role in the transportation system, becoming the mode of transportation with the fastest growth rate and the greatest development potential [1, 2]. Statistics show that in terms of the ownership of civil aviation aircraft, by 2017, there were more than 365,000 general aircraft worldwide, an increase of nearly 30% compared with 2010. Within the global air Passenger system, the number of passenger trips reached 4.1 billion in 2017, an increase of 7.1 percent over 2016, and the total number of annual passenger trips is expected to exceed 6.4 billion by 2030, according to current projections [3, 4].

Therefore, in the foreseeable future, the number of global civil aviation aircraft, civil aviation traffic will continue to maintain high growth.

In the face of the growing civil aviation transport industry, in order to effectively prevent collisions between aircraft and aircraft, and between aircraft and obstacles, and maintain and accelerate the air traffic order, the role of air traffic control has become increasingly prominent, and its importance has been increasingly recognized by people. In order to solve air traffic safety, airspace congestion, flight delay and other problems, the introduction of real-time voice and image processing, satellite navigation, database management and other advanced technologies into air traffic control can effectively improve air traffic safety and flow, and relieve the pressure of controllers. These advanced technical means and air traffic management system, while ensuring air traffic safety, will effectively improve air traffic processing efficiency, to minimize delays, to respond to user needs in a timely manner.

In order to more comprehensive understanding of the air traffic control technology development situation, this article through to the air traffic control related patent analysis, research the air traffic control technology development trend and technology distribution, help researchers understand the air traffic control technology development trends, grasp the air traffic control technology development focus and development direction, so as to provide reference for the development of the air traffic control technology.

2. Analysis of Global Patent Application Trends

In order to analyze the application trend of global air traffic control technology, this paper has made statistics on the number of patent applications in the direction of global air traffic control since 1920, and the change trend is shown in Figure 1. As can be seen from Figure 1, before 1988, the number of patent applications related to air traffic control technology was relatively small, with an average annual application of less than 1 item. After 1988, the number of patent applications showed a trend of rapid development. Thus, the analysis of trends in air traffic control patent filings can be divided into two phases, namely the embryonic phase (before 1987) and the rapid development phase (from 1988 to the present).

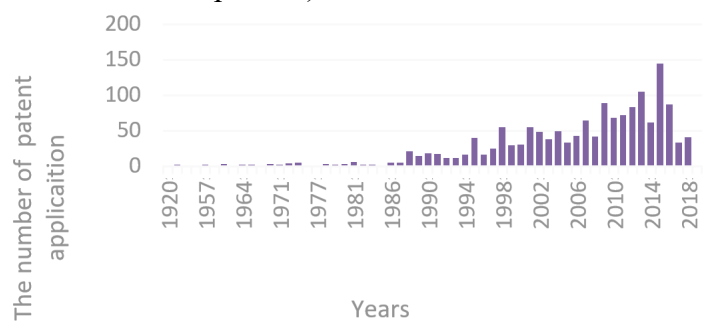


Figure 1 Patent application trends of air traffic control

2.1. The Germination Stage

From the invention of the Wright brothers to the early stage of the development of civil aircraft in 1934, the majority of the aircraft were propeller type, with relatively few Numbers, short flight range and slow speed. At this stage, the aircraft can only operate on a visual basis under good weather conditions, using rivers, lakes, railways and other typical terrain features as landmarks for piloting flights. The characteristics of this phase of flight led to the formation of the International Air Navigation Commission (ICAN) at the Versailles Peace Conference in 1919, which established "general rules" for air traffic. From the 1930s to the mid-1940s, with the emergence and development of radio communication technology, flight gradually developed from visual flight to instrument flight.

In this stage, with the increase of flight flow and flight speed, the air traffic control center, tower, terminal and other organizations appeared one after another. In 1938, the United States enacted the Civil Aviation Act, which provided for a new regulation, the Civil Aviation Ordinance. In November 1941, the CIVIL Aviation Administration of the United States began to coordinate air traffic control operations and set up organizations including air traffic control center and airport traffic control tower. At the same time, the air traffic control department under the Civil Aviation Administration came into being. In April 1947, in order to guarantee the safety and development of International Civil Aviation transport, the International Civil Aviation Organization (ICAO) was established. ICAO is mainly used to coordinate International Civil Aviation relations, solve International Civil Aviation disputes, and formulate relevant International Aviation regulations. With the installation and use of long-range air route radar in 1956, radar display began to be used in the air traffic control system for the dynamic identification of aircraft trajectory. Driven by computer technology, relevant automation equipment began to be introduced into the air traffic ground control system, and the concept of flow control center and terminal area appeared in 1970, which further standardized and refined the responsibility scope of air traffic control work [5].

It can be seen that in the embryonic stage, with the promotion and promotion of radio communication and radar technology, the air traffic control system gradually developed and improved. At this stage, the focus of atC development is to determine the organizational structure of air traffic control, the scope of its responsibilities, the improvement and improvement of relevant regulations, the establishment of air traffic control centers, towers and other infrastructure, etc. Therefore, the number of applications for relevant technology patents at this stage is relatively small, with an average annual application of less than 1 item.

2.2. Rapid Development Period

During the period of rapid development (1988-present), with the rapid development of civil air transport industry, information technology, satellite navigation and computer technology, the technical level of air traffic control has been constantly improved. Air traffic control gradually from is given priority to with people, machines, key monitoring equipment such as radar is used to collect the flight data, automatic processing flight information, generate short-term conflict warning to provide decision-making method using the computer, data acquisition phase of air traffic flow forecast, into ordered by customers and spatial planning, the airspace management, operation airspace capacity evaluation direction [6].

At this stage, with the development of global economy and the progress of science and technology, the research on air traffic control operation and its related technologies has been increasingly enhanced and deepened. In order to cope with the growth of civil air transport, to solve the future air transport security, efficiency problems. In 1983, the International Civil Aviation Organization (ICAO) proposed the use of satellite and digital information to provide communications (C), navigation (N) and surveillance (S) services for aircraft, space and ground facilities, and made the proposal a future navigation systems programme. However, due to the technical conditions at that time, the scheme was not implemented in the actual system.

With the development and maturity of communication, navigation and surveillance technologies, the International Civil Aviation Organization (ICAO) interlinked air traffic management with communication, navigation and surveillance on the basis of the original FANS in 1991, and proposed and adopted the new concept of navigation system of communication, navigation, surveillance/air traffic management system [7, 8]. In order to enhance the influence and competitiveness of European countries in the field of global civil air transport and air traffic control, the Single European Air Traffic Management Research Programme was established in 2004. Based on the operation concept of the planned trajectory, the plan replans the European airspace, utilizes the advanced technical means to effectively integrate the airport and the air traffic control system, improves the efficiency of air traffic control system, reduces flight delay and guarantees the safety of civil aviation system, so as to realize the efficient operation of civil air transportation within Europe [9, 10]. In 2005 the United States launched the next generation air transportation system, the system explicitly specify the target of air transport system, and automatic dependent surveillance, the required navigation performance, wide-area information management system, data communication and other core technology, the related systems and platforms such as infrastructure deployment and development planning, in order to meet the future on the development of the efficiency and security of air transport, maintain its leading position in the global aviation domain [11].

In 2007, China put forward a new generation of civil aviation air traffic management system development overall framework, in order to improve the efficiency and safety of air transport system, enhance the competitiveness of the aviation transport service as the goal, based on the performance of air navigation, based on the data link and accurate positioning of aviation integrated monitoring, air traffic control operation coordination control and the civil aviation air traffic information service platform four directions as the research direction, use advanced technology to change the mode of the domestic air traffic, promoting technological innovation in the field of air traffic, promote and adapt to the needs of the domestic rapid development of civil aviation transportation.

It can be seen that in the stage of rapid development, with the continuous emergence of new technologies, cloud computing, artificial intelligence, big data and other new technologies are constantly integrated with air traffic control technology, and informatization, intelligence and integration gradually become the common goals of the air traffic control industry and technology development of all countries in the world. Therefore, the development and application of new technologies in the field of air traffic control have been strengthened worldwide to achieve efficient and safe operation of the air transport industry. At the same time, patent application and protection can effectively promote the technical development in the field of air traffic control, enhance the

competitiveness of the state and enterprises in the field of air traffic control, and protect the growing awareness of labor achievements [12, 13].

With the development of technology and the promotion of patent protection awareness, the number of patent applications in the field of air traffic control technology has increased significantly. From 1988 to 2018, the number of global air traffic control patent applications totaled 1,458, with an average annual number of 47 applications, including 144 applications in 2015. During this period, the number of global air traffic control patent applications increased exponentially over time. In the next few years, it can be expected that with the development of the civil air transport industry and the global economy, the number of air traffic control patent applications will continue to grow rapidly.

3. Analysis of Geographical Distribution

Figure 2 statistics the output of patented technology of each country or region in the world to understand the investment in air traffic control and technological innovation strength of each country or region. From the analysis results, as the traditional power and region in the field of civil aviation, Europe and the United States in the direction of air traffic management technology patents accounted for nearly 50% of the world's total applications. Among them, the United States ranks the first in the world in the number of patent applications in the field of air traffic management technology, accounting for 36% of the total applications, with a total of 450 applications. Its technical strength and number of patent applications in this field are obviously stronger than those in other countries and regions. Europe also played an important role in the field of air traffic management technology, accounting for 9% of the total number of patent applications, totalling 112 items. As emerging developing countries in the field of air traffic control, air traffic control in the field of development of Japan and China began to gradually developed from the 1950 s, in terms of an application for a patent for the air traffic control technology, China accounts for 30% of the total number, total of 380, Japan accounted for 13% of the total number, total of 134, two emerging countries account for half of an application for a patent for the air traffic control technology.

There are several reasons why the United States, Europe, China and Japan have been able to dominate the field of air traffic management technology

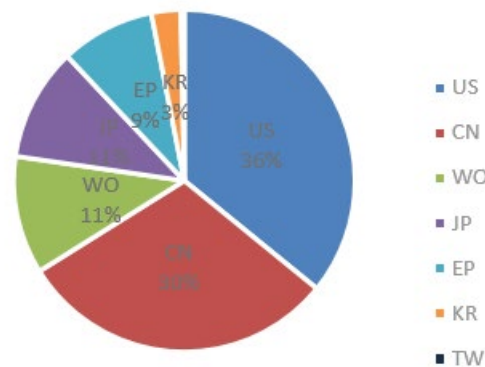


Figure 2 Patents distribution figure about air traffic control in the global regions

3.1. Internal Demands for the Rapid Development of Civil Aviation

Since the early 20th century, the Wright brothers successfully flew the world's first aircraft, opening the door to applied research in the field of general aviation in the United States, and quickly recognized the important role of civil aviation in economic and social development. According to statistics, by 2017, the United States had more than 210,000 general aviation aircraft, accounting for more than 70% of the total number of general aviation aircraft in the world. In the construction of general aviation airports, the United States has more than 20,000 general aviation airports [14]. In the context of the rapid development of the aviation industry, the United States domestic air transport routes, passenger/freight volume, the number of airports are far ahead of other countries and regions.

On the other hand, Europe has the longest history in the field of civil aviation. Long before planes were in widespread use, the German Led Zeppelin founded the world's first civil air transport company in 1909. In the 1960s, in order to reduce research and development costs, improve production efficiency, and form scale effect in the field of civil aviation, European countries established Airbus through cooperative operation. The decision has helped Europe, which in the late 1960s had less than 10% of the global market for international civil aviation, to compete fully with the United States [15].

Although Japan is small in size, its territory is rugged and mountainous, and the distance between its two ends is more than 3,000 kilometers. These geographical conditions provide space for the development of Japan's air transport industry. At the same time, with a large population and poor natural resources, Japan's import and export trade occupies an important position in the economic development. With its advantages of high efficiency and rapid development, air transport in Japan has been able to develop rapidly. Through formulating targeted policies and adopting advanced management methods, Japan supports domestic civil aviation transport industry, which enables domestic aviation enterprises to develop rapidly. Among them, Ana has become one of the world's largest commercial airlines. Tokyo's Haneda Airport ranks among the world's top 10 airports by annual passenger throughput of more than 80 million passengers [16].

In the early years after the founding of the People's Republic of China, air transport in China was very small. According to the statistics in 1950, China's total air transport turnover ranked only 37th in the world. After more than 40 years of reform and opening up, with the sustained and rapid growth of the domestic economy, by 2008, its total transportation turnover reached 37.68 billion ton-km, passenger transportation reached 193 million people, and freight and mail transportation reached 4.077 million tons respectively. Since 2005, China's total air transport turnover has risen to the world's second position, becoming a veritable air transport power. [17]

Driven by the high growth demand of air transportation in the above-mentioned countries and regions, the role of air traffic control in ensuring system safety and improving operation efficiency has become the driving force for it to apply for relevant technology patents actively.

3.2. Policy Drive in the Field of Science and Technology

As the most technologically advanced countries and regions in the world today, in order to seize the commanding heights in the field of science and technology, the United States, Europe, China and Japan all take scientific research as the strategic goal of national sustainable development and continue to improve and invest in scientific research plans and financial investment.

First of all, in terms of scientific research plans, although the US federal government implements a decentralized and flexible management system, it sets and plans the route and goal of national scientific and technological development by formulating targeted science and technology policies. Its typical programs, such as the "two-bomb program", "Apollo", "Star Wars" and so on in the last century, have achieved the desired effect and played a strong role in promoting the development of American science and technology. As the birthplace of modern science, Europe has long played an important role in the process of world scientific research. To guide and coordinate scientific research within Europe through the formulation of strategic development directions for major science and technology. The most typical example is the EU Research Framework program, which started in 1984. It covers almost all research projects in Europe and focuses on cutting-edge science and technology in the world. By integrating europe-wide resources, the programme has improved the efficiency of scientific research and promoted the development of scientific research in Europe. According to its domestic development situation, China has formulated scientific and technological development plans suitable for its own characteristics, centralized allocation of domestic scientific research resources, and constructed a new scientific research system to enhance its scientific and technological competitiveness.

The most important of these is the 863 Project. Biotechnology, space technology, information technology, laser technology, automation technology, energy technology, new materials technology, Marine technology and other high-tech fields of strategic significance are the key development

directions of China's scientific and technological fields, which have promoted and promoted breakthroughs in key scientific and technological fields in China. In order to achieve sustained and rapid economic development after the war, Japan took "saving the country by science and technology" as its national policy and vigorously developed science and technology from various aspects such as scientific research system, financial means and education system.

Secondly, in terms of financial input, the proportion of research expenditure in THE US GDP has been maintained at above 2.5% all the year round, and the research expenditure in recent years has been over 200 billion US dollars for a long time. In its seventh S&T Framework Programme, Europe has invested more than 50 billion euros in areas such as information and communication, new technologies for materials and manufacturing, energy and transportation; in 2017, China's investment in scientific research reached 1.76 trillion yuan, accounting for 2.13% of China's GDP, ranking second in the world. Since the 1960s, the Japanese government has been continuously increasing investment in scientific research funds, which increased from 184.4 billion yen in 1960 to 16.9 trillion yen in 2005, with an increase of 91 times.

With the guarantee of scientific research programs and financial input, the scientific research in the above-mentioned countries and regions has achieved rapid development and taken a leading position in the field of science and technology. Thanks to the progress of science and technology, the air traffic control technology in these countries and regions has been fully developed. Therefore, scientific research programs and financial input lay the foundation for these countries and regions to take the lead in patent applications in the field of air traffic control technology.

When H₂ approaches the critical distance from Pt₅ cluster to chemisorption, the outer electrons of adjacent Pt atoms migrate into the anti-bond orbit of H₂ space, the interaction between H and H decreases, and the H-H bond energy decreases. At the same time, the interaction strength between H and Pt increases, this promotes the dissociation of H₂ on the surface of Pt cluster, which is the intrinsic electronic mechanism by which H₂ can dissociate easily on Pt₅ clusters.

3.3. Gradually Increasing Awareness of Patent Protection

The United States has recognized the importance of patents since its founding. In order to promote the development of science and technology and protect the rights and interests of inventors, the protection of interests has been written into the Constitution.

During its more than 200 years of development, the United States has been able to achieve remarkable achievements in many fields such as economy, science and technology, military and so on. One of the most important factors is its awareness of patent application and protection, as well as its sound intellectual property system.

Similarly, Europe, as the first region to realize the value of patents, is the birthplace of the world's intellectual property protection, and the earliest patent law was born in Europe.

Through relevant patent applications, it encourages European and American enterprises to continuously innovate and develop in the field of air traffic control technology, and promotes enterprises to obtain economic benefits and market share through patents.

China and Japan are also increasingly aware of the huge role patent protection plays in promoting scientific and technological progress and economic development in their scientific and economic development and economic competition.

In the patent protection consciousness gradually enhanced, under the action of the United States, Europe, China and Japan have realized that the patent in scientific research and the role of market competition, to enhance its competitiveness in air traffic control areas, maintain its leading position in the field, these countries and regions we intensified the efforts on the patent application in the field, made these countries and regions in the leading position in the field of patent application within the territory.

4. Composition Analysis of Patented Technology

As shown in Table 1, patent applications in the field of air traffic control technology mainly involve digital signal processing methods related to air traffic control system, radio positioning,

navigation and surveillance, and air traffic control. Among them, the air vehicle traffic control system has the most technical reserves.

Table 1 The main technology distribution table about air traffic control in global region

IPC	CN	US	WIPO	EU	JP	KR	TW
G08G	202	91	49	46	44	15	0
G01S	26	116	29	25	34	5	2
G06F	26	57	12	4	5	4	0
G01C	14	33	6	3	4	0	0
G05D	13	17	7	2	0	0	0
H04B	13	10	5	4	4	0	0
G09B	8	8	5	7	6	0	0
G08B	4	23	4	0	1	0	0
G06Q	21	1	3	0	0	3	0
B64F	1	7	0	0	19	0	0

4.1. Air Traffic Control System

In respect of the air traffic control system for air vehicles, 237 related patent applications were filed, mainly relating to the general technology of the said air traffic control system. In terms of the overall technical direction of air traffic control system, the distribution of global patent applications is shown in Figure 3. As can be seen from Figure 3, patents of the overall technical direction of the global air traffic control system mainly come from China, the United States, the European Union and Japan. Among them, China filed 202 patents in this major technology direction, accounting for about 45% of the global total.

At the same time, it can be seen from the statistical data shown in Table 1 that the patents applied by China in this direction account for 62% of the patents applied in the direction of air traffic control, which is the key direction of technological development in the field of air traffic control in China.

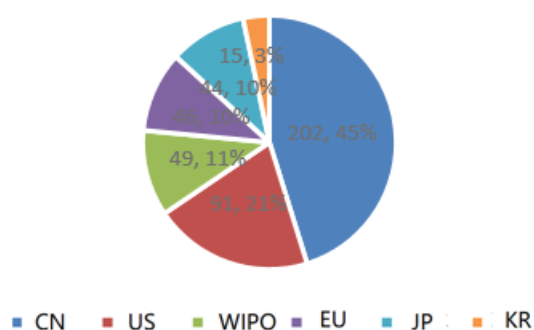


Figure 3 The distribution of air traffic control system in global regions

4.2. Radio Orientation, Navigation and Monitoring

In terms of radio orientation, navigation and surveillance, a total of 237 related patent applications were filed, mainly relating to radar surveillance, target positioning and target tracking in the said air traffic control field. In the direction of tracking, positioning and monitoring technology, the distribution of global patent applications is shown in Figure 4. It can be seen from Figure 4 that the patents of navigation, ranging and positioning technology are still mainly from China, the United States, the European Union and Japan. Among them, the United States filed the most patents in the master technology direction, accounting for 116 patents, accounting for 49% of the global applications of the master technology direction.

At the same time, can be seen from the statistics shown in table 1, with China the focus of the direction of the air traffic control system overall technology is different, the United States apply for patent in tracking, positioning, monitoring the direction of the air traffic control 32% of the patented technology direction, is the focus in the field in the direction of development, Japan, European Union, China in the direction of the technology to apply for patent respectively, 34, 25 and 26, of their own in the direction of the air traffic control technology patent 29% of the total, 28%, 7%.

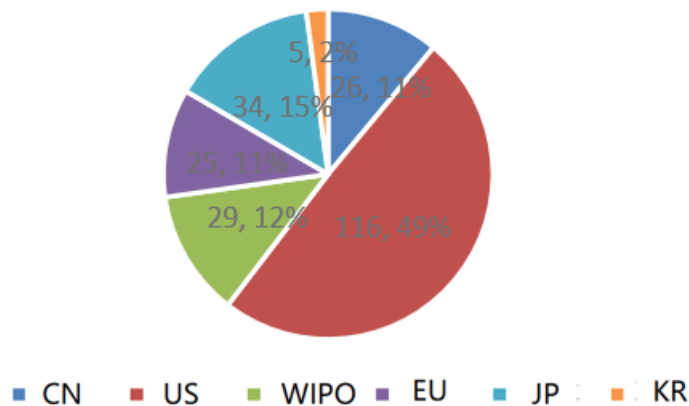


Figure 4 The distribution of direction, navigation and surveillance in global regions

4.3. Digital Signal Processing Method

In terms of the air traffic control digital signal processing method, a total of 108 related patent applications, mainly involving the use of radar simulation training plan, and track data to the controller's workload into prediction, through the data processing method to adjust air traffic flow and the use of computer simulation technology for airspace management and planning, control, traffic control and traffic management decision support in areas such as providing more reasonably and effectively, etc. The main content. In the direction of digital signal processing, the distribution of global patent applications is shown in Figure 5. As can be seen from Figure 5, the NUMBER of patents applied by the United States in this principal technology direction is the largest, reaching 57, accounting for more than half of the global number of applications in this principal technology direction.

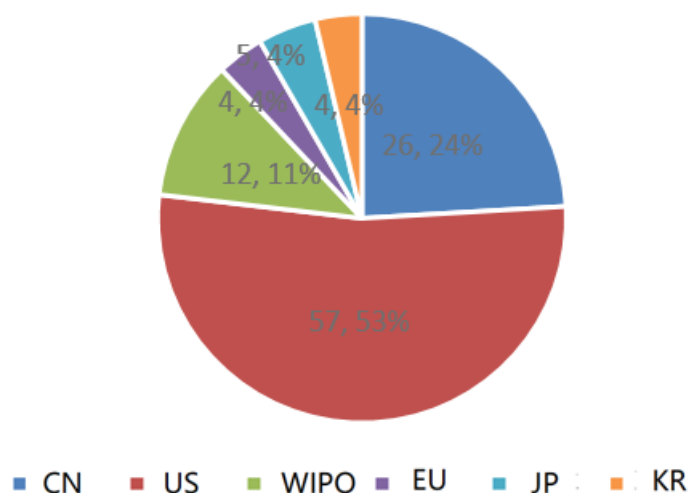


Figure 5 The distribution of digital signal process method in global regions

At the same time, it can be seen from the statistical data shown in Table 1 that the PATENTS applied by the United States in the direction of digital signal processing account for 16% of the patents applied in the direction of air traffic control technology, and the corresponding patents applied by China in the direction of digital signal processing account for 7% of China's patents in

the field of air traffic control technology.

4.4. Other

Other aspects in the field of air traffic control technology, mainly including for air traffic control simulation training and evaluation system, controllers fatigue test method, the controller working load forecasting method, sector performance testing, the aircraft wake separation, the air traffic flow predictive control and the control effectiveness evaluation, and many other aspects. Similar to the main technical directions of air traffic control system, radio positioning, navigation and surveillance, and digital signal processing methods related to air traffic control, the patent applications are still mainly from China, the United States, the European Union, Japan and other countries and regions.

5. Conclusion

Air traffic control plays an important role in preventing collisions between aircraft and obstacles and maintaining and accelerating the orderly flow of air traffic. Air traffic control technology involves the content of the numerous, made up of multiple complex system and tasks, the requirements controllers have to air traffic management information processing, inference and decision-making abilities at the same time, also asked the air traffic control system has the ability of intelligence, automation, for the air traffic control system can collect data from the air condition forecasting, controllers, airspace management, flight state detection and simulated training, and other technology enhances the working efficiency of the control point of view, to ensure the safety of air traffic management system.

This paper analyzes the global patent data of air traffic control technology. The results show that with the rapid development of civil air transportation industry, science and technology and the gradual enhancement of patent protection awareness, the number of patent applications related to air traffic control technology develops exponentially. As air traffic control systems to the development trend of intelligent, automated direction, the United States, China, Europe and Japan and other major countries in relation to the main direction of the air traffic control technology, such as air traffic control system's overall orientation technology, radio, navigation, surveillance, and the air traffic control digital signal processing, etc., increased the technology investment. Through the analysis of global patent data, we can accurately grasp the future development trend and characteristics of air traffic control technology, which has a high reference value and function for the development of relevant technologies in China.

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