



Research on the Global Patent Trend of Artificial Intelligence Medical Device

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Abstract. With the accelerated integration and innovation of artificial intelligence technology in the field of medical devices, medical devices continue to develop in the direction of automation and intelligence, and artificial intelligence medical devices have gradually become an important subdivision of the medical device industry. This paper analyzes the global patent situation of artificial intelligence medical devices, including analysis of patent application trends, patent output countries, patent application countries, main applicants, technology clustering topics, etc., to grasp the development trend of global patent applications and understand the global development trend and research hotspots in the field, so as to provide data support and reference suggestions for the development of artificial intelligence medical devices. This paper finds that the research on artificial intelligence medical devices has passed the germination and slow development period, and has now entered the stage of rapid development; the global patents of artificial intelligence medical devices are mainly concentrated in three areas: medical detection and diagnosis, medical image processing, and medical data processing.

Keywords: Artificial Intelligence · Medical Device · Patent Trend · Patent Analysis

1 Introduction

As an important tool of modern medical treatment, medical devices play an extremely important role in disease prevention, diagnosis and treatment. With the development of social economy and the continuous increase of people's health awareness, the demand for medical machinery is also increasing. In 2020, the global medical device market continues to maintain a steady growth, with the global medical device market scale reaching US\$477.4 billion, which increases by 5.64% year-on-year [1]. With the global outbreak of the COVID-19 epidemic, the demand for monitors, ventilators, infusion pumps and portable color ultrasound and mobile DR (mobile digital X-ray machine) of medical imaging businesses has increased significantly. The number of orders for

medical equipment such as medical protective equipment, nucleic acid detection boxes and ECMO has surged in various countries around the world, the sales price has risen sharply, and some medical equipment continues to be out of stock. It is estimated that the global medical device industry will exceed US\$500 billion in 2021.

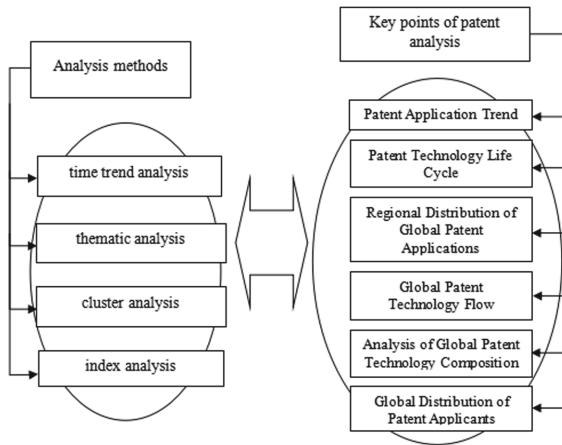
Artificial intelligence (AI) is rapidly becoming a part of our daily life. With the continuous integration and development of artificial intelligence technology in innovative industries, the medical device industry has gradually become a field where artificial intelligence technology is widely used. Artificial intelligence technology has added innovative wings to the industrial development of medical devices. Medical devices continue to develop in the direction of automation and intelligence, so that automatic functions replace manual operations, and machine learning assists or even replaces manual diagnosis. It has brought profound changes to the model of disease diagnosis, treatment and rehabilitation, and has also provided new means for people's health quality. In the current field of medical devices, artificial intelligence is widely used in auxiliary diagnosis, medical imaging, drug mining, intelligent medical robots and health management systems [4]. The field of artificial intelligence medical devices (AIMD) is expected to grow in the coming years as artificial intelligence is implemented in more and more fields of medicine.

Based on the current status of patent applications in the field of artificial intelligence medical devices, this paper compares the domestic and foreign patent distribution trends, and comprehensively uses quantitative and qualitative analysis methods to analyze and study the patent application status, so as to grasp the development trend of patent applications, find out the regional distribution of patent applications, understand the global development trends and research hotspots in this field, and compare and analyze the patent layout of the main applicants, in order to provide data support and reference for the development of artificial intelligence medical devices in our country from the perspective of patent protection.

2 Methodology

The patent database used in this study is the IncoPat technology innovation information platform. The keywords in the field of medical device technology are sorted through the "Medical Device Standard Catalogue" of the State Drug Administration [2], and the IPC classification number is obtained by consulting relevant medical device patent analysis reports or patent research literature [3]. The retrieval method in the field of artificial intelligence technology is obtained based on the WIPO patent analysis report on artificial intelligence "WIPO Technology Trends 2019 Artificial Intelligence" and the methodology of data collection [5]. The deadline for this study to retrieve AIMD patent data is December 31, 2021.

In this study, we use quantitative and qualitative analysis methods, such as time trend analysis, thematic analysis, cluster analysis and index analysis, to mainly analyze and study the application trend, technology life cycle, regional distribution, technology flow, technology composition, and main applicants of the global patents, as shown below.



3 AIMD Patent Analysis

3.1 Global Patent Development Trend

3.1.1 Patent Application Trend

Statistical analysis of global patent applications in the field of artificial intelligence medical device technology for the past 40 years is shown in Fig. 1. It can be seen that the overall situation of global artificial intelligence medical device patent applications can be divided into three stages:

Germination period: From 1981 to 1997, artificial intelligence technology has not penetrated deeply into the field of medical devices, researchers have not yet been widely interested in the research and development of artificial intelligence medical devices, and the number of global patent applications for artificial intelligence medical devices is relatively small.

Slow development period: From 1998 to 2010, although the number of patent applications for artificial intelligence medical devices was still small, the overall application trend was steadily increasing year by year, which shows that with the continuous development and popularization of artificial intelligence technology, more and more researchers are aware of the application of artificial intelligence in the field of medical devices, so the number of patent applications for artificial intelligence medical devices is on the rise.

Rapid development period: From 2011 to 2021, the number of patent applications for artificial intelligence medical devices in this stage is in a rapid increase, indicating that the demand for artificial intelligence medical devices in the market is increasing, and the technology is on the rise. Since not all patent applications of the year 2020 and 2021 have been published, the number of patent applications thereof is given only for reference.

The global patent application trends in the fields of medical devices and artificial intelligence technology for the past 40 years are analyzed respectively, as shown in Fig. 2, so as to compare with the patent application trends of artificial intelligence medical devices. It can be seen that the development of both medical devices and artificial

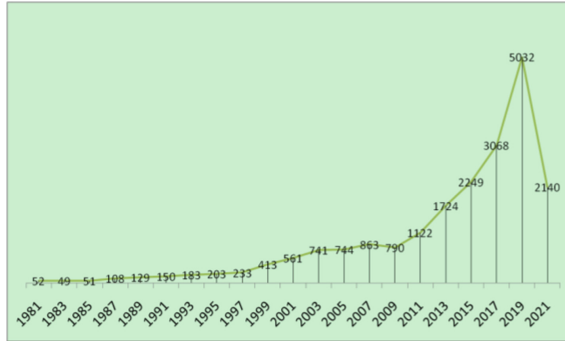


Fig. 1. Global patent application trends for artificial intelligence medical devices.

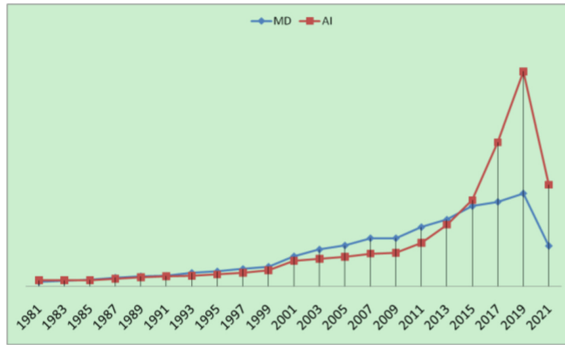


Fig. 2. Global patent application trends for medical devices and artificial intelligence, respectively.

intelligence technology is relatively early and relatively large-scale. In the 1980s, there have been a considerable number of patent applications. Medical devices have ushered in rapid development after 2001, while artificial intelligence technology has experienced two plateau periods from 1981 to 2000 and from 2001 to 2010, and developed rapidly after 2011.

By comparing the global patent application trend of artificial intelligence medical devices with the global patent application trends in the fields of medical devices and artificial intelligence technology, it can be seen that the changing trend of global patents of artificial intelligence medical devices is consistent with the global patent application trend of artificial intelligence technology. As a result, the development of artificial intelligence medical devices depends more on the progress of artificial intelligence technology. With the development and progress of artificial intelligence technology, its penetration and application scenarios in the field of medical devices continue to increase, and artificial intelligence medical devices develop accordingly.

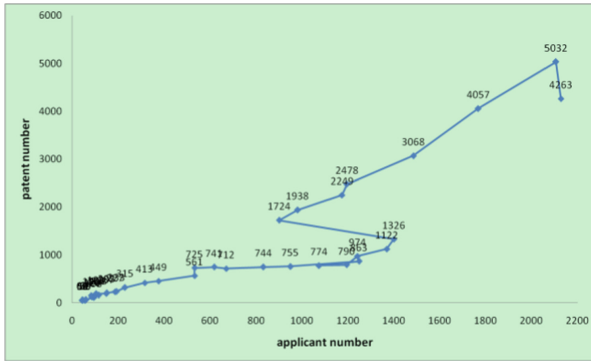


Fig. 3. AIMD patent technology life cycle.

3.1.2 Patent Technology Life Cycle

The patent technology life cycle of artificial intelligence medical devices is analyzed, and Fig. 3 shows the curve of the number of patent applications vs. the number of applicants for global patents of artificial intelligence medical devices for the past 40 years. It can be seen that from 1981 to 2011, the number of applicants for artificial intelligence medical device patents continued to increase, but the number of patents did not increase significantly. From 2012 to 2013, the number of applicants decreased sharply, while the number of patent applications increased significantly, indicating that the industry concentration of artificial intelligence medical devices has been further improved. After 2013, both the number of patent applications and the number of applicants have been increasing over time, indicating that artificial intelligence medical devices are in a period of rapid development and expansion.

3.2 Regional Distribution of Global Patent Applications

3.2.1 Technology Source Country/Region

As shown in Fig. 4, according to the analysis of the main application countries (technology source countries) of global patents for artificial intelligence medical devices, it can be seen that the technology sources of global patent applications for artificial intelligence medical devices are mainly the United States, China, Japan, Germany and the Netherlands. Specifically, the United States has 12,688 patent applications for artificial intelligence medical devices, ranking first in the world in the number of applications, accounting for 30.91% of the total global patents for artificial intelligence medical devices; followed by China, Japan and Germany, with a proportion of 25.59%, 16.97% and 7.58% in the total applications respectively.

The international scale index of the main application countries for artificial intelligence medical device patents is analyzed, as shown in Fig. 5. The international scale index refers to the difference in the number of global patent applications and patents after the merger of the same family, which can reflect the global technology layout. International scale index = the number of global patent applications/the number of patents after the merger of the same family, the larger the index, the better, and the minimum value

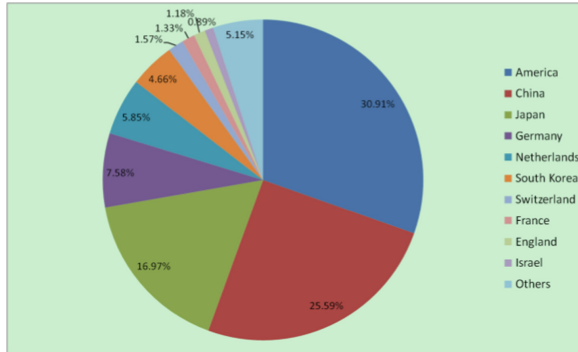


Fig. 4. Source countries/regions of global AIMD patents.

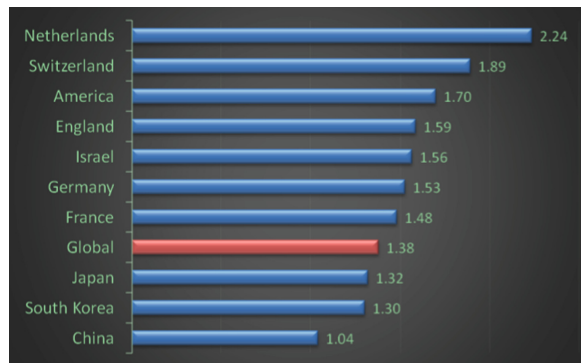


Fig. 5. The international scale index of AIMD patents for the main application countries.

is 1. While the number of global patent applications is large and the international scale index is large, it indicates that the scale of the patent family is relatively large, the share of the global market is larger, and the global distribution is extensive [6]. The family merger adopted in this work is the DocDB family merger in the Incopat database.

As can be seen, the international scale index of the global artificial intelligence medical device technology field is 1.39. Among the world's major patent application countries, the international scale index of the Netherlands, Switzerland, the United States, the United Kingdom, Israel, Germany and France is higher than the global level, while Japan, South Korea and China's international size index is lower than the global level. The number of global patent applications for artificial intelligence medical devices in China is 10,505, ranking second in the world, but the international scale index of China's artificial intelligence medical device field is only 1.04, indicating that China's patent family in the field of artificial intelligence medical devices is relatively small, and the market share is not large.

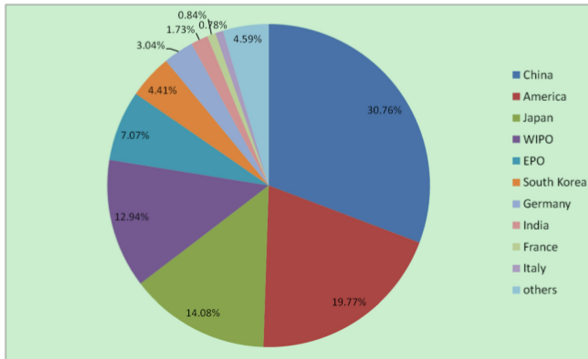


Fig. 6. Target countries/regions of global AIMD patents.

3.2.2 Technology Target Country/Region

The layout of patents in different countries or regions (technology target countries/regions) shows that the applicant attaches great importance to the potential application market in the country or region. The number of patent applications measures the market attractiveness of the country or region, and also reflects the country's encouragement and emphasis on innovation. The cost of the applicant's patent layout in other countries or regions will be higher, so most of the patents are of high quality, which also reflects the applicant's innovation ability and competitiveness in this field.

Figure 6 shows the disclosure of global patents for artificial intelligence medical devices by country. It can be seen that the technology target countries/regions are mainly China, the United States, Japan, the World Intellectual Property Organization (WIPO) and the European Patent Office (EPO). China is the largest technology target country, accounting for 30.76%, followed by the United States, Japan, WIPO and EPO, accounting for 19.77%, 14.08%, 12.94% and 7.07% respectively. This shows that in the field of artificial intelligence medical device technology, the countries and regions where applicants want to apply for patent protection are mainly China, the United States, Japan and Europe.

3.3 Global Patent Technology Flow

In order to more clearly show the technology flow of major countries/regions in the field of artificial intelligence medical devices, the relevant data of these countries/regions were analyzed to obtain the patent application flow relationship between the major countries/regions, as shown in Table 1. The table shows the distribution of patent applications of the main technology source countries/regions in the main technology target countries/regions.

It can be seen that each major technology source country first attaches great importance to patent protection in its own market. The United States attaches the most importance to the patent layout in the global market, and is the largest country in exporting technology, followed by Japan, with a significant number of patent layouts in China, the United States, WIPO and EPO. In addition to the European market, Germany and

Table 1. Technology flow of AIMD patents in major countries/regions.

| source | target | | | | |
|-------------|--------|---------|-------|------|------|
| | China | America | Japan | WIPO | EPO |
| America | 920 | 4873 | 1366 | 2500 | 1063 |
| China | 9899 | 145 | 62 | 325 | 26 |
| Japan | 598 | 909 | 4038 | 713 | 389 |
| Germany | 854 | 719 | 126 | 476 | 413 |
| Netherlands | 486 | 504 | 5 | 666 | 581 |

Table 2. IPC technology composition for AIMD global patents (Top 5).

| IPC | meaning | Patent number |
|------|---|---------------|
| A61B | diagnosis; surgery; identification | 25493 |
| G06T | general image data processing or generation | 5821 |
| G06F | electrical digital data processing | 4987 |
| G16H | healthcare informatics, i.e. information and communication technologies specifically designed to handle or process medical or health data | 4939 |
| A61M | devices for introducing media into or onto the human body; devices for transferring human media or for removing media from the human body; devices for inducing or ending sleep or coma | 3317 |

the Netherlands pay more attention to the patent layout in the Chinese and American markets. Although China is the second largest technology source country for artificial intelligence medical device patents, it is the least compared to other major technology source countries in terms of distribution to other countries/regions. The number of patents filed by China in other countries is almost negligible compared to the number of patents filed in China itself. It shows that compared with the United States, Japan, Germany and the Netherlands, China's technology export to overseas is far behind, and the overseas patent layout is relatively weak.

3.4 Analysis of Global Patent Technology Composition

The technology compositions of global patents for artificial intelligence medical devices are analyzed, through which the technology categories covered and the innovation heat of each technology branch are revealed. Table 2 shows the number distribution of global patents for artificial intelligence medical devices in various technology directions (by IPC category, small group).

Combining with the results from patent sand table analysis, it can be concluded that the research and patent layout of artificial intelligence medical devices are currently

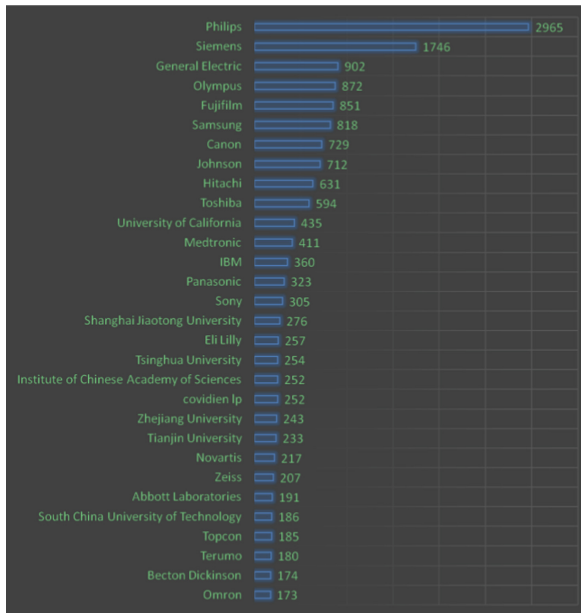


Fig. 7. Top 30 applicants for AIMD global patents.

mainly concentrated in three sub-fields: detection and diagnosis, medical imaging and image processing, and medical information/data processing.

3.5 Global Distribution of Patent Applicants

The main applicants of global patents for artificial intelligence medical devices are analyzed. Figure 7 shows the ranking of the top 30 applicants of patent applications, and Table 3 provides statistics on the countries to which they belong and the numbers of patents they apply.

As can be seen from Fig. 7 and Table 3, among the top 30 applicants, institutions from Japan and the United States occupied the most seats, with 10 and 9, respectively, and their total patent applications reached 4,843 and 3,694 respectively. There are 6 institutions in China, ranking third. Judging from the average number of applications in the countries where the top 30 applicants belong, although there are only one or two institutions for Germany, the Netherlands and South Korea among the top 30 applicants in the world, their average number of patents is higher than that of other countries, indicating that Germany, the Netherlands and South Korea have formed an oligopoly pattern in the field of artificial intelligence medical devices in their own countries, while Japan and the United States have formed a relatively good competition landscape. It is worth mentioning that although 6 institutions of the top 30 applicants are from China, these 6 institutions are all universities and scientific research institutions.

The technology compositions of the patents applied by the main global patent applicants in the main technical target countries/regions are analyzed to understand the technology layout direction of the main patent applicants. Through 3D patent sand table

Table 3. The distribution of the top 30 applicants.

| the country of the applicant | the number of institutions | total number of patent applications | average number of applications |
|------------------------------|----------------------------|-------------------------------------|--------------------------------|
| Japan | 10 | 4843 | 484 |
| America | 9 | 3694 | 410 |
| China | 6 | 1444 | 241 |
| Germany | 2 | 1953 | 977 |
| Netherlands | 1 | 2965 | 2965 |
| South Korea | 1 | 818 | 818 |
| Switzerland | 1 | 217 | 217 |

analysis of patent applications of the top 30 applicants in the main technical target countries/regions, it can be seen that the layout of the main global patent applicants in the field of artificial intelligence medical devices is also mainly concentrated in medical imaging, the processing of medical parameters, data, signals and related medical systems, the detection, diagnosis and treatment of patients and biomarkers.

4 Conclusions

From the perspective of global patent application trends, the research on artificial intelligence medical devices has passed the germination period and the slow development period. At present, the number of patent applications in the field of artificial intelligence medical devices is in a stage of rapid growth in both the number of applicants and the number of applications, indicating that with the continuous development of artificial intelligence technology, its penetration and application in the field of medical devices has become more and more extensive, thus driving the development of artificial intelligence medical device technology.

From the perspective of geographical distribution of patents, China, the United States, Japan, Germany, the Netherlands and South Korea are the main patent application countries in the field of artificial intelligence medical device technology, while China, the United States, Japan and Europe are the main patent distribution countries or regions.

From the perspective of international patent protection, the United States and Japan attach the most importance to patent protection in important international markets such as China, the United States, Japan and Europe, while Germany and the Netherlands pay more attention to the Chinese and American markets as well as the European market. Although China ranks second in the number of global patent applications, the number of patent layouts in other countries/regions is relatively small, and international patent protection needs to be strengthened.

From the perspective of patent technology composition, artificial intelligence medical device patents are mainly concentrated in three sub-fields: the application of artificial intelligence technology in detection, diagnosis and surgical treatment; use of artificial

intelligence technology in medical imaging and medical image processing; use of artificial intelligence technology related methods or systems for medical data, signal, and information processing.

From the perspective of the main applicants of global patents, the main applicants in the United States, Japan, Germany, the Netherlands, and South Korea are mostly enterprises. Among them, the patent applications for artificial intelligence medical devices in Germany, the Netherlands and South Korea are mainly concentrated in 1 or 2 enterprises, forming an oligopolistic competition pattern, while the artificial intelligence medical device patents in the United States and Japan are scattered among 9 to 10 main applicants, forming a relatively good competition pattern; in contrast, the main applicants in China are universities or scientific research. Therefore, China needs to strengthen communication and cooperation between enterprises and universities and research institutes, so as to promote the market transformation of artificial intelligence medical devices.

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