

Research on the Technological Innovation Ability of the Global Autonomous Vehicle Industry

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Abstract—As a breakthrough to lead industrial transformation, upgrading and optimization, the emergence of autonomous vehicle provides a safer, energy-saving, environmentally friendly and convenient way to travel, which helps reduce the burden of drivers and the risk of accidents. This study uses technology patent data of the autonomous vehicle industry from 2006 to 2020 to analyze the technological innovation capability of the global autonomous vehicle industry from a patent perspective, and concludes that: all national enterprises join the cross-border innovation cooperation of the global autonomous vehicle industry, and the overall quality and value of innovation are high.

Keywords— Autonomous Vehicle; Industrial technology innovation; Innovation ability

I. INTRODUCTION

Under the background of a new round of scientific and technological revolution, major developed countries in the world, such as the United States, Europe and other regions, attach great importance to the autonomous vehicle industry, think that this industry is the main strategic highland of the future automobile industry competition, and have issued relevant policies and regulations to support it [1]. In 2020, the United States issued the "Ensure the Leadership of American autonomous vehicle Technology", and the National Development and Reform Commission and the Ministry of Industry and Information Technology of China jointly issued the "Smart Vehicle Innovation and Development Strategy" to jointly promote the industrialization process. In this context, this study uses the technical patent data of the autonomous vehicle industry from 2006 to 2020 to analyze the technological innovation capability of the global autonomous vehicle industry from the perspective of patents. This study is of great significance for the improvement of the technological innovation capability of the global autonomous vehicle industry.

II. REVIEW OF RELATED STUDIES

A. Related research on industrial technology innovation ability

Freeman (1997) put forward the theory of industrial innovation for the first time, and systematically discussed the technological innovation from the perspective of industrial development, and analyzed the trend of industrial innovation and the generating power of [2]. Porter (2002) discusses it from the perspective of the competitiveness of technological innovation. Chinese scholar Wu Youjun (2004) [3] proposed to evaluate the six factors of industrial technology innovation ability, and pointed out the impact of the measurement level and combination of these six factors on the innovation ability. Li Yan (2019) [4] proposed that industrial technology innovation should be led by core enterprises, with other enterprises participating together, and the comprehensive use of various innovation means. However, the development of the autonomous vehicle industry cannot be separated from the

cross-border cooperation and industrial integration among multiple industries. The span of this emerging industry is more complex, and the cooperation between technological innovation is particularly important.

B. Related research on technological innovation of autonomous automobile industry

Most of the existing literature expounds the operability of [5] of autonomous driving technology from an engineering perspective, and then there are very few problems and solutions about the innovation of autonomous vehicle technology. Dong Yang et al. (2018) [6] proposed the need to continuously improve the ability of independent research and development and cooperative development through the cooperation of industry-university-research institutes, so as to establish the industrial chain of technological innovation ability. Xiaomiong Wang (2019) through the analysis of automobile industry intelligent upgrade environment and foundation, put forward from the policies and regulations, establish industry alliance measures [7], Putz (2019) [8], Lee (2020) and other foreign scholars stressed that autonomous driving industry in the early stage of technology development, should pay more attention to safety responsibility, should use the corresponding laws and regulations and guide the development of the industry [9].

III. ANALYSIS OF THE TECHNOLOGICAL INNOVATION CAPABILITY OF THE GLOBAL AUTONOMOUS AUTOMOBILE INDUSTRY

A. Analysis of the technology innovation trend of the global autonomous vehicle industry

Based on the Incopat patent database, a total of 72,465 technology patents in the global autonomous vehicle industry were identified by using keyword retrieval statements. The above data were further downloaded, cleaned, and analyzed. Figure 1 depicts the annual change in the number of technology patents in the global autonomous driving industry from 2006 to 2020. From the changing trend of patent applications, from 2006-2020, the whole process can be divided into two stages: the first stage is 2006-2015, the number of technology applications is small, technology

innovation is in the bud; the second stage is 2016-2020, the patents, technology innovation is in the growth period. In general, the technological innovation of the global autonomous vehicle industry is becoming more and more diversified, and the innovation capacity is constantly strengthened.

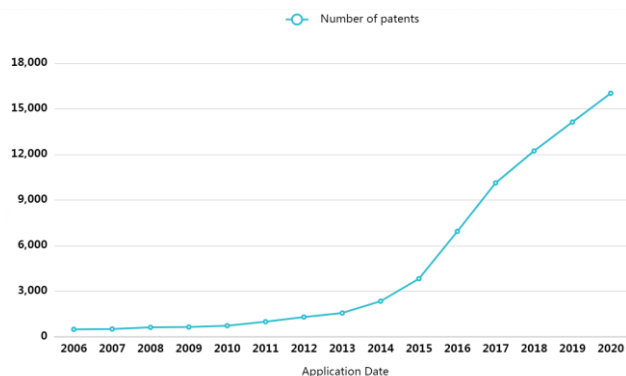


Fig. 1. Patent application trend of technological innovation in the global autonomous vehicle industry

B. Distribution of technology innovation institutions in the global autonomous automobile industry

Through the statistical analysis of patentees for technological innovation in the global autonomous vehicle industry, patentees can be divided into six categories, namely, enterprises, individuals, universities, research institutes, organizations and others (Table 1). Among them, the global autonomous vehicle enterprises technology patent application accounted for 88.69%, indicating that the main body of the global autonomous vehicle technology innovation is the enterprises. Autonomous driving technology innovation in universities accounts for 7.01%, which is an important force of autonomous vehicle technology innovation. There are 2,482 personal patents, accounting for 3.43%, and individuals also contribute to the innovation of autonomous vehicle technology. In addition, the proportion of industry-university-research cooperation patents between research institutes and organizations is very low, less than 1%.

TABLE I. Classification of patentees of global autonomous driving technology

Type of patentee	Number of patent applications / item	proportion /%
enterprise	64272	88.69%
individual	2482	3.43%
colleges and universities	5081	7.01%
graduate school	530	0.73%
Organs and groups	80	0.11%
other	20	0.03%

The global autonomous vehicle technology applicants are ranked by the number of patent applications, and the top 10 are shown in Table 2. Among them, SAMSUNG ELECTRONICS CO LTD and ROBERT BOSCH GMBH have an absolute advantage in their patent applications for autonomous vehicle technology innovation, accounting for 52.14 percent of the top 10 total applications. Number one is SAMSUNG ELECTRONICS CO LTD, which has the most

patent applications in global autonomous vehicle technology innovation. This shows that it is not the traditional car companies that are at the forefront of the autonomous vehicle field. ICT and technology companies occupy a relatively important position, which also proves that the emerging field of autonomous driving needs multi-industry integration and diversified development.

TABLE 2. Distribution of Global autonomous driving technology Application Institutions

Ranking	Patent application institution	Application volume / item
1	SAMSUNG ELECTRONICS CO LTD	5045
2	ROBERT BOSCH GMBH	1157
3	WAYMO LLC	814
4	Beijing Baidu Netnews Technology Co., LTD	776
5	Samsung Electronics Corporation, Inc	753
6	HONDA MOTOR CO LTD	750
7	BAIDU USA LLC	704
8	Huawei Technologies Co., Ltd	647
9	VALEO SCHALTER UND SENSOREN GMBH	639
10	AUDI AG	610

C. Technology identification of the global autonomous vehicle industry

According to the quantity distribution of autonomous driving in various technology directions displayed in the Incopat patent database, it can clearly analyze the technology categories covered by autonomous driving. Table 3 presents the top 10 technical categories classified by IPC classification. As can be seen from the IPC classification of the autonomous vehicle industry, the development of this emerging industry is closely related to automotive, communications, sensors, radar, and other technologies. The above results show that in the development of autonomous vehicle technology, two different development routes are formed: one is directly cross-border technology enterprises and start-ups. They cross the low level of autonomous vehicle and point to L4 and L5 level autonomous vehicle. They focus on the landing of technical solutions, regardless of the cost. The other is the traditional car companies, which seek cooperation with other industries while developing their own development, and gradually grow to the autonomous vehicle level on the original basis. The two models have different starting points, but they have the same mission and goals. They both need to integrate multiple technologies and multiple fields to achieve industrial cooperation.

TABLE 3. Global application fields of autonomous driving technology

Ranking	IPC Classification Number (Major Category)	Patent number
1	B60 (General Vehicle)	28248
2	G05 (Control; Regulation)	15259
3	G06 (calculation; calculation or count)	12390
4	G01 (Measurement; Test)	11175
5	H04 (electric communication technology)	10969
6	G08 (Signal Unit)	10821
7	B62 (B62B Hand 8 V)	4003
8	G07 (accounting unit)	1956
9	A01 (Agriculture; forestry; animal husbandry; hunting; trapping; fishing)	1264
10	B64 (Aircraft; aviation; navigation)	1254

D. Analysis of the active technological innovation in the global autonomous vehicle industry

The technology research and development of autonomous vehicles is highly uncertain and complex, and it is also inseparable from the cross-border cooperation and technological innovation of countries around the world. Figure 2 shows the ranking of patents for global autonomous driving technology in each country. It is not difficult to see that the number of patents in China is 29,919, accounting for the first place, with the highest activity. Although China is not in an important position in the initial period, but the latecomers, Baidu launched a series of Apollo program and other measures, making China at the forefront, by 2020, initially establish an independent research and development system and infrastructure construction system, aiming to complete the system infrastructure construction and make key breakthroughs in core technologies by 2025. The United States and Japan are second only to China in patents, with 12,596 and 3,989, respectively. There is no doubt that autonomous driving has emerged in developed countries such as Europe and the United States, which are also the source of technological innovation and an important target market. India and Russia are also ranked high in their global technological innovation capabilities, and overall, their technological innovation capabilities and influence are higher than those in other unspecified countries.

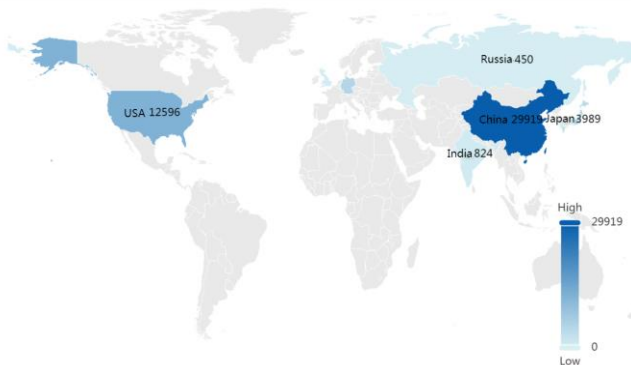


Fig. 2 Global regional ranking of autonomous driving technology innovation capability

E. Quality analysis of technology innovation in the global autonomous vehicle industry

Further, this paper measures the quality of global autonomous driving technology innovation based on two indicators of patent value and technology advancement in Incopat patent database. Figures 3 and 4 show the quality of technological innovation in the global autonomous vehicle industry. In the radar diagram of FIGS. 3 and 4, the higher the number 1-10 is, the stronger the patent value and technological advancement are. The value of technology patents in the global autonomous vehicle industry is mostly concentrated in 9, indicating that the value of patents is relatively high, and high-value technology innovation accounts for a large proportion, which also proves that the emerging industry of autonomous driving needs multi-technology integration. In addition, looking at the patent advancement of Figure4, the advanced technology

advancement of the global autonomous driving automobile industry is mostly concentrated in 9 and 10, indicating that its overall advanced nature is very high, with more cutting-edge technologies and more high-value technologies.

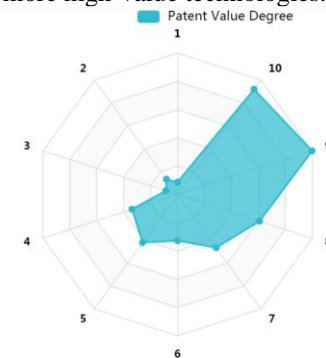


Fig. 3 Patent value of technological innovation in the global autonomous vehicle industry

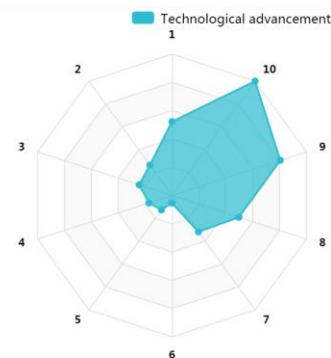


Fig. 4 Advanced nature of technological innovation in the global autonomous automobile industry

IV. CONCLUSIONS AND SUGGESTIONS

A. Main conclusions

Under the background of economic globalization, the technological innovation of the global autonomous vehicle industry is an emerging technology field focused on in the world, and also an inevitable trend of the future development of the automobile industry. It is of great significance to realize the innovation breakthrough in the field of artificial intelligence. Based on the IPC classification, based on 72,465 global autonomous driving technology innovation patent information, this paper makes a systematic and structural analysis of the technological innovation capability of the global autonomous driving vehicle industry. The research results show that: First, the technological innovation of the global autonomous driving industry can be divided into two stages: embryonic stage (2006-2015) and growth stage (2016-2020), and the global autonomous driving vehicle industry technological innovation is in the stage of rapid growth rate. Second, the main body of technological innovation in the global autonomous driving automobile industry is enterprises, indicating that from research and development to put into production, many research and development have been implemented into practical application. The technology has certain research and development capabilities, and most of the technologies can be successfully transferred to enterprises.

Third, from the perspective of the development of subdivided technology categories, the global autonomous driving automobile industry has a wide range of design technologies, and has high requirements in automobile enterprises, communication, control, computing and other fields. Fourth, from the global ranking of the number of patents of autonomous driving technology in various countries, China, the United States and Japan rank among the top in the number of patents, and they are the backbone of the development of autonomous driving. Fifth, from the perspective of innovation quality, the overall value of technology patents in the global autonomous driving automobile industry is still quite high, and it has a strong advanced nature.

B. Policy recommendations

This study was conducted by grooming. According to the results and combined with the industrial development situation, this paper puts forward suggestions to optimize the technological innovation level of autonomous driving automobile industry:

First, form a development strategic consensus at all levels, and improve technical research and design. First of all, the technical design and planning in the field of autonomous driving should be improved, and the direction of future development should be determined. The formulation of future industrial-related policies, the revision of laws and technical standards should be carried out in an orderly manner in accordance with the policy planning to ensure the continuity of the policies. Secondly, we should form the pattern of national standards and group standards go hand in hand, complete the basic platform design required for technological innovation of autonomous driving automobile industry, promote the construction of major platforms such as key engineering laboratories and kechuang center, strengthen the market drive, establish the whole social ecological system, and realize the commercialization of different scenarios.

Second, optimize the financial environment, increase investment in innovation and make breakthroughs in key technologies. Most of the enterprises in the global autonomous driving automobile industry are in the initial stage and growth period, and these enterprises are high-tech enterprises, so they need large capital investment and short financing cycle. Therefore, it is very important to optimize the financial environment and provide a high-quality financing environment for enterprises, so the government needs to provide financial support, loan discount interest and other means to strengthen the support. At the same time, it is difficult to implement the autonomous passenger car scene. All countries need to optimize technological innovation paths, make full use of the development of key technologies such as chips and sensors, challenge cutting-edge technologies, and form core competitiveness.

Third, enhance the industrial cohesion ability and promote the formation and development of industrial alliance. Countries should concentrate their superior resources within their industries to promote industrial technological innovation and boost their development. At the same time, all countries need to establish multi-form and multi-subject industrial alliances led by core enterprises, develop cross-industry

coordination mechanisms, give full play to the different advantages of the government, enterprises and research institutes, break through bottlenecks in key core technologies, and promote the formation of a win-win mechanism of mutually supporting industrial alliances and complementary resources.

Fourth, coordinate the industrial testing and application, and strengthen the mutual connectivity of demonstration bases. The final landing of autonomous driving needs continuous testing and application to test the effect, so as to promote more innovation investment of each subject, and to accelerate the industrialization process. In addition, the testing process should be simplified to facilitate enterprises to carry out road testing, reduce the burden on enterprises, and enhance the interconnection and interconnection between the testing sites, so as to help the regional communication.

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