



# Multi-Dimensional Thinking on the Development Direction of Intelligent Driving Vehicles in China

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**Abstract.** With the gradual maturity and commercialization of automobile intelligent driving technology, the original value distribution pattern of China's intelligent driving automobile industry chain will be overturned. The policy mix to be improved, the new technology to be continuously iterated, and the business model with the transformation of underlying logic have a great impact on the sound development of this field. Therefore, based on CiteSpace, this paper combs and analyzes 645 Chinese core journal literatures in the field of automotive intelligent driving, reveals the research hotspot and evolution trend in the field of automotive intelligent driving in China, and makes multi-dimensional thinking on the future development direction of this field. The findings are as follows: (1) On the whole, the number of publications on intelligent driving research in China is increasing, and the development potential is huge; (2) There is less cooperation among scholars and research institutions, so inter-organizational cooperation should be strengthened; (3) Domestic research focuses on intelligent driving, driverless driving, artificial intelligence and other aspects. The keywords of vehicle-road collaboration and intelligent vehicle industrialization are the current research hotspots; (4) The end of intelligent driving is not smart cars, but a larger dimension of smart transportation, smart city.

**Keywords:** Bibliometric analysis; Autonomous driving; Driverless; CiteSpace; Artificial intelligence

## 1 Introduction

With the acceleration of the deep integration of automobiles with the new generation of communication technology, artificial intelligence, the Internet and other industries, the automotive industry is undergoing the most profound transformation in a century. Autonomous vehicles are the breakthrough of technological change and transformation and upgrading of the automotive industry, and have become the inevitable choice to promote the transformation and upgrading of the manufacturing industry in the new era and build an automobile power. Countries around the world are focusing on the field of intelligent driving vehicles to seize the commanding heights of future strategies.

China attaches great importance to autonomous vehicles at the strategic level. From "Made in China 2025" to the "14th Five-Year Plan", through the formulation of a series of top-level strategies and supporting policies, vigorously layout the autonomous vehicle industry, and promote the commercialization and standardized development of autonomous vehicles. In May 2015, The State Council issued relevant documents, and the development of intelligent connected vehicles was officially raised to the national strategic height for the first time. In February 2020, the National Development and Reform Commission and 11 other ministries and commissions jointly issued the Intelligent Vehicle Innovation and Development Strategy to accelerate the development of high-level autonomous driving; Starting from 2021, China will enter the "14th Five-Year Plan" stage, where the integration and collaboration of "people, vehicles, roads and clouds" are becoming increasingly important. Pilot and application of autonomous driving, car-road collaboration and other technologies are accelerating<sup>1</sup>. According to incomplete statistics, as of December 31, 2023, more than 80 policies related to the autonomous driving industry have been issued by the national level and local governments to safeguard the development of the autonomous driving industry.

Intelligent driving technology is the use of advanced environmental perception, information interaction, intelligent decision-making, automatic control and other technologies, through the organic integration of transport tools, infrastructure and operation control, to achieve partial or complete automated operation of road traffic, which is a profound change to the traditional transport mode and travel mode. The development of autonomous driving technology cannot be separated from technology iteration and the strengthening of the overall manufacturing capacity of the industry. With the acceleration of a new round of scientific and technological revolution and industrial change, key technologies such as electronic and electrical architecture, core sensors, lidar, and automotive operating systems have made breakthroughs and gradually matured<sup>2</sup>, and intelligent connected vehicles with automatic driving as the core have become the strategic direction of the development of China's automotive industry, and the automatic driving industry has entered a leap-forward development stage, and the development process of the industry has accelerated.

Scholars have carried out a large number of research on automobile autonomous driving technology, mainly involving intelligent network, artificial intelligence, unmanned driving and ethical policies, etc. However, due to the characteristics of decentralized and complex content in the field of automobile autonomous driving<sup>3</sup>. Therefore, there is still room to expand the research on new research hotspots, new research trends and visualization analysis based on co-occurrence map in this field. Based on this, this study visualized and analyzed literature in the field of automotive autonomous driving based on CiteSpace software, conducted knowledge graph analysis on domestic research institutions, core authors, keyword co-occurrence and clustering, hot topic words emergence, etc., so as to explore research hotspots and evolution trends in China's autonomous driving field.

## 2 Data sources and research methods

### 2.1 Data sources

China National Knowledge Network (CNKI) was used as the literature source database, the subject (SU) was used as the search field, AND the search words SU= (autonomous driving OR unmanned driving OR intelligent driving OR artificial intelligence OR car-road collaboration OR intelligent network) AND SU= (automobile) were set. The data sources were selected from Chinese core journals or above, and the time range was not limited. In order to improve the accuracy of the data and the credibility of the research, further manual screening was carried out to eliminate the irrelevant topics, missing fields and repeatedly published literature. Finally, a total of 645 valid literature were obtained. After data conversion, 645 valid sample data were finally obtained.

### 2.2 Research methods

Based on bibliometric analysis, this paper uses CiteSpace 6.1. R6 software to conduct visualization analysis on the retrieved 645 literature data, and draws the knowledge map of co-occurrence, clustering and emergence of author, research institution, research topic and keywords. In addition, a quantitative study is conducted on this field based on the distribution structure, quantitative relationship and change rules of research hotspots in the literature<sup>4</sup>, so as to explore the dynamic and evolving trends of hot spots in the field of automotive autonomous driving, and thus help to predict the changing trends of hot spots in the field of automotive autonomous driving.

## 3 Bibliometric analysis

### 3.1 Time distribution

The annual publication volume of literature is an important index to measure the trend and popularity of a particular research field. **Fig. 1** shows the published literature on autonomous driving research in China from 1992 to 2022. In terms of the overall trend, the research process of automotive autonomous driving in China can be roughly divided into three periods: the embryonic period (1997-2014), the exploratory period (2015-2020), and the rapid development period (2021 to date).

(1) Embryonic stage (1992-2014) : Unmanned driving was first applied in some fixed routes or fixed scenarios such as mines, ports, trunk logistics, and parks. The National Natural Science Foundation of China has held the "Smart Car Future Challenge" since 2009, which has spawned research on autonomous driving technology, while Internet giants have also begun to dabble in the field of driverless driving. The number of literatures produced in this stage is small, and it is in the embryonic stage of scientific research exploration and academic accumulation in this field, but it has ignited the fire of the research on automobile autonomous driving.

(2) Stable development period (2015-2020) :More Internet giants and many startups will flood into the field of automatic driving, and China's automatic driving

will achieve leapfrog development. At the same time, with the support of industrial policies and relevant laws and regulations, the automated driving industry chain has gradually matured. Therefore, from 2015 to 2020, the number of published literatures increased steadily and rapidly.

(3) Rapid development period (from 2021 to the present) : In 2021, domestic departments such as the Ministry of Industry and Information Technology, the Ministry of Transport and the Ministry of Public Security issued policies to escort the development of automatic driving, and called for the coordination of scientific research resources to carry out research on key technologies for the application of automatic driving in the industry. Therefore, the research related to automobile autonomous driving has become a hot topic of continuous attention and discussion in the current academic circle and all walks of life, and the number of documents will increase exponentially in 2021, and gradually mature.

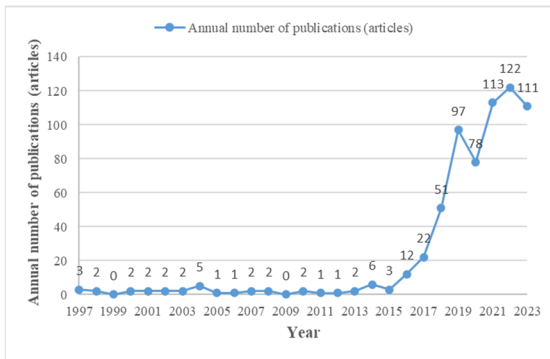


Fig. 1. Statistics of the number of published papers in each year.

### 3.2 Author analysis

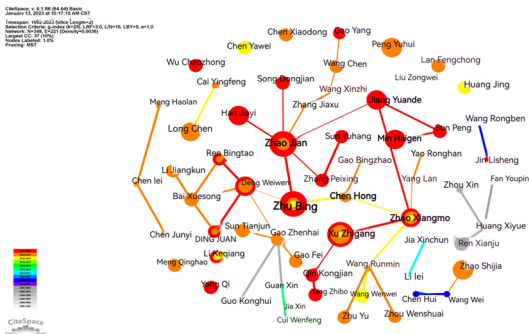


Fig. 2. Atlas of authors of Chinese automotive autonomous driving research literature.

By studying the co-occurrence map of literature authors, we can reveal the research status, the co-authorship and the degree of cooperation in this field. In Fig. 2, a total of

349 network nodes and 221 lines are drawn, among which the number of authors' publications is represented by the size of nodes, and the cooperation intensity between authors is represented by the lines between nodes. The network density of the co-occurrence map of authors in domestic automotive autonomous driving research literature is 0.0038, and the density values of the co-occurrence map are all small. Only the co-occurrence network cluster with Zhu Bing, Zhao Jian, Zhao Xiangmo and Xu Zhigang as the core appears. This indicates that most Chinese scholars engaged in this field are in the state of independent research, the research is relatively scattered, has not formed a stable and very cohesive research group, and the closeness of cooperation between authors still needs to be further strengthened.

According to Price's law, there is a minimum publication requirement for a core author in a certain research field, which is set as  $mp$ .  $mp$  can be calculated by the following formula<sup>5</sup>:

$$mp = 0.749\sqrt{np \max}$$

In the calculation formula,  $np_{\max}$  is the number of published papers of the authors who published the most papers during the statistical period. The sample data is put into the formula to calculate  $mp \approx 2.59$  articles in the domestic automotive autonomous driving research field, which is rounded into 3 articles. Therefore, the number of articles published by core authors in this field should not be less than 3. The results showed that there were 35 core authors and 156 published papers in total, accounting for 24.33% of the total published papers in the field, which was lower than the standard of stable core author group (50%). It indicates that the current research time of automotive autonomous driving in China is short, there are many segmented technology fields and new research directions, and the perspectives of relevant research in China are scattered. With the deepening of relevant research, the research pattern will be further clustered with autonomous driving as the core<sup>6</sup>.

### 3.3 Mechanism analysis

**Fig. 3** shows the cooperative network map of domestic automotive autonomous driving research institutions drawn according to literature data. There are 309 nodes, but only 55 connections, and the network density is 0.0012. The top 10 institutions in terms of publication volume from large to small (including its affiliated secondary colleges, laboratories and research institutes) were Jilin University (43 articles), Chang 'an University (28 articles), Tongji University (27 articles), Tsinghua University (21 articles), Chongqing University (14 articles), Beijing University of Aeronautics and Astronautics (13 articles), Jiangsu University (11 articles) and Hunan University (11 articles), Chinese Academy of Sciences (10 papers), China Automotive Technology and Research Center Co., LTD.

It can be seen that universities, research institutes and large enterprises account for the vast majority of published literature, which indicates that large enterprises and research institutions represented by universities play an important role in the research of automotive autonomous driving. However, the density of institutional cooperation

co-occurrence network is only 0.0012, which indicates that domestic scholars' research on the field of automotive autonomous driving is mostly carried out independently, and the cooperation among institutions is relatively rare.

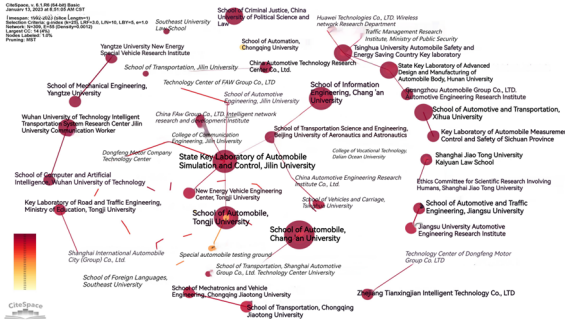


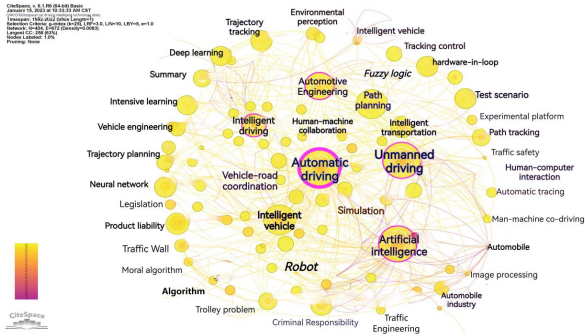
Fig. 3. China Automotive autonomous driving research institute cooperation network.

## 4 Cluster analysis of research hotspots

### 4.1 Keywords co-occurrence network analysis

Keywords are condensed and summarized the overall content of the article. Through the analysis of keywords, we can understand the research hotspots in the field of automotive autonomous driving and the future evolution trend. In CiteSpace, keyword co-occurrence analysis was carried out, and the knowledge map of Chinese auto autonomous driving keyword co-occurrence network was obtained, which included 404 nodes, 672 connections and a network density of 0.0083. Keywords co-occurrence network connection is complex, the degree of co-occurrence is high, and there are more connections between nodes. It can be seen that domestic automotive autonomous driving research hotspot is relatively rich, involving a wide range of technical fields.

Keyword co-occurrence frequency can effectively reflect the research hotspots of this research field. The co-occurrence frequency and centrality obtained by statistical analysis of sample data are shown in Table 1. Among them, centrality is an indicator reflecting the degree of academic attention of a certain keyword, which can be used to judge the importance of a certain keyword in the network. Nodes with centrality greater than 0.1 can be judged as key hubs in the domain.



**Fig. 4.** Chinese auto autonomous driving research literature keywords co-occurrence network.

In addition, it can be seen from **Table 1** and **Fig. 4** that there are more large nodes in the center of the keyword co-occurrence network, and the keywords are closely connected and highly centralized, indicating that the research hotspots of automotive autonomous driving in recent years are concentrated in artificial intelligence, unmanned driving, intelligent driving and other fields. At the same time, it can also be seen that there are many scattered nodes distributed at the edge of the co-occurrence network map, indicating that the intelligent vehicle driving is taking the autonomous driving field as the core and developing to the joint development and system development of different subdivisions and different vertical tracks<sup>7</sup>.

**Table 1.** High frequency keywords in Chinese auto autonomous driving research.

Number	Keyword	Frequency	Centrality
1	Automatic driving	141	0.48
2	Artificial intelligence	62	0.13
3	Automobile engineering	50	0.11
4	Unmanned driving	38	0.14
5	Intelligent vehicle	36	0.09
6	Intelligent driving	18	0.13

## 4.2 Keywords cluster analysis

In CiteSpace, Q values (module values) and S values (average contour values) are commonly used to measure the clarity and confidence of clustering. The knowledge map of keyword clustering network obtained based on sample data is shown in **Fig. 5**. The connection lines between each clustering module and the unrevealed nodes represent the closeness of the correlation between each keyword.  $Q=0.6935$ , greater than the critical value 0.3, indicating that the divided clustering structure is significant, while  $S=0.9062$ , greater than the critical value 0.7. It shows that the clustering results are reasonable.





**Table 2.** The emergence of key words in Chinese auto autonomous driving research.

Keyword	Strength	Begin	End	1997--2023
Intelligent vehicle	2.99	1997	2005	*****----- -----
Simulation	2.52	1997	2000	****----- -----
Pattern recognition	1.92	2000	2006	-----*****----- -----
Predictive control	1.87	2004	2011	-----*****----- -----
Driving technique	1.46	2004	2017	-----*****----- ***-----
Intelligent transportation	1.26	2019	2020	----- -----**-----
Path planning	2.19	2020	2023	----- -----****
Automobile industry	2.04	2020	2023	----- -----****
Vehicle-road collaboration	1.45	2020	2023	----- -----****

Note: "-" indicates the year in which the keyword appears, and "\*" indicates the year of keyword emergence.

## 5 Conclusion and prospect

Based on bibliometrics, this paper uses CiteSpace software to analyze the number of articles published, authors and institutions, co-occurrence, clustering and emergence of keywords in 641 domestic literature in the field of automotive autonomous driving from 1992 to 2022, and draws a visual knowledge map. It intuitively shows the development trend, frontier hot spots and evolution of this field, and provides reference for future scholars involved in this field.

The research results of this paper are as follows:

(1) Development trend: The number of publications related to the field of automotive autonomous driving in China has been on a steady rise in the past 10 years, and the growth rate continues to rise, especially in the past 5 years, showing an explosive growth, indicating that this field is attracting attention and has huge research potential. China has experienced a period of scientific research and exploration, academic accumulation and wave in the field of autonomous driving and is now in a stage of leapfrog development.

(2) Research hotspots: Through keyword co-occurrence and cluster analysis, it can be seen that vehicle-road collaboration, route planning and intelligent vehicle industrialization are the research hotspots in the current stage and even the next stage. Compared with the high technological lead of the United States, China's "cloud + car + road" technological route has the opportunity to overtake on corners. At the same time, in the past two years, China has promulgated a number of policies related to vehi-

cle-road collaboration, intelligent transportation, intelligent network connection and other areas of autonomous driving, accelerating the commercialization process of full-level autonomous driving in China and boosting the development of autonomous vehicle industry from intelligence to network connection.

(3) Cross-organizational cooperation: As can be seen from the joint picture of authors and institutions, universities, scientific research institutions and auto giants play a vital role in the field of autonomous driving, showing strong vitality and promoting the development of this field. However, the existing network structure of authors and institutions is relatively simple, and the degree of cross-organization cooperation is not deep. According to the theory of competition and cooperation, in order to realize leap-forward development of China's research in the field of autonomous driving, various research subjects should strengthen cross-organizational cooperation and build a deeper cooperation network, so as to generate new ideas, form and improve the research framework in this field, and promote the vigorous development of the field of autonomous driving.

(4) Policy empowerment: The automobile industry is accelerating the reform. The era of automobile electrification, networking and intelligent integration has opened. Deepening policy guidance and continuous innovation of application ecology is the only way to promote autonomous driving to a new level. The national and local government departments should continue to introduce policies, regulations and guidelines for autonomous driving, and add both stock policies and incremental policies. At the same time, through the effective combination of policy tools, market driving policies and technology promotion policies can be combined, so as to effectively attract various innovators and organizations to participate in technological innovation activities in the field of autonomous driving, so as to provide policy empowerment for the high-quality development of China's autonomous driving industry<sup>10</sup>.

(5) Future development direction: With the maturity and commercialization of autonomous driving technology, the original value distribution pattern of the automobile industry chain will be overturned. The end game of autonomous driving is not smart cars, but larger dimensions of smart transportation and smart cities. Intelligent vehicles are only a part of intelligent transportation "people, car, road, network", and intelligent transportation is also an organic part of a smart city. Therefore, the research of autonomous driving has just started, and many subdivisions and cross tracks deserve further study.

In addition, the sample data in this study are mainly from the database of China National Knowledge Network, so the accuracy of data and measurement results needs to be further improved. In the future, multiple databases can be selected for analysis, and on this basis, autonomous driving topics or technologies can be further subdivided. More in-depth and specific research can be conducted by subdividing vertical fields and emerging research hotspots, so as to make research conclusions more perfect and credible.

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