CiteSpace-based hotspot study and visualization analysis of automotive steering stability

Chunliang Li [1, a], Zheng Xu [1, b], Xulong Wang [1, *], Yifan Jia [2, c]

[1] Tianjin University of Technology and Education, Tianjin, China

[2] Jiangsu vocational college of electronics and information, Jiangsu, China

* Corresponding Author Email: xulong.wang@tute.edu.cn, [a]3498766415@qq.com, [b]forpal@163.com, [c]1940299003@qq.com

Abstract. With the rapid development of the automobile industry, the research on automobile steering stability has become particularly important. In order to summarize the current research status and development trend of automotive steering stability, this study collects relevant literature from 2001 to 2024 as data samples based on the Web of Science database, visualizes and analyzes the number of articles, countries, institutions, scholars, and keywords, and generates the relevant network maps. It can be seen that the current automotive steering stability research technology field is in a rapid development stage, and the rapid development of autonomous driving technology and new energy vehicles promotes the research of steering stability to be more intelligent and integrated.

Keywords: Steering stability, CiteSpace, bibliometrics, visual analysis.

1. Introduction

Vehicle steering stability refers to the ability of a vehicle to maintain its intended trajectory during driving, especially when turning or changing lanes. This performance mainly depends on the vehicle's suspension system, tire grip, steering system and electronic stability control system and other factors [1]. Good steering stability not only improves driving safety and comfort, but also enhances the driver's confidence in the vehicle's handling and ensures that the vehicle can be driven smoothly and controllably under various road conditions. Reduce the risk of accidents [2]. For the study of automotive steering stability literature research and bibliometric analysis of research is still relatively lacking. Therefore, this paper uses CiteSpace software combined with Excel table to study the relevant literature on automotive steering stability through bibliometric analysis, to explore the research hotspots of automotive steering stability, to keep up with today's research trends, to study the research methodology of automotive steering stability, technical routes and so on to do a large number of literature research, through the literature research, bibliometrics, knowledge mapping and other methods of analysis. The study is analyzed through literature research, bibliometrics, knowledge mapping and other methods. We hope to provide certain reference for future scholars studying this field data sources and research methodology.

1.1. Data sources

In this paper, the academic journals included in the WOS core database were used as the data source. In this paper, we use “automobile steering stability” as the subject term to search academic journals, choose the search time range from 2001 to 2024, and limit the selected journal types to SCI, CPCL, SSCI, etc. We manually filtered the search results, deleted the irrelevant literature such as conference, news, etc. and exported the literature in plain text format. CiteSpace, 470 academic journals were finally identified as the research literature of this paper, and the literature was exported in plain text format.

1.2. Research methodology

In this paper, we use bibliometric method to carry out the research and cluster analysis with the help of CiteSpace software to explore the current research content and research hotspots in the field of automotive steering stability research in-depth. CiteSpace is a scientific bibliometric analysis software

developed by Prof. Chaomei Chen of Drexel University in the U.S.A. It is mainly used to visualize and analyze the knowledge structure in the scientific literature and the dynamic changes [3]. It helps researchers discover research frontiers, hotspots and trends by constructing and analyzing co-citation networks, keyword co-occurrence networks, etc., and supports a variety of functions, such as data import, network construction, clustering analysis and result visualization [4] [5]. In this paper, we used CiteSpace V software, version 6.3R3.

2. Analysis of the number of publications

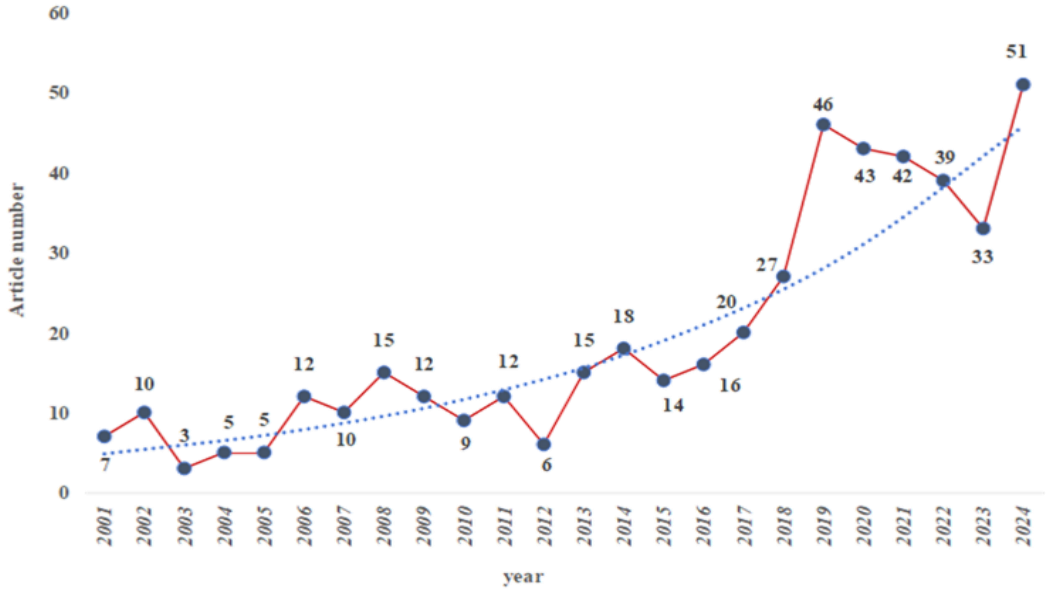

Figure 1. Trends in automotive steering stability publications

Fig 1 is a comparative graph of the number of articles published by scholars studying automotive steering stability between 2001-2024, and this paper chooses to start the statistical analysis from the 21st century. During the period of 2001-2014, the trend of slow growth is maintained, and the number of publications is kept at ten or less. The number of publications between 2014-2019 shows a rapid growth trend, because the rapid development of electric vehicles during this period provides a new platform for studying automotive steering stability. The steep increase in the number of publications on automotive steering stability around 2019 is due to the fact that researchers started to focus on some new steering stability control strategies for distributed drive electric vehicles. Meanwhile the rise of online conferences, seminars, and other formats during the new crown epidemic also facilitated researchers and promoted the output of academic results. A relatively high number of publications is maintained throughout 2019-2024, with the number of publications reaching a peak of 51 in 2024. Overall, it indicates that the research heat and attention of automotive steering stability is increasing.

3. Analysis of cooperation networks

Generally, the simultaneous presence of different authors or institutions in a paper is considered to be a collaborative relationship. Collaboration mapping is used in a visual way to evaluate the academic impact of researchers and research institutions, and to discover their collaborative relationships with each other. In the following, collaboration network mapping is mapped and analyzed at three levels: country, institution and author.

3.1. Country cooperation mapping analysis

Figure 2. Cooperation cluster graph of countries

The 470 articles in the field of automotive steering stability research from 2001 to 2024 were contributed by 33 countries, and the node type of the national collaborative network map was set as "Country", Nodes=33, Links=47. As shown in Fig. 2, the top 5 countries in terms of the number of articles were China (273articles), Korea (62articles), the United States (45articles), Canada (27articles), and Japan (27articles), respectively. of which China accounts for 61%, which is more than all other countries combined, indicating that China's research in the field of automotive steering stability research is more profound and extensive. The top five countries in terms of centrality are China (0.67), the United States (0.37), Japan (0.27), Canada (0.22), and England (0.20). Again, it is China that has the highest centrality, which is more indicative of the importance that China has placed on automotive steering stability research over the years as well as the fact that there is close cooperation with other countries or regions.

3.2. Analysis of cooperation of issuing bodies

Table 1. Institutional Issuance

Institution	Number of papers	Centricity
Tsinghua University	38	0.12
Jilin University	32	0.14
Nanjing University of Aeronautics & Astronautics	26	0.03
Hefei University of Technology	22	0.02
Jiangsu University	16	0.01
Beijing Institute of Technology	15	0.01
Hunan University	15	0.07
University of Waterloo	14	0.08
Shanghai Jiao Tong University	14	0.01

As can be seen from Table I, the highest number of articles among all institutions is Tsinghua University with 38 articles. It accounts for 8% of the total number of publications. Most of the research on automotive steering stability is concentrated in research universities, especially Tsinghua University, Jilin University and Nanjing University of Aeronautics and Astronautics, which are the top three in terms of the number of publications. Tsinghua University's research is mainly focused on the optimization of vehicle dynamic control, active steering technology, and multi-axis control system, while Jilin University is leading the way in optimization of the four-wheel independent steering (4WIS) system and intelligent control methods, and Nanjing University of Aeronautics and Astronautics mainly researches the path of self-driving vehicles. It proves that they have strong scientific strength

and research potential in automotive steering stability. At the same time, these institutions have more cooperation with other institutions, forming are search system and network centered on them, and playing a certain role as a bridge in the cooperation between institutions. On the whole, however, there are still some decentralized research institutions that have formed a number of relatively decentralized sub-networks. At present, however, research institutions are cooperating relatively closely with each other, and the various research institutions and research teams are more united, initially forming a research group with a certain degree of cohesion.

3.3. Analysis of cooperation of issuing bodies

From Fig 3 and Table II, the top five authors in terms of published papers are Zhao, Wan zhong (10 papers), Li, Liang (8 papers), Wang, Xiangyu (6 papers), Wu, Jian (6 papers) and Khajepour, Amir (6 papers). According to Price's law, the authentication formula for core authors is M=0.749 (Nmax)1/2, where Nmax is the number of publications by the author with the highest number of publications, and M is the minimum number of publications by core authors [6].

There is only one author, Zhao, Wan zhong, with more than ten publications, and the M-value is calculated to be 3. Therefore, three or more publications can be certified as core authors. In the field of automotive steering stability, there is a core group of authors and collaborative network formed by Zhao, Wan zhong, Li, Liang, Wang, Xiangyu and Wu, Jian, and several networks around scholars, such as Khajepour, Amirhe, Chen, Long, Zhao, Jing and so on. However, as a whole, some research scholars are still working independently, and cooperation between authors should be strengthened.

Table 2. Top10 Core authors in automotive steering stability

Rank	Author	Number of papers	Year of issue	Rank	Author	Number of papers	Year of issue
1	Zhao, Wanzhong	10	2018	6	Wang, Xiangyu	6	2023
2	Chen, Long	9	2018	7	Chen, Wuwei	6	2006
3	Li, Liang	9	2013	8	Wu, Jian	6	2018
4	Khajepour, Amir	7	2016	9	Ji, Xuewu	6	2016
5	Yim, Seongjin	7	2010	10	Zhao, Jing	5	2020

Figure 3. Research scholar's collaborative network

4. Analysis of Research Hotspots

A research hotspot is one or more topics of common interest to scholars in a certain research field, with strong temporal characteristics. In this study, noun terms and subject terms are used as the source

of hotspot vocabulary, and CiteSpace software is utilized to represent hotspots and developments in automotive steering stability research by identifying high-frequency subject terms.

4.1. Keyword co-linear analysis

The keyword frequency analysis of the literature data based on the WOS database literature was conducted to obtain relevant statistics. A total of 478 keywords were obtained, and the keywords that appear more frequently are shown in Fig 4.

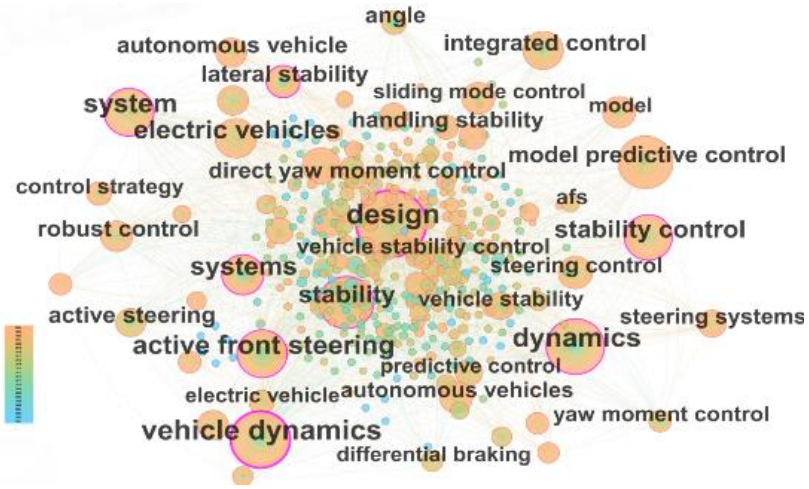

Figure 4. Keyword Common Line Network

After ignoring the basic keywords such as design, dynamics, system, stability, etc. As can be seen from the chart, the keywords with high frequency are model predictive control, active front wheel steering, path tracking, integrated control, sliding mode control and so on. It contains the research content, application scenarios, research methods of automobile steering stability, as well as control strategies to control automobile steering stability. It can be roughly divided into two research focuses: one focuses on the upper-level control strategies to maintain automobile steering stability, such as model predictive control, sliding mode control, integrated control, etc. The other is to study the control system design of automobile steering stability such as active front wheel steering system. The above analysis of the frequency and covariance of the keywords for automotive steering stability can be used as a reference for future research on automotive steering stability.

4.2. Keyword Cluster Analysis

Keyword clustering analysis demonstrates research hotspots and trends by automatically categorizing keywords in the literature based on co-occurrence frequency and semantic relationships. This method helps to reveal the connections between keywords and the interactions and evolutionary paths of different research topics.

On the basis of keyword co-occurrence analysis, keyword clustering analysis is performed on the data obtained from WOS according to the co-occurrence relationship between keywords and their intensity, and the LLR algorithm (log likelihood ratio algorithm) is used for clustering to form 9 effective clustering labels, and the clustering results are displayed visually. As shown in Fig. 5, it can be seen that the nine clustering labels are #0 roll stability, #1 active steering, #2 autonomous vehicle, #3 active front steering, #4 predictive control, #5 electronic stability, #6 active safety, #7 stability criteria, #8 mathematical model. according to the keyword clustering diagram, excluding duplicates and keywords with low relevance, it can be seen that the research mainly focuses on electric vehicles, and the research is on steering roll stability, active steering, active front wheel steering, and judgment of stability criteria, and the research methods are model predictive control, active safety and so on. Summarizing the nine clusters leads to the following trends: deeper development of intelligence and automation, wider application of active control technology, innovation of mathematical modeling and control strategies, strengthening of multidisciplinary cross research, and attention to stability

standardization. These trends reflect that with the continuous progress of technology, especially the development of autonomous driving, electrification and other emerging fields, the research on steering stability is moving towards a more intelligent and systematic direction.

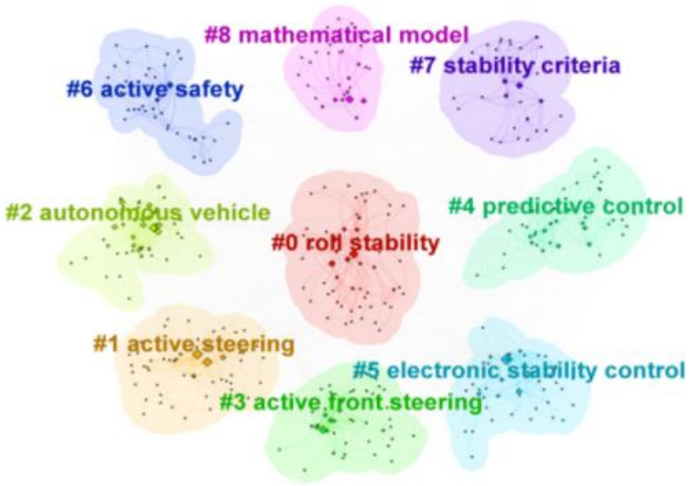

Figure 5. Keyword clustering mapping

4.3. Keyword emergence analysis

Fig 6 shows the distribution of the top 15 keyword emergence intensity, from the figure we can clearly see that from 2007-2024, the hot trend of research on automobile steering stability has been changing, and the recent research hotspot has been long time focusing on the model predictive control and active front-wheel steering system, and the degree of keyword emergence is relatively low before 2007, which indicates that in these years for this field of Around 2018, people began to be keen on researching a variety of advanced control strategies to ensure the steering stability of automobiles. And around 2012, the rapid development of electric vehicles provided a very good research platform for the study of automobile steering stability [7]. The research on steering stability of electric vehicles has also begun to deepen gradually. In recent years, the research on model predictive control[8], pendulum stability control, automatic driving, and phase plane method is also increasing.

Top 15 Keywords with the Strongest Citation Bursts

Keywords	Year	Strength	Begin	End	2001 - 2024
systems	2007	3.15	**2007**	2013	
vehicle	2013	3.54	**2013**	2019	
active front steering	2006	3.52	**2013**	2017	
yaw stability control	2015	3.27	**2015**	2018	
predictive control	2017	3.46	**2017**	2020	
electric vehicles	2012	3.47	**2018**	2019	
road vehicles	2019	3.15	**2019**	2020	
yaw stability	2019	3.11	**2019**	2020	
stability analysis	2018	3.75	**2020**	2021	
path tracking	2019	4.26	**2021**	2024	
stability criteria	2021	3.74	**2021**	2024	
model predictive control	2008	4.53	**2022**	2024	
coordinated control	2018	3.07	**2022**	2024	
phase plane	2022	3.05	**2022**	2024	
of the art	2022	3.05	**2022**	2024	

Figure 6. Keyword Surfacing Map

5. Summary and outlook

5.1. Conclusion

This paper provides an overview of the research dynamics and trends in the field of automotive steering stability by performing a CiteSpace mapping network analysis of the core literature in the field of automotive steering stability in the WOS database for the period from 2001 to 2024. The analysis reveals that automotive steering stability research has been growing year by year since 2013, especially after the research boom in the field of electric vehicles, which has reached a peak of 51 publications in 2024. China is a leader in this field of research, especially Tsinghua University and Jilin University with outstanding contributions. The research hotspots focus on advanced control strategies to enhance steering stability, especially in active front-wheel steering and steering roll stability, and the commonly used control methods include model predictive control and sliding mode control. The research applications mainly focus on the direction of path tracking and coordinated control.

5.2. Outlook

Through the analysis of CiteSpace software on the study of automotive steering stability, we can see that in future research should be appropriate to strengthen the cooperation between institutions, in order to form a close network of research in this field, and at the same time through a large number of analyses we can see that for the improvement of automotive steering stability is mainly to study the optimization of the mechanical structure of the car and the steering stability control strategy is mainly in the subsequent research. In the subsequent research, we can consider optimizing the vehicle dynamics such as and adding advanced driver assistance system to improve the steering stability of the vehicle.

Overall, future research on vehicle steering stability will focus on intelligence and multi-scene adaptability. The research on advanced control strategies such as model predictive control and sliding mode control still has more room for development. Autonomous driving technology will promote the development of active steering and all-wheel control to improve safety under extreme working conditions. The judgment criteria for automobile stability will also develop in the direction of intelligence and multidimensionalization. The use of advanced technologies such as wire-controlled steering and active suspension can greatly improve the stability of automobile steering lateral inclination. At the same time, virtual simulation and big data analysis will accelerate the optimization of the dynamic model, provide a more comprehensive steering performance assessment, and lay the foundation for the future of intelligent Internet and green mobility.

Acknowledgments

This work was supported by the Science and Technology Project of Tianjin under Grant 23KPHDRC00170.

References

[1] Caleffi F, Rodrigues S D L, Stamboroski S D J, et al. Small-scale self-driving cars: A systematic literature review [J]. Journal of Traffic and Transportation Engineering (English Edition), 2024, 11 (02): 271 - 292.

[2] Tang B, Yang Z, Jiang H, et al. Stability-Considered Lane Keeping Control of Commercial Vehicles Based on Improved APF Algorithm [J]. Chinese Journal of Mechanical Engineering, 2024, 37 (01): 127 - 142.

[3] Chen C M. Science Mapping: A Systematic Review of the Liter ature [J]. Journal of Data and Information Science, 2017, 2 (2): 1 - 40.

[4] Liang Y, You J, Wang R, et al. Urban Transportation Data Research Overview: A Bibliometric Analysis Based on CiteSpace [J]. Sustainability, 2024, 16 (22): 9615 - 9615.

[5] Gao J, Li J, Geng Y, et al. Research progress of health education for adolescents based on CiteSpace analysis [J]. Environment, Development and Sustainability, 2024, (prepublish): 1 - 40.

[6] Liang Kaili, Cao Xiaoshu, Huang Xiaoyan. Research progress on bike sharing travel based on CiteSpace [J]. Progress in Geography, 2017, 36 (6): 762 - 733.

[7] Deng J, Ren X, Lin H, et al. Functionally gradient materials for sustainable and high-energy rechargeable lithium batteries: Design principles, progress, and perspectives [J]. Journal of Energy Chemistry, 2024, 99 (12): 426 - 449.

[8] Li Z, Guo Y, Wang G, et al. Level Curve Tracking via Robust RL-Guided Model Predictive Control [J]. IEEE/CAA Journal of Automatica Sinica, 2024, 11 (12): 2512 - 2514.