

Trend Analysis of Construction Methods for Automotive Operational Scenario Libraries based on Patent Analysis

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Abstract

In recent years, the scenario library of vehicle operating conditions is becoming more and more important for vehicle R & D and test. However, it is always an important link to build a scenario library of automobile working conditions, aiming at the problems such as the method of constructing the elements of the scenario library, ensuring the validity of the test scenario, and the methods of testing and evaluation, from the perspective of patent, this paper uses patent analysis method to search the patents in the fields related to the construction of automobile working condition scenario database, and analyzes the patent types, patent technology distribution and patent trends of key applicants, the research trend of the construction method of vehicle working condition scene database is studied. The results show that the future construction of vehicle scenario database will pay more attention to the accumulation of data and the improvement of the diversity of scene elements.

Keywords

Patent Analysis; Vehicle Scenario Library; Scenario Construction.

1. Introduction

In recent years, the Chinese government has attached great importance to the development of the automotive industry [1]. It has formulated a series of relevant policies to promote innovation, research and development, and application in areas such as new energy vehicles and intelligent connected vehicles [2]. Simultaneously, the intelligentization and sustainable development of automotive operational scenarios have become important directions for national scientific and technological innovation. In this context, research on automotive operational scenarios based on patent analysis holds significant practical significance and social value.

In terms of policy support, the government has introduced a series of policies. For example, on November 2, 2020, the General Office of the State Council issued a notice titled "Development Plan for the New Energy Vehicle Industry," which clearly outlined the state's support and encouragement for new energy vehicles and intelligent connected vehicles. On April 28, 2020, the National Development and Reform Commission and other departments jointly issued a notice titled "Measures to Stabilize and Expand Automobile Consumption," which proposed a series of measures to promote automobile consumption, providing guarantee and support for the demand and market of automotive operational scenarios. The introduction of these policies will create a favorable policy environment and market opportunities for technological innovation and marketization of automotive operational scenarios.

Against this background, this paper aims to conduct in-depth research on the technical characteristics, market demands, and future trends of automotive operational scenarios from the perspective of patent analysis. It aims to provide guidance and reference for enterprises

and research institutions, thereby promoting the sustainable development of the automotive industry.

2. Current Research Status at Home and Abroad.

An automotive operational scenario library refers to a collection of data sets used to simulate the driving conditions of vehicles under different road surfaces, weather conditions, and driving styles. It is of great significance for research on vehicle performance evaluation, fuel consumption optimization, and reduction of exhaust emissions.

In China, several automotive operational scenario libraries have been developed. For example, the "China Urban Road Operational Scenario Database" launched by China Automotive Technology and Research Center includes urban road operational scenario data from 26 cities, including Beijing, Shanghai, Guangzhou, and Shenzhen. The "Beijing Metropolitan Area Road Operational Scenario Database" released by Tsinghua University covers driving data from major road sections in Beijing. These databases provide researchers with foundational data support for vehicle performance evaluation and optimization.

Internationally, the European Commission has developed the "Worldwide Harmonized Light Vehicles Test Procedure" (WLTP) with the aim of standardizing emissions and fuel consumption testing globally. Additionally, the United States Environmental Protection Agency has established standardized testing procedures such as the "Federal Test Procedure" (FTP) and the "Highway Fuel Economy Test Procedure" (HWFET) [3]. These procedures serve as guidelines for emissions and fuel economy testing.

Table 1. Statistics of Annual Automotive Patent Publications.

year	Chinese automotive patents		Invention patents		Utility model patents		Design patents	
	Number of publications	Year-on-year growth	Number of publications	Year-on-year growth	Number of publications	Year-on-year growth	Number of publications	Year-on-year growth
2022	362244	12.96%	169693	12.43%	147380	15.77%	45171	6.42%
2021	320679	8.66%	150927	8.01%	127305	6.13%	42447	19.82%
2020	295112	8.08%	139731	6.46%	119956	13.03%	35425	-0.66%
2019	273047	2.94%	131256	1.02%	106132	4.63%	35659	5.25%
2018	265249	11.70%	129931	11.86%	101437	13.53%	33881	5.99%

Overall, automotive-related research has received extensive attention and importance both domestically and internationally. Especially in China, the number of automotive patents has shown a consistent upward trend over the years. According to the statistical results from Table 1 of the Global Automotive Patent Big Data Platform, the quantity of Chinese automotive patents has experienced a noticeable recovery and increase in the past five years. The number of invention patents has consistently been higher than utility model patents and design patents [4]. Moreover, in 2022, the number of invention patent publications witnessed a year-on-year growth of 12.43%, reaching its peak. This trend is also evident in the field of automotive operational scenario libraries, as all 18 relevant patents published in 2022 were invention patents, according to data from CNKI.

In the future, with the development of the automotive industry and the improvement of testing standards, research on the construction of automotive operational scenario libraries will continue to gain attention and evolve towards more refined and high-quality approaches.

3. Patent Analysis of the Current Situation.

3.1. Types of Patent Applications

According to the search query "automotive and scenario library" conducted on China National Knowledge Infrastructure (CNKI), Wanfang Data, and the Global Automotive Patent Big Data Platform AUTO pat, a total of 114 published patents were retrieved from the period of 2016 to May 2023. Based on the constituent elements of automotive operational scenario libraries such as environmental factors, accident cause analysis, traffic environment factors, and data collection of vehicle operating conditions, a selection of 69 patents with high relevance was made. All of these patents are invention patents.

3.2. Distribution of Patent Applicants

Universities and automotive manufacturing companies have shown greater attention and research investment in the field of automotive operational scenario libraries, as shown in Figure 1. Among them, 11% of the applicants are from universities, accounting for 14.5% of the total patent applications, while 17.8% of the applicants are from automotive manufacturing companies, accounting for 20.3% of the total patent applications.

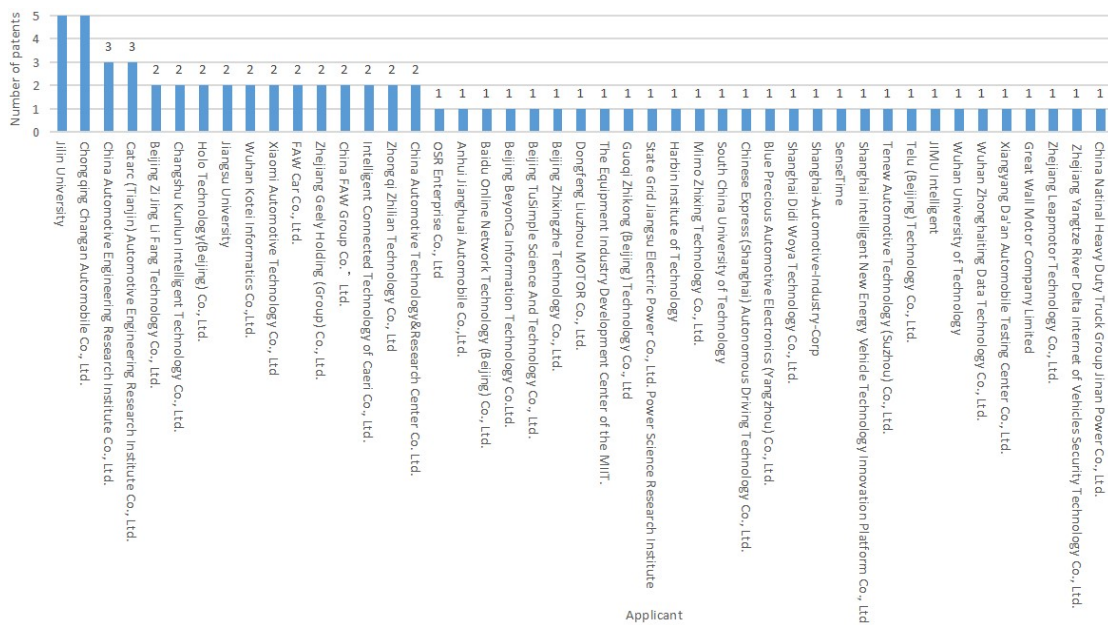


Figure 1. Ranking of Patent Applicants for Automotive Work Cycle Scenario Library from 2016 to May 2023.

3.3. Distribution of Patent Technologies

Automotive operational scenario libraries are important tools for testing and evaluating autonomous driving systems. They provide diverse road conditions, weather scenarios, and other data to help developers better simulate real-world road environments. Therefore, through an analysis of the first-level technical field distribution data of retrieved patents on the Global Automotive Patent Big Data Platform AUTO pat, it can be observed that 75% of the patent technology research trends are focused on "Intelligent Connected Vehicles". Based on the data obtained from the main thematic keywords of patents on CNKI from 2016 to May 2023, as shown in Figure 2, the specific research directions of patents in the field, within the broader research direction of intelligent vehicles, mainly concentrate on "construction methods/ establishment methods," "storage media," "data acquisition and testing," and other aspects. Based on the detailed innovative points and technical content of these patents, the following aspects can be summarized as the main areas of patent research in this field.

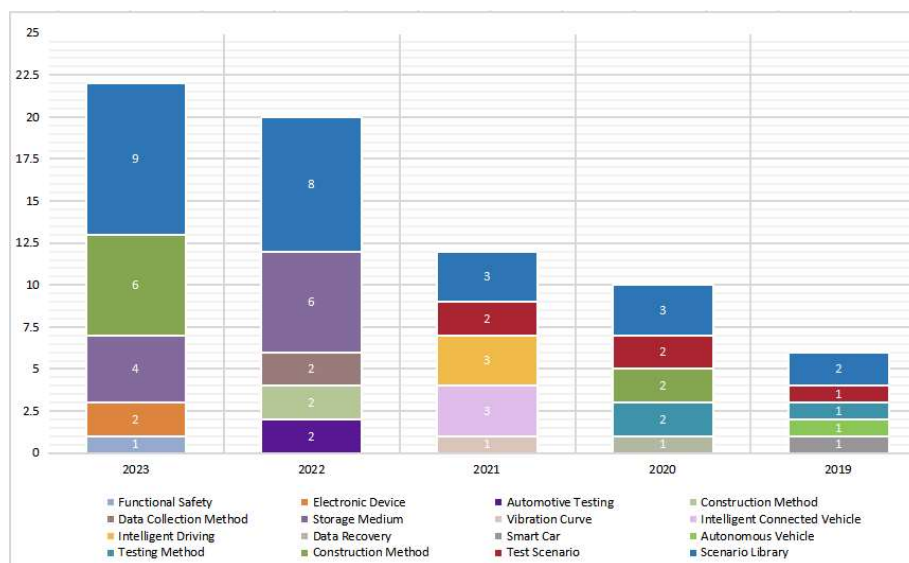


Figure 2. Statistics of the main themes of relevant patents in the automotive operating condition scenario library from May 2016 to May 2023.

3.3.1. Methods for Constructing Automotive Scenario Libraries

In both domestic and international contexts, numerous patent technologies related to the construction of automotive scenario libraries have been developed. These include methods for generating simulated scenarios based on virtual reality technology, methods for collecting real-world scenarios using satellite images, and automated scenario generation methods combining deep learning and other artificial intelligence technologies. In terms of automotive operational scenario construction methods, current patents focus on the construction of scenario library elements. For example, a patent application filed by the Ministry of Industry and Information Technology for the development of equipment industries, titled "Method and Apparatus for Constructing a Scenario Library for Testing Intelligent Connected Vehicles" (CN202211402067.9), extracts scenario elements from direct and indirect driving data to obtain functional scenarios, including design and operational condition elements and behavioral elements. The patent further elaborates that design and operational condition elements include target objects, driver/passenger state information, and host vehicle state information, while behavioral elements include host vehicle initial state information, anticipated host vehicle actions, and target object actions. The method involves parameterizing the elements of the functional scenarios to obtain logical scenarios, validating the validity of the logical scenarios to remove invalid ones, and obtaining updated logical scenarios. Finally, a scenario library for testing intelligent connected vehicles is constructed based on the updated logical scenarios [5].

3.3.2. Testing and Evaluation of Autonomous Driving Systems

Construction of automotive scenario libraries plays a crucial role in the testing and evaluation of autonomous driving systems. Relevant patent technologies primarily include testing methods based on scenario classification, evaluation methods based on simulation platforms, and scenario recommendation methods based on machine learning. For instance, a patent application by Jilin University titled "Method for constructing a test scenario library for autonomous driving vehicles" (CN114818381A) describes a method that involves depicting scenario information, parameterizing key variables of the scenario, extracting raw data for cut-in scenarios, fitting the cut-in scenario data, sampling and generating an initial scenario library using a multi-parameter Gibbs sampling method, designing a scenario risk function, designing a cut-in scenario auxiliary objective function, constructing a surrogate model, searching for key

scenarios using the risk function, assisting the objective function in guiding the search, and generating a test scenario library [6].

3.3.3. Data Sharing and Annotation

In order to promote the development and application of automotive scenario libraries, related patent technologies also involve data sharing and annotation, such as methods for scene data collection, storage, and transmission, and crowd-based scene data annotation methods. For example, the patent "Data collection method, device, equipment, and storage medium" (CN114079665A) filed by Zhejiang Geely Holding Group Co., Ltd., involves obtaining vehicle data collected by onboard sensors and road data collected by roadside sensors during vehicle operation. The vehicle data and road data are synchronized in time and space, and then fused based on high-precision maps to generate target data. The target data is used for scene classification, and scene data corresponding to multiple scenes is obtained. An automatic driving scene library is then constructed based on the scene data [7].

By analyzing the content of the existing 69 invention patents related to automotive scenario libraries, integrating the ideas of automotive scenario library construction methods, and combining the content of the three patent research directions analyzed above, the method for constructing an automotive scenario library can be summarized into 10 steps, as shown in Figure 3, from data acquisition to test case generation.

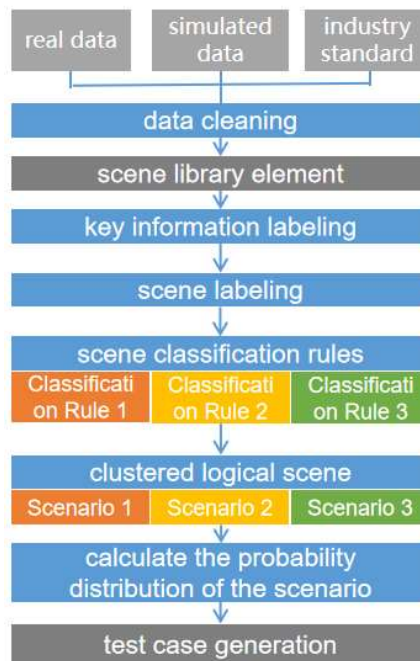


Figure 3. Methodology for building a vehicle operating condition scenario library

3.4. Patent Application Trends for Automotive Scenario Libraries

In terms of the number of patent publications, as shown in Figure 4, the analysis of patent data from the CNKI Patent Search Platform reveals the trends in the number of patent publications in three dimensions: invention patent publications, invention patent grants, and the number of patents related to automotive scenario libraries.

It can be observed that in 2023, both the number of patent publications and patent grants related to relevant inventions are increasing. Particularly, the number of patents related to automotive scenario libraries with "scenario library" as the main theme shows a significant and remarkable upward trend.

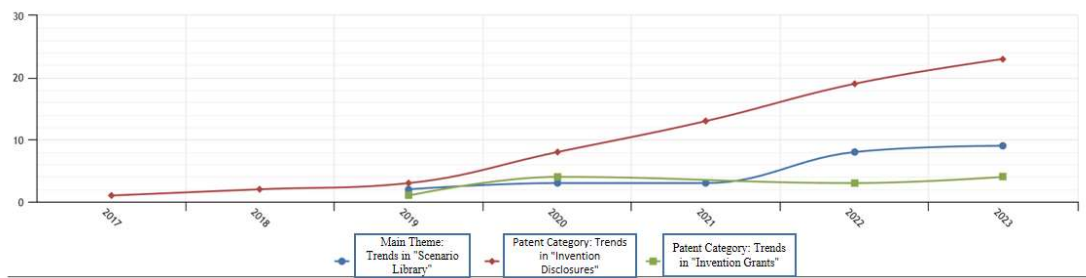


Figure 4. Development Trend of Relevant Patent Quantity.

In terms of patent research content, based on the statistics of secondary, tertiary, and quaternary technical fields of the retrieved patents from the AUTO pat Global Automotive Patent Database, as shown in Figure 5, the current patents have gradually involved hot technology development directions in the automotive industry, such as intelligent connected vehicles, human-machine interaction, and platform technologies. These explored areas offer significant research and development opportunities, indicating the focus on further deepening the research direction of automotive scenario libraries.

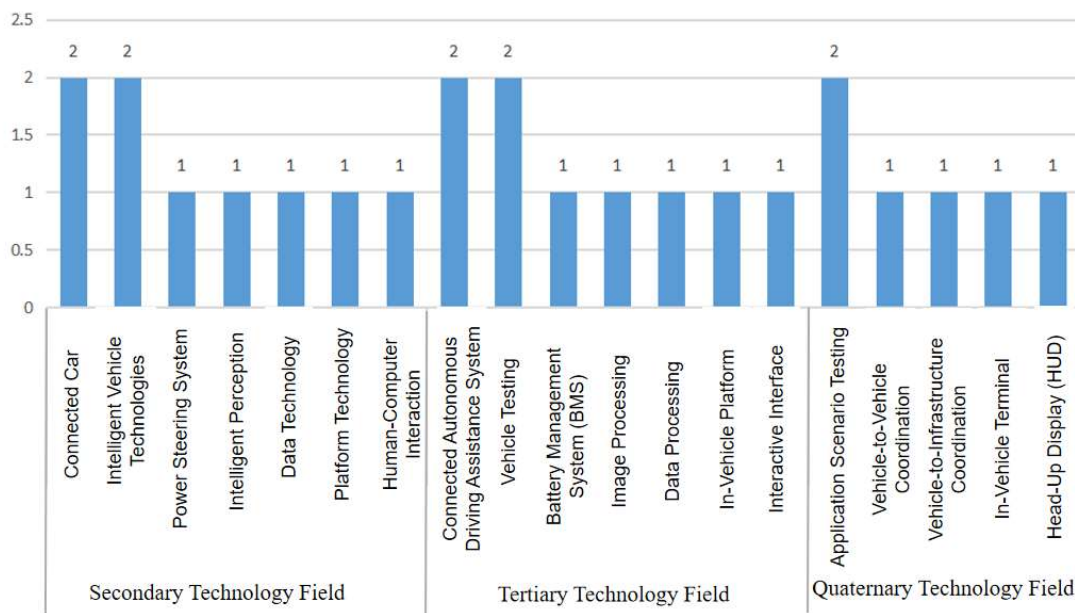


Figure 5. The detailed technical fields of the relevant patents for Automotive Working Condition Scenario Library

4. Conclusion and Outlook

Based on the analysis of existing patents, the research optimization directions for the construction, evaluation, and testing methods of automotive scenario libraries, which have long been a means to deeply explore the operating conditions of automobiles, can be summarized as follows:

- (1) In terms of model accuracy and reliability, as the application scope of automotive scenario libraries continues to expand, there is an increasing demand for higher precision and reliability of the models. Future research should be devoted to further improving the predictive capabilities and reliability of the models to meet the complex and diverse needs of users. In terms of reliability based on patent retrieval results, in addition to collecting real vehicle operation data and road condition information, the utilization of large-scale and real traffic

accident data is rare. Incorporating the collection of traffic accident big data as part of data decision-making can contribute to enhancing the authenticity of predictive results.

(2) In terms of the expansion of scene elements, the automotive scenario library can be applied not only in the automotive manufacturing industry and academic research, but also in other fields such as driver assistance systems and autonomous driving. Therefore, based on the patent retrieval results, it is evident that enriching the diversity of scene elements is an important research focus. Considerations of user behavior and social factors, such as human-machine interaction and accident causation, should also be incorporated into the construction of scene elements to provide more comprehensive and accurate support for applications in intelligent transportation and smart mobility.

(3) In the aspect of data collection and processing techniques, the construction of automotive scenario libraries heavily relies on extensive data collection and processing work. Future research will explore more efficient and accurate data collection and processing techniques. This can include the utilization of multi-modal data collection techniques to incorporate a wider range of sensors, thereby enhancing the comprehensiveness of data collection during vehicle operation, such as monitoring battery conditions and tire conditions. The aim is to optimize the richness, efficiency, and quality of the scenario library, as well as expand its application in areas such as driver assistance systems and connected vehicles.

As automotive scenario library construction techniques and research methods continue to advance, they can provide valuable references and guidance for various stakeholders, including automotive manufacturers and traffic safety, thereby contributing to the overall development of the automotive industry.

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