Research on Autonomous Driving Based on Multi-Sensor Information Fusion Technology

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Abstract: With the continuous development of artificial intelligence, deep learning and sensor technology, autonomous driving based on multi-sensor information fusion technology has become the vital research direction of the automobile industry. This paper analyzes the multi-sensor information fusion technology and introduces the visual sensors and radar sensors commonly used in autonomous driving in detail. This paper concludes that multi-sensor technology has the characteristics and advantages of obtaining information more quickly, high real-time performance and high system robustness. Moreover, this technology effectively improves the shortcomings of traditional single sensors, such as single information acquisition, low accuracy and poor real-time performance, and makes a good foundation for the development of autonomous driving technology. At the same time, many studies have shown that multi-sensor information fusion technology has important significance and far-reaching influence in the three fields of road information perception, automatic parking technology and vehicle safety systems in autonomous driving. However, multi-sensor information fusion technology is a multi-domain, multi-theoretical and interdisciplinary technology, so it is still facing various challenges in applying it to autonomous driving functions.

1 INTRODUCTION

With the rapid development of intelligent vehicles and 5G technology, autonomous driving technology has become the focus of today's automobile industry. Autonomous driving is an advanced auxiliary driving system that can assist or even replace human beings to complete a series of driving behaviors. It includes artificial intelligence, machine vision, automatic control systems and other parts. All parts work together to provide drivers with a more convenient, comfortable and intelligent driving experience. To realize the function of automatic driving, cars often use infrared, cameras and other visual sensors for two-dimensional road information like traffic lights and street pedestrians. Additionally, radar sensors and GPS positioning technology provide information on vehicle speed, distance, and other location information. After processing various types of information, the cars can realize corresponding control. However, the information obtained by a single sensor has the disadvantages of one-sidedness, singleness, inaccuracy, and susceptibility to external interference. For example, radar sensors cannot perceive the color and characteristics of objects such as traffic lights. The camera can distinguish road signs well, but it cannot accurately determine the distance and speed of vehicles, and the camera is susceptible to extreme weather such as heavy fog and lighting (Hao et al. 2022). Thus, multi-sensor information fusion technology has become the key to the research of autonomous driving. By fusing and collaboratively processing the data of different sensors, the drawbacks of a single sensor can be solved and the reliability and accuracy of the autonomous driving system can be promoted significantly.

The development of autonomous driving based on multi-sensor information fusion technology brings many benefits to today's society. For example, self-driving cars use sensors and various algorithms to perceive road condition information, avoid obstacles in time, reduce traffic accidents, and improve driving safety. By sensing and predicting traffic conditions, vehicles can effectively avoid congested roads and optimize traffic efficiency. In addition, vehicles make autonomous decision-making and precise control through real-time perception of the environment, providing more travel choices for vulnerable groups, such as the elderly and the weak. Hu et al. (2021)

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improved the accuracy of the system by integrating radar and visual sensors, while Yang et al. (2019) used multi-sensor information fusion technology to optimize the original lane change warning system. It is evident that the advancement of multi-sensor information fusion technology has a significant effect on autonomous driving.

This paper classifies and introduces the multi-sensor information fusion technology, and reviews several literature, which reflects the research status and significance of multi-sensor information fusion technology in autonomous driving. At last, this paper also puts forward the challenges and development direction of this technology in autonomous driving.

2 CLASSIFICATION AND CHARACTERISTICS OF MULTI-SENSOR INFORMATION FUSION TECHNOLOGY

2.1 Classification of Multi-Sensor Information Fusion Techniques

Multi-sensor information fusion technology fuses the independent observation data of multiple sensors through a series of computer algorithms. It uses multiple sensors to work together to obtain more effective and comprehensive information. Therefore, the system can eliminate the limitation that a single sensor can only obtain part of the object information, and improve the accuracy and intelligence of the whole sensor system (Shuo et al. 2018).

According to the different data processing flows, the information fusion processing structure is divided into three types: distributed, centralized and integrated (Su 2018). The distributed fusion structure means that each sensor uses its own independent data processing system. The central processor receives the outputs of data processing and uses them for fusion processing. All types of initial data gathered by each sensor are transferred directly to the central processing system for fusion processing, which enables real-time processing, according to the centralized fusion structure. The integrated fusion structure integrates the advantages of distributed fusion structure and centralized fusion structure. The integrated fusion structure not only fuses the original data, but also fuses the decisions of each sensor, which enhances the accuracy of the system to some extent. However, the amount of calculation is too large, and the system data transmission capability has higher requirements (Su 2018).

Table 1 shows the performance comparison of the three fusion structures. After comprehensive comparison, it is found that the integrated structure can achieve high reliability of the system while ensuring a certain accuracy, and its fusion control is simpler than that of the distributed structure."

Based on the abstract degree of information processing, multi-sensor information fusion technology is divided into data-level fusion, feature-level fusion, and decision-level fusion (Chen 2016). Data-level fusion is also called pixel-level fusion (Shuo et al. 2018). This method directly fuses the information collected by the sensor, maintains the characteristics and properties of the data to the to the maximum degree, and reduces the data loss, but the data calculation is too large and the real-time performance is poor. The feature level fusion extracts the features of the information provided by each sensor, then fuses these features into a specific feature quantity, and then analyzes and processes them to obtain useful information for the system. Although this method can process the signal quickly, there are problems such as information loss and large information errors (Chen 2016). Decision-level fusion is the highest level of information fusion. After feature-level fusion, it jointly judges and processes the extracted feature quantities. This method has the strengths of high fault tolerance, strong robustness, small calculation workload and high accuracy.

Table 1: The comparison of three structural performance (Shi & Yang 2022).

Structure	Loss of information	accuracy	Communication bandwidth	reliability	Computation speed	Fusion processing
Distributed structure	high	low	small	high	fast	easy
Centralized structure	low	high	big	low	slow	difficult
integrated structure	medium	medium	medium	high	medium	medium

2.2 Advantages of Multi-Sensor Information Fusion Technology

Compared with a single sensor, multi-sensor information fusion technology can identify targets in more complex environments. By fully acquiring and fusing the data information of the target, this technology can reduce the amount of information, thereby significantly improving the efficiency and accuracy of target recognition (Chen 2019). Multi-sensor information fusion technology generally benefits from the following aspects: Firstly, multi-sensors work together to obtain multi-source information, solve the problem of single, one-sided and high uncertainty of information, and greatly increase the credibility of the target system. Secondly, multiple sensors process and analysis the data, so that the system can enhance the system's resolution, fault tolerance and reliability (Shi & Yang 2022). Thirdly, multi-sensor fusion technology uses a series of computer technologies to automatically analyze, optimize and synthesize the collected information in time and space, and obtain a considerable description of the research objectives. What's more it is a data processing method based on multi-sensor, multi-source information is utilized as the processing object, and the core of automatic optimization analysis is achieved through coordinated optimization and comprehensive processing. Ultimately, applying this technology to the automobile system enhances real-time performance, enabling quick and accurate responses to various conditions, thereby improving driving smoothness and operational stability.

3 APPLICATION OF MULTI-SENSOR INFORMATION FUSION TECHNOLOGY IN AUTOMATIC DRIVING

3.1 Commonly Used Sensors for Autonomous Driving

In automatic driving, visual sensors and radar sensors are often fused to obtain accurate body state and road information. This paper will introduce common visual sensors and radar sensors in automatic driving. Common visual sensors include camera sensors and infrared sensors. Among them, the data information generated by the camera is 2D data, and the perception accuracy of the shape and category of the object is high. The disadvantage is that it is greatly affected by external illumination conditions, and it is difficult to apply to all weather conditions. The infrared sensor does not directly contact with the measured object during measurement, so it has the advantages of no friction and fast response. Its disadvantages are insufficient sensitivity, ease to be interference, and difficulty in penetrating the object.

Radar sensors include laser radar, ultrasonic radar, and millimeter wave radar. To use lidar, the process involves transmitting the detection signal to the target and comparing it with the received signal reflected from the target. The target's relevant information can be obtained after proper processing. Ultrasonic radar and millimeter wave radar use the propagation and reflection of ultrasonic waves in the air to obtain information such as examples, characteristics, and speed of the cars. Among them, millimeter wave radar works in the millimeter wave band and can measure farther distances and have stronger anti-interference ability than ultrasonic radar.

3.2 Research and Application of Multi-Sensor Information Fusion Technology in Automatic Driving

Nowadays, with the proliferation of artificial intelligence, deep learning, sensors and other technologies, autonomous driving has been made possible by the use of multi-sensor information fusion technology., and this technology is becoming more and more mature. For example, vehicles rely on multi-sensor information fusion technology to more accurately complete the road information perception function. It can also help cars accurately and quickly complete parking identification and improve automatic parking technology. And in the vehicle safety system, the technology also has a vital role. The following will introduce the application of multi-sensor information fusion technology in these three aspects.

3.2.1 Road Information Perception

Vehicles will encounter various unexpected situations during driving, and excellent road perception ability can help vehicles accurately perceive all kinds of information and detect road environment, then help vehicles realize data analysis, decision control and other functions. To a certain extent, it ensures the efficient operation and real-time performance of the system, improves the optimization

efficiency of road traffic, and reduces the occurrence of traffic accidents.

Hu et al. (2021) proposed a vehicle tracking method on the strength of information fusion of millimeter wave radar and visual sensor, reducing radar position error. The final results indicate that this tracking method can effectively track the vehicle position information and improve the system's accuracy. Wang et al. (2023) constructed a multi-sensor fusion perception system of millimeter wave radar and camera, and proposed a two-level information fusion perception strategy of target decision, then carried out experiments in urban tunnel roads. The experimental results show that the multi-sensor perception information target-decision two-level fusion strategy can meet the reliable perception requirements of unmanned vehicles in the special environment of the tunnel, improve the system accuracy, and make up for the shortcomings of insufficient perception of a single sensor in the tunnel. Wang (2020) fused the millimeter-wave radar with the Leopard Imaging visual sensor to remove the abnormal signal in the data and designed an interpolation time fusion scheme to realize the fusion of radar and visual sensor data in space and time. Finally, the vehicle detection method is used for experimental verification. The results show that the multi-sensor detection algorithm can effectively improve the vehicle detection rate. In conclusion, sensor information fusion technology significantly contributes to road information perception, enhancing the accuracy and reliability of vehicle systems.

3.2.2 Automatic Parking Positioning Function

The automatic parking positioning function in autonomous vehicles generally involves the comprehensive utilization of sensors like cameras and various radars. By using this method, the accurate positioning of obstacles can be realized, and the information perceived by each sensor is combined to solve the problem that a single sensor can only detect the parking space line of the parking space or can only detect the empty parking space formed by vehicles on both sides (Zhang et al. 2023). For example, Yang et al. (2023) used an ultrasonic radar on the side of the car body, and at the same time used a fisheye camera. The radar and the camera worked together to accurately determine and identify the location of obstacles in the parking space. The experimental results show that the multi-sensor information fusion technology can increase the anti-interference of the system and achieve the expected accuracy. Zeng (2020) proposed a new multi-sensor fusion method. This method first fuses the data obtained by ultrasonic sensors, image sensors, and wheel speed sensors to determine the type of parking space to achieve path planning. At the same time, the research team established a fuzzy rule base and used MATLAB / Simulink software to simulate, which proved the feasibility of the method.

3.2.3 Vehicle Safety System

The autonomous vehicle can also combine various sensors that detect the running state of the vehicle body to fuse and correct the data obtained by multiple sensors, which can send out an early warning in time before the vehicle failure and reduce the occurrence of road accidents. Guan jointly calibrated the camera and lidar and fused the two sensor data based on the BP neural network of cumulative error (Guan 2021). The team also improved the observation accuracy of different sensors and realized that the system still has high-quality information perception and decision-making ability in the scene with fewer obstacles, so that the vehicle can complete the lane keeping and obstacle avoidance function in a particular scene. Zhang et al. (2023) proposed a multi-target vehicle tracking algorithm and longitudinal collision avoidance warning strategy based on multi-source sensor data fusion. They combine radar and camera sensors to achieve safe following of multi-target vehicles in dense cluttered environments. Yang et al. (2019) proposed a lane change warning model based on the fusion of lidar, camera, long-range millimeter-wave radar, lateral millimeter-wave radar, differential GPS, and IMU. The team fully considered the decisive factors such as vehicle speed and relative distance in the determination of the acceleration of the model, optimized the original model, and made the multi-sensor fusion lane change warning model more sensitive and efficient.

3.3 Challenges Faced by Multi-Sensor Information Fusion Technology in Autonomous Driving

Although multi-sensor information fusion technology has shown many advantages and has been widely used in autonomous vehicles, there are also some challenges and problems that need to be solved. Here are some of the key issues:

(1) At present, most of the automatic driving technology based on multi-sensor information fusion technology is used in good road conditions, and

extreme conditions and harsh environments are also a huge challenge for automatic driving.

(2) At present, most autonomous driving uses the fusion of two sensors, which can appropriately increase the type and number of sensors to obtain more comprehensive information and improve the accuracy and stability of the system.

(3) The use of multi-sensor information fusion technology will obtain a large amount of data, but the on-board memory is less, and it is difficult to meet the storage and processing calculation of a large amount of data in some specific cases. The data should be optimized as much as possible or the on-board memory should be expanded to meet the technical requirements to obtain more excellent performance of autonomous vehicles.

4 CONCLUSION

With the advance and proliferation of the automobile industry and the era of data, multi-information fusion technology can be applied to various scenarios of autonomous driving, thereby improving the performance of vehicles in all aspects. It can also help the car to obtain more comprehensive, accurate, and rapid information on road conditions and vehicle conditions, and provide a better driving experience for the driver. Especially in the three aspects of road information perception, automatic parking positioning function and vehicle safety system, multi-sensor information fusion technology optimizes the original model and makes the vehicle automatic driving function perform better. However, the theory and method of realizing excellent automatic driving functions are constantly changing, and the automatic driving vehicle relies on the accuracy and speed of obtaining data information to optimize and realize each target instruction. Therefore, appropriately increasing the number of sensors, real-time fusion of acquired data, ensuring the high accuracy of the system and low data loss rate have become the research direction of automatic driving technology in the future. Ensuring optimal performance of intelligent vehicles in harsh environments and enhancing vehicle memory capacity are ongoing challenges for autonomous driving technology.

REFERENCES

F.F.Hao et al., Shanxi Electronic Technology, (03): 93-6 (2022).

Y.P.Hu et al., China Mechanical Engineering, **32**(18): 2181-8(2021).

M.L.Yang et al., Automotive Engineering, **41**(10): 1197-203+227(2019).

S.Shuo et al., Auto Electric Parts, (09): 41-3(2018).

J.P.Su, " Research on the key technology of the multi-sensor information fusion,"MA.Eng thesis, Xidian University, 2018.

X.D.Shi and S.K.Yang, Communication & Information Technology, (06): 34-41 (2022).

Y.C.Chen, The Automotive Semi-active Suspension State Monitoring System,MA.Eng thesis, Xi'an Technological University, 2016.

Z.H.Chen, International Journal of New Developments in Engineering and Society, **3**(5) (2019).

M.S.Wang et al., China Mechanical Engineering 1-13 (2023).

Y.B.Wang, Research on Road Vehicle Recognition Based on Multi-sensor Data Fusion, MA.Eng thesis, Nanjing University of Aeronautics and Astronautics, 2020.

C.T.Zhang et al., Chinese Journal of Automotive Engineering, **13**(05): 603-14 (2023).

Y.F.Yang et al., Proceedings of the Institution of Mechanical Engineers, **237**(5): 1021-46 (2023).

H.J.Zeng, Research on Automatic Parking Control System Based on Multi-Information Fusion, MA.Eng thesis, Xi'An University of science and technology, 2020.

Y.F.Guan, Development of lane keeping and obstacle avoidance system based on multi-sensor information fusion ,MA.Eng thesis, Heilongjiang University, 2021.

J.H.Zhang et al., Journal of Zhejiang University(Engineering Science), **57**(11): 2170-8(2023).