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Application of Intelligent Technology in Automotive Perception Systems

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***Abstract**: With the rapid development of information technology and automation technology, intelligent vehicles have become an important development direction of the automobile industry, and environmental perception technology is one of its core technologies. The intelligent environment perception system can enable the car to perceive, identify and track the environment, objects, creatures, etc., provide safety guidance for drivers, and ultimately reduce the incidence of safety accidents. Intelligent environment perception technology can enable cars to better obtain information about the surrounding environment, and further improve the intelligence and automation level of cars. However, its development and application still face a series of challenges.*
On this basis, this paper introduces the relevant concepts, functions, sensing objects, sensing devices and technologies, analyzes the existing problems of intelligent vehicle environmental perception technology, and discusses the intelligent perception technology and future development direction, in order to provide some reference for relevant researchers and provide assistance for the intelligent development of automobiles.
***Keywords**: Automotive, Environmental Perception, Intelligent Technology, Internet of Vehicles;*

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I. Introduction

Today's world is undergoing major changes unseen in a century, a new round of scientific and technological revolution and industrial transformation is in the ascendant, and intelligent vehicles have become the strategic direction of the development of the global automotive industry. The development of intelligent vehicles can greatly promote the transformation and upgrading of the automobile industry, strengthen the new momentum of economic growth, and its related technological breakthroughs are conducive to enhancing the basic capacity of the industry, enhancing the ability to lead a new round of scientific and technological revolution and industrial transformation, and can accelerate the construction of national strategic planning such as manufacturing power, science and technology power, network power, transportation power, and smart society, which is of great strategic significance for enhancing comprehensive strength. Intelligent vehicles mainly rely on technologies such as artificial intelligence, visual computing, radar, global positioning and networked communication, so that the car has the ability to perceive the environment autonomously, make decisions, plan and control. At present, the most basic but most challenging task facing intelligent vehicles is to perceive the road traffic environment in real time, accurately and robustly. To this end, smart cars are equipped with multi-modal sensors to accurately detect the categories, locations, movement states, and trajectories of various road traffic targets, thereby adding a pair of global eyes to smart cars.

This paper first introduces the relevant concepts and functions, perception objects, sensing devices and technologies, then analyzes the existing problems of intelligent vehicle environment perception technology, and finally discusses the intelligent perception technology and its future development direction.

II. Concept and role

The current smart car refers to the combination of traditional cars with emerging technologies such as the Internet and artificial intelligence to realize intelligent vehicles between vehicles and between vehicles and road infrastructure. Smart cars can obtain more accurate and comprehensive road information through information exchange between vehicles and between vehicles and road infrastructure, helping drivers predict road conditions and avoid potential traffic accidents.

To some extent, the essence of "perception" is to "capture the signal", and then the hidden information in the signal needs to be interpreted. Anyone with a lot of driving experience may encounter a situation where they do not find anything unusual when they check the condition of the car and the surrounding environment before getting into the car, but within a short period of time between entering the car and starting the vehicle,

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there may be an unexpected situation around the vehicle. For example, small cats, dogs, and children will suddenly appear around the vehicle and happen to be in the blind spot of the occupants, which will eventually cause accidents without anyone in the car. As can be seen from similar cases, drivers can suddenly encounter unexpected situations at any stage of driving a vehicle. Based on this, the environment perception system is set up in the car, and the specific environmental signals are captured by a plurality of devices with perception functions, and then the relevant information is displayed in the on-board intelligent control system in advance, which can provide great help to the driver and help reduce the incidence of various malignant accidents during driving.

Contextual awareness technology collects information about the vehicle's surroundings through a variety of sensors, including road conditions, other vehicles, pedestrians, weather conditions, and more. Using a variety of equipment and technologies such as radar and cameras, smart cars can accurately and quickly perceive various complex environments and respond accordingly. By integrating a variety of perception devices and artificial intelligence algorithms, the environmental perception technology is combined with the autonomous driving system to realize the autonomous driving function of the vehicle and improve driving safety and comfort.

III. Primary perceptual object

The automotive environment perception system mainly perceives the following contents.

(1) The driving status of the vehicle. The perception system needs to monitor the state of the driver in the car, and secondly, it needs to perceive the driving status of the vehicle and surrounding vehicles.

(2) Objects around the vehicle. When the vehicle is in the starting state, there should be no object in contact with it within a certain range (including the safety range and blind spot), and any behavior that violates this principle is a potential safety hazard and may cause a vicious accident at any time. Therefore, the vehicle-mounted environment perception system needs to perceive a variety of moving or stationary objects on the ground within a certain range of the vehicle itself, whether there are pedestrians around, and the ground within a certain range that may affect the normal passage of the vehicle and interfere with safe driving. In addition, the perception system also needs to perceive traffic signs and traffic lights while the vehicle is moving.

(3) Roads. The environmental perception system mainly identifies whether the road is a structured road. For structured roads, the main objects of perception are the boundaries of the road and various lane markings, and for unstructured roads, the main objects are the paths that can be used by vehicles to pass normally. At the same time, whether the road is smooth, whether there are defects, whether there is congestion, and the weather conditions along the road at the origin and destination are all important objects within the scope of driving environment perception.

In general, there are many core perception objects of automobiles, mainly vehicles, pedestrians, traffic signs, traffic lights, and lane markings. In the process of perception, the system needs to perceive, identify, track and monitor the movement and stationary state of the vehicle itself, the people in the vehicle and the personnel outside the vehicle. The perception requirements for the driving environment are: to identify static objects and obtain the information in them. After the objects in the moving state are perceived, the moving trajectory and real-time position of these objects need to be tracked, and finally the next position of the objects should be judged in advance, so as to ensure driving safety.

IV. Primary perception devices and technologies

(1) Inertial elements

The inertial elements in the environmental perception system are represented by wheel speed sensors, automotive acceleration sensors, steering wheel sensors, gyroscopes and other components. These sensing devices will transmit relevant information about the vehicle's driving process to the perception system, so as to understand the driving status of the vehicle in real time.

(2) Ultrasonic radar equipment

(i) Performance

The main function of ultrasonic radar is to detect whether there are interferences within a certain range of the rear of the vehicle in the process of reversing. In order for ultrasonic radar to play a long-term sensing role, it must have the following characteristics: First, the frequency of ultrasonic radar should be relatively fixed. As the frequency increases, so does the radar range. Second, the overall structure of ultrasonic radar must be as simple as possible and the volume should be as small as possible. The purpose of this design is to keep the cost of radar as low as possible on the one hand, and to simplify the perception and pre-processing of environmental information during reversing on the other hand, and ultimately improve reliability. Third, the perception sensitivity of ultrasonic radar should be targeted--the sensitivity to temperature, humidity and weather changes in the natural environment should be as low as possible, so as to effectively resist the interference caused by the

natural environment to the perception process;

(ii) Drawbacks

The current stage of vehicle-mounted ultrasonic radar also has some shortcomings: First, the detection range of the radar is very limited. Although from the actual effect, the safety of reversing can be guaranteed to a large extent, but it is impossible to predict the unexpected situation in advance. Second, ultrasonic radar is only suitable for environmental perception during low-speed driving, and once the vehicle speed increases, the perception accuracy will be reduced to a certain extent. This is because the ultrasonic waves emitted by the radar have a certain diffusion angle, which can only perceive and measure the "distance", but cannot effectively measure the direction. Therefore, there are requirements for the driving speed of the vehicle, and in order to ensure the accuracy of perception, multiple ultrasonic radars are installed on the front and rear bumpers of the car. Third, when the car passes through uneven ground, the effectiveness of the radar will be greatly reduced, and it is difficult to detect objects within the monitoring range. It can be seen that in order to improve the environmental perception performance of smart cars, an important way is to improve the performance of radar.

(iii) Principle

In general, the composition of automotive ultrasonic radar for perception consists of an (ultrasonic) transmitter, a (return ultrasound) receiver, and a plug-and-switch switch. The specific configuration is as follows: (1) The transmitter and receiver need to be installed on the same plane. The purpose of this is to ensure that the emitter is capable of emitting ultrasonic waves of a specific frequency and is able to meet the ultrasonic waves reflected back from the detection surface within the effective detection range. (2) the receiver mainly receives the returned ultrasonic wave, and after the information is uploaded to the vehicle-mounted intelligent system, the central processing unit of the system parses the time from ultrasonic emission to the return transmission, and then calculates the distance that the ultrasonic wave travels. (3) The main function of the data line is to transmit the data information obtained by the radar to the control unit of the vehicle-mounted intelligent system.

The specific principle of obstacles within the sensing range of ultrasonic radar is as follows. First, the transmitter will send out ultrasonic pulses; secondly, the ultrasonic waves propagate in the air, and if they touch the surface of the obstacle, they will be reflected immediately; thirdly, the reflected waves will also be transmitted to the receiver through the air; finally, all the parameters generated in the above process will be immediately uploaded to the on-board intelligent system, and the central processing unit will parse the information from the beginning of the ultrasonic pulse to the return reception, and then calculate the actual distance between the ultrasonic radar probe and the obstacle surface according to the speed of the ultrasonic wave in the propagation medium. It should be noted that there is a high probability of difference between the measured distance and the actual distance, which is affected by the volume and height of the obstacle. Specifically, the measurement distance depends on the wavelength and frequency of the ultrasonic waves emitted by the transmitter. At this stage, ultrasonic radar is not effective in detecting objects that are close to the outer surface of the vehicle. Therefore, before starting the vehicle, the driver must check the vehicle for obstacles within a certain area of the front and rear of the vehicle in accordance with the traffic rules.

(3) The application principle of vision sensors

The main function of the vision sensor is to comprehensively process the image information (including static pictures and dynamic videos) captured by the camera, and then detect the target and judge the result after completing the data output. At present, the vision sensors in smart cars and driverless cars are generally installed in the camera, and the built-in artificial intelligence algorithm can greatly improve the efficiency and quality of object detection and image processing.

(i) Functionality

The functions of the vision sensor are mainly focused on the following aspects: First, it can comprehensively identify the distance information between the object and the vehicle in the monitoring field of view, the color information of all objects in the monitoring field of vision, the texture information of the surface of the object, and the shape and depth information of the object. Second, in addition to detecting the physical objects in the monitoring field of vision, it can also identify the road conditions, the distribution of nearby vehicles, whether there are pedestrian approaches, whether there are traffic indication signs, and the information in the signs (including traffic lights). Third, modern powerful vision sensors generally have built-in vision SLAM systems, which can achieve "simultaneous positioning" and "image creation" only through the camera, so as to achieve the purpose of "real-time acquisition of scene information". It should be noted that this kind of "real-time acquisition of scene information" is not based on "prior knowledge", so it has a strong ability to adapt to the environment.

(ii) Principle

Vision sensors mainly include light sources, lenses, image sensors, analog or digital converters, image processors, image memory and other components, and their main function is to obtain sufficient raw images for the vision system to process. The results of physics (optics) research tell us that the representation of things seen by the human visual system is actually the light reflected by the object. Therefore, the vision sensor first simulates the process of seeing objects with human eyes and completes the recognition of basic information of physical objects. The specific process is as follows: (1) After the light source irradiates the physical target, the lens of the vision sensor will record the corresponding information. (2) This information is then transmitted to the image sensor, which in turn forms an analog image signal. (3) The analog image signal is converted into a digital image signal through an analog-to-digital converter. (4) After further processing by the image processor, the image signal is compressed and finally stored in the image memory.

(iii) A monitoring range calibration system for vision sensors

In order for the vision sensor to provide accurate monitoring information for the vehicle driver, the monitoring coordinates of the vision sensor must always remain "relatively stationary" with the vehicle during the monitoring operation, that is, the vehicle is always the coordinate origin, and the vision sensor needs to change with the change of the vehicle's position. Only in this way can the information transmitted to the vehicle by the vision sensor help the driver accurately obtain information about the vehicle's surroundings.

V. Existing problems in automotive environmental perception technology

The environmental perception technology of intelligent vehicles can be divided according to different classification methods, and can generally be classified according to the sensing device, perception object and perception principle. Perception technology can use image processing technology to obtain road information, use sound waves to detect the surrounding environment, and use optical principles to detect the surrounding environment. Visual, sound, radar and other sensors can identify and track vehicles, pedestrians, obstacles, etc. by collecting road image information to provide vehicle location and improve the environmental perception and safety of smart cars. Intelligent transportation and autonomous driving require high-precision and high-reliability environmental perception technology, which can obtain information about surrounding roads, vehicles, pedestrians, etc., optimize traffic flow, and realize traffic monitoring and congestion prediction functions.

Traditional sensing technology is not adaptable to environmental changes, so it cannot process a large amount of data and image information in a short period of time. In the future, smart cars will adopt a combination of multiple perception technologies, such as lidar, camera, millimeter-wave radar, etc., to improve the accuracy and accuracy of environmental perception by integrating multiple perception technologies. However, there are still the following major problems in the current automotive environment perception technology.

(1) Environmental identification is complex

There are many kinds of objects involved in the driving environment of smart cars, and the environment itself is complex and changeable, so environmental perception technology needs to be able to recognize and deal with various situations. However, the recognition rate of existing environment perception technologies may be significantly reduced when dealing with certain uncommon objects or encountering complex environments. Existing algorithms are often ineffective in handling these situations because small animals, complex traffic signs, and roadworks equipment are rarely present in the training data when training the environmental awareness technology of smart cars.

(2) Insufficient data processing capacity

Contextual sensing technology involves the processing of large amounts of sensor data, which requires both powerful computing power and efficient algorithms. However, the current hardware devices and algorithms of smart cars may not be able to meet the needs of real-time and efficient processing of large amounts of data. The research shows that the data processing capacity of current smart cars is sufficient in most cases, but in the case of high-speed driving or complex environments, its processing power may not be able to meet the needs of real-time processing of environmental data, which will produce perceptual delays, which in turn affect the real-time response ability of the car.

(3) There are hidden dangers in security and privacy protection

The environmental perception technology of intelligent vehicles involves the collection and processing of a large amount of data, including vehicle information, driver and passenger information, environmental information, etc., and involves the privacy protection of drivers and passengers. There is no good solution to the

balance between data collection and privacy protection for smart cars. At the same time, the connected nature of smart cars also makes them vulnerable to cyber attacks, so how to prevent malicious attacks and protect the security of smart car systems has become an important issue at present.

(4) There is a problem with perceptual accuracy

In most cases, smart car cameras and radar sensing devices can accurately perceive the environment. However, under extreme environmental conditions, the performance of these devices can be significantly reduced. Relevant studies have shown that in strong light environments, the perception accuracy of smart car cameras will decrease, and in rainy and snowy weather conditions, the accuracy of smart car radars will also decrease. The problem of equipment accuracy degradation in such extreme environments poses a hidden danger to the safe driving of the car. Although researchers have been looking for solutions, such as designing more powerful algorithms and more advanced sensors, these problems have not been completely solved with the current state of the art.

VI. Intelligent perception technology

(1) Machine learning

Smart cars encounter many different objects and environmental situations while driving, so environmental perception technology needs to recognize and process a large amount of data information. Deepening machine learning techniques, using more and richer training data, or conducting large-scale training in simulated environments can improve the ability of environment-aware systems to recognize and process complex environments. Among them, the diversity of training data is the key to improving the performance of environmental perception models, such as data in various scenarios such as urban environments, rural roads, and highways. Collecting and training with data from various scenes and objects can enable the environment perception model to better identify and process the complexity of the actual driving environment. At the same time, environmental perception simulation training is also an effective method. Computer graphics technology can be used to create realistic virtual environments that can simulate a variety of extreme and rare driving situations. By training on a large scale in these simulated environments, environment-aware models can improve their performance in real-world environments and overcome the complexity of environmental recognition.

(2) Distributed processing and edge computing

Intelligent vehicle environment perception technology needs to process massive amounts of data, and the processing power of a single processor is often difficult to handle. In this case, distributed processing and edge computing are a viable solution. Distributed processing is a computing architecture that splits large computing tasks into multiple smaller tasks and processes them in parallel across multiple processors or computing devices. In the environment perception technology of intelligent vehicles, various perception tasks can be assigned to sensors such as cameras and radars. Each of these sensors has its own processor that processes the data it collects. In this way, by distributing the processing load, the overall data processing efficiency of the environment perception technology can be greatly improved. Edge computing is another effective way to process data, which can move data processing tasks to the source of the data as much as possible, that is, to the "edge". In the environmental perception technology of smart cars, edge computing can pre-process and analyze part of the sensor data, so that only the processed important data needs to be sent to the central processing unit, which greatly reduces the burden of data transmission and the processing burden of the central processing unit. In addition, edge computing also contributes to improving the real-time responsiveness of intelligent vehicle systems because it reduces the transmission delay of data. All in all, with distributed processing and edge computing, technicians can process large amounts of environmental perception data more efficiently, improving the environmental awareness and real-time response capabilities of smart cars. At the same time, this approach also helps to reduce energy consumption and improve the operational efficiency of smart cars.

(3) High-performance technology

Data processing capabilities are critical to the environmental perception technology of smart cars. Environmental perception technology involves a large amount of sensor data, so it requires powerful computing power and efficient algorithms. Therefore, in order to improve the data processing capabilities of environmental perception technology, researchers need to improve it from both hardware and software aspects. On the hardware side, more powerful processors and dedicated AI accelerators can be leveraged. For example, processors with better GPU performance have powerful parallel processing capabilities, which are conducive to processing large amounts of sensor data. On the software side, improving and optimizing algorithms is also the key to improving the data processing capabilities of environmental perception technologies. Some deep learning models require significant computational resources due to their complexity. In this regard, some optimization

techniques, such as model compression and pruning algorithms, can greatly reduce the complexity of the model. Model compression techniques can meet the computational requirements by reducing the number of model parameters or reducing the accuracy of parameters, and will not significantly reduce the performance of the model. Therefore, improving processor performance, optimization algorithms, and deep learning models will help improve the data processing capability of environmental perception technology and the environmental perception ability of intelligent vehicles.

(4) Privacy protection technology

For the environment perception technology of smart cars, how to protect the user's data security and privacy while ensuring its functionality is an important issue. This involves two levels: one is that the intelligent car system itself needs to be protected from malicious attacks, and the other is the protection of data privacy to prevent the leakage of user data. Among them, the safety protection of intelligent vehicle systems is the foundation. With the development of intelligent and networked automobiles, the automobile is no longer just a mechanical equipment, but also a complex information system. This makes the car vulnerable to cyberattacks. To this end, technicians need to strengthen the security protection of intelligent vehicle systems and adopt various security technologies and methods, such as firewalls, intrusion detection systems, and security protocols, to prevent malicious attacks on vehicles. At the same time, it is also necessary to regularly conduct security detection and vulnerability scanning of smart cars to ensure the security of automotive systems. For data privacy protection, designers can adopt more secure data transmission and storage methods to reduce the risk of data breaches. For example, encryption can be used to encrypt the transmission and storage of data, so that even if the data is intercepted, it cannot be directly interpreted. In addition, some advanced privacy protection techniques such as differential privacy and homomorphic encryption can be used. These technologies can carry out certain data processing and analysis while protecting data privacy, so that technicians can not only use data, but also protect the privacy of users. In addition, designers can follow the principle of data minimization and collect only the minimum amount of data necessary for the smart car to perform its tasks. At the same time, the purpose of data collection and use, as well as the protective measures taken, can also be fully explained to users before using the product, so that users can obtain the right to know and the right to choose. It can be seen that by adopting various security and privacy protection technologies, technicians can effectively consider this problem, so that users can enjoy the convenience brought by smart cars while ensuring their own security and privacy.

(5) Multi-sensor fusion technology

For smart cars, sensor technology is a core part of their environment perception technology. Although significant progress has been made in sensor technology in recent years, the sensing accuracy of sensors still needs to be improved in extreme weather conditions. Researchers can develop new types of cameras that can maintain high perceptual accuracy in less than ideal environmental conditions, such as strong sunlight, fog, rain and snow. For example, high dynamic range imaging can be used, which enables the new camera to capture detailed image information even in bright light conditions. For radar equipment, the radar's environmental perception in bad weather can be improved by improving the signal processing algorithm. In addition, different types of sensors have their own advantages and disadvantages, so multi-sensor fusion technology can be used to improve sensor perception accuracy. For example, cameras have good environmental perception in visible light but are degraded in situations such as low light or fog, while radar can provide accurate range and speed information, but has poor color and texture perception. The application of multi-sensor fusion technology can comprehensively use the advantages of these sensors to make up for their shortcomings, so as to improve the overall perception accuracy of the sensor. For example, algorithms such as deep learning can be used to fuse data from smart cars' cameras and radar sensors to generate a more complete and accurate environmental perception model. In this way, even if the performance of a single sensor is degraded due to some extreme environments, the fusion of multiple sensors can still make the environment perception technology of smart cars maintain high sensing accuracy.

In short, under complex and changeable road traffic conditions, vision sensors still face difficult target detection, large image acquisition workload, and difficult calculation, and also face many shortcomings in dealing with road traffic conditions with complex traffic structure and mixed people and vehicles. Intelligent vehicle environment perception technology needs to collect a large amount of information such as vehicle location, speed, and direction, which also increases the risk of data being attacked or stolen. Therefore, it is necessary to take measures to protect the security of data, such as data encryption, identity authentication, firewalls, etc. Multi-sensor information fusion involves the integration and management of multiple sensors, multiple algorithms and multiple data sources, and the complexity of the system is high, so it is necessary to design a reasonable architecture and algorithm to improve the maintainability and scalability of the system.

VII. Future directions

As one of the key technologies to realize autonomous driving, the future development direction of intelligent vehicle environment perception technology mainly focuses on the comprehensiveness, safety, intelligence, and lightweight of perception.

First, environmental awareness hardware systems need to be lightweight and integrated. First of all, sensors can be developed in a smaller size, which reduces the space occupied by the sensor. At the same time, new MEMS technology can realize chip-level integration of sensors such as millimeter-wave radar, thereby greatly reducing the size of sensors. Secondly, new materials and processes can be used to lighten the weight of sensors. For example, the use of new materials such as carbon fiber and ceramics instead of metal not only reduces the mass of the sensor, but also improves its robustness, removes unnecessary parts, and optimizes the internal structure design.

Second, environmental perception technology needs to have intelligent environmental understanding and prediction capabilities. This requires the development of more intelligent algorithms, so that environmental perception technology can understand traffic scenarios based on perceived information, predict the movement trajectory of other vehicles, pedestrians, and animals, and make correct decisions. In addition, environmental perception technology also needs to be deeply integrated with other technologies such as high-precision maps and Internet of Vehicles to obtain more environmental information in real time.

Third, it is necessary to improve the safety and reliability of environmental awareness technologies. On the one hand, it is necessary to design the sensing system with safety redundancy to ensure that a single sensor can still work normally in the event of a failure, and on the other hand, it is necessary to develop a more stable and reliable perception algorithm to improve the reliability of the environmental perception technology through algorithm redundancy and multi-sensor fusion. In addition, it is also necessary to ensure that the autonomous driving system has the ability to respond to complex situations.

Fourth, it is necessary to improve the comprehensiveness of environmental perception technology to achieve all-round perception of the surrounding environment. This requires more sensors, such as lidar and millimeter-wave radar, and data fusion to form a complete 3D model of the environment around the vehicle. At the same time, it is necessary to consider the impact of environmental issues such as weather on the sensor, so that the environmental perception technology of smart cars can maintain the stability of perception under conditions such as rain and snow.

VIII. Summary

In short, environmental perception technology has a very important value in the development of intelligent vehicles, although its development faces a series of challenges, but also has broad development prospects and great application potential. In the future, researchers should overcome these challenges through continuous research and innovation, solve technical shortcomings, and realize the wide application of intelligent technology in automotive environmental perception systems, so that intelligent vehicle technology can develop in an orderly manner, provide better services for daily travel, and promote the sustainable development of intelligent vehicles.

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