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Analyze the Advantages and Disadvantages of Different Sensors for Autonomous Vehicles

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ABSTRACT
To realize the autonomous operation of vehicles in an unpredictable urban environment, multiple real-time systems must be interoperable, including environmental perception, positioning, planning and control[1]. Sensors have played an indispensable role in providing correct judgments and making correct actions for autonomous driving technology. The sensor acquires external information through different means and transmits it to other components. At present, the sensors of mainstream autonomous vehicles on the market are mainly divided into four categories： 1. Cameras for Autonomous Vehicles 2. Ultrasonic Sensors 3. Laser Scanner 4. Radars[2]. The purpose of this article is to find out how to choose the sensor of the autonomous driving car. This article compares the advantages and disadvantages of these four different sensors. In this paper, by looking for the effects of some special circumstances that may exist on the sensor and the sensors that have been widely used in the market, to find out their possible impact and why they are widely used. Automakers like Tesla are chosen to use only the camera for Autonomous Vehicles. In the case of foggy weather or poor visibility, the camera is difficult to function well. After analyzing several types of sensors, the author found that each type of sensor has significant defects. Only when two or more types of sensors appear in a car can the vehicles fully perceive the surrounding environment.

Keywords: *Cameras for Autonomous Vehicles, Ultrasonic Sensors, Laser Scanner, Radars, Autonomous driving*

1. INTRODUCTION

With the popularization of electric vehicles, autonomous driving technology has gradually entered the public's field of vision. Autonomous driving technology is also being innovated time and time again in order to provide users with a safe driving experience. As a key accessory for autonomous driving, sensors acquire real-time surrounding information for the vehicle. Nowadays, major auto manufacturers have chosen different sensors to act as the "eyes" of electric vehicles. This article will analyze the performance and possible failures of the four types of sensors in the car, and explore which sensor is more suitable for autonomous vehicles. Sensors obtain external information through different means, 1. Cameras is the most commonly used vision sensor in vehicles.Due to low cost and easy installation, camera integration in modern vehicles has become increasingly common. 2.Ultrasonic sensors use sound waves to measure the distance to objects[3]. 3. Laser scanners provide robust and precise depth measurements of their surroundings[4]. For autonomous driving, 3D-laser scanner is more suitable, but for some reason, the application of 2D-laser scanners is more common, which will be introduced later. 4. The radar system estimates the speed and distance of objects by measuring the change of reflected wave frequency according to the microwave and the Doppler effect[3]. Although they have different methods of obtaining information, but the ultimate goal is to collect real-time surrounding environment data to help autonomous vehicle make correct judgments. The purpose of this article is to provide help for the sensor selection and development direction of future autonomous vehicle based on the experiments of others for each sensor and the performance of some sensors on the car.

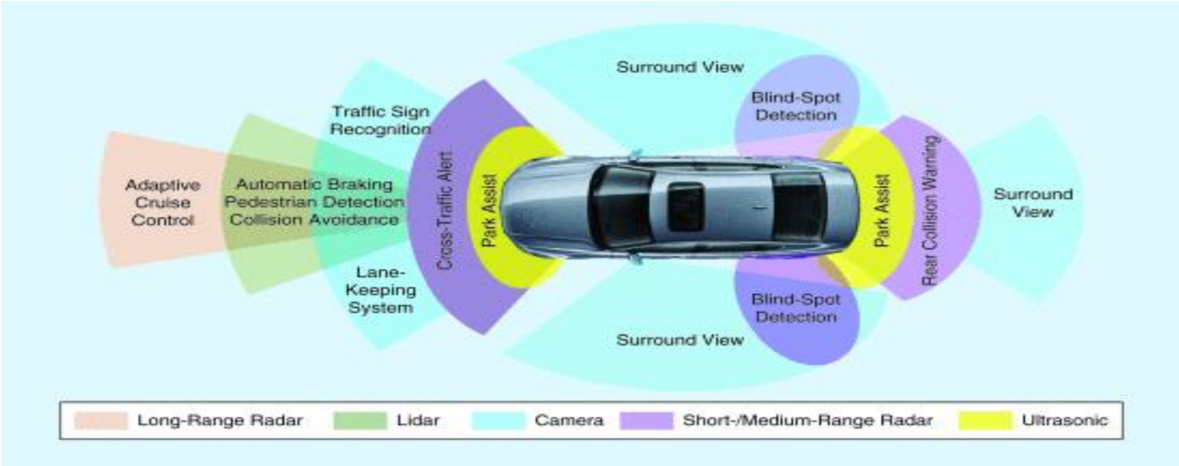

Figure 1 The state-of-the-art ADAS sensors used[3].

2. ANALYSIS

2.1 Cameras for the Autonomous Vehicles

Traditionally, laser and radar sensors are too expensive to achieve large-scale applications, and their ability to identify target categories is limited. Therefore, visual information is essential to the actual automatic driving system. Inspired by human visual perception, the vision based dangerous object detection system uses the images captured by the vehicle camera to detect dangerous objects directly. Compared with laser and radar sensors, the camera not only has low cost, but also can capture more traffic information, including object category, object distance, traffic signs and signals[5]. The camera can imitate the human eye to obtain the surrounding situation in real time and feed it back to the car. But the amount of these pictures and videos is huge, and autonomous vehicles must process them in real time and give correct feedback. If autonomous driving can be achieved through a camera, low-cost hardware can meet the needs of major automakers. Pure visual deep learning requires a lot of data, and it still needs continuous exploration to strengthen image processing and recognition capabilities.

Cameras are passive light sensors. From people's daily experiences, they can be blinded or fooled in many ways. The major finding is: Automotive cameras do not provide enough noise reduction or protection, and under strong light conditions, they can be blinded or permanently damaged by strong light, which will further lead to failure of camera-based functionalists[6]. Strong light is not uncommon in life, some special light can cause damage to the camera. If a car owner happens to be damaged or blocked by a foreign object while driving at a high speed, the car will not be able to obtain the surrounding information in real time to give correct feedback, which is very dangerous.

2.2 Ultrasonic Sensors

Among all obstacle detection sensors, ultrasonic sensors have the largest market share and are expected to be more and more installed on vehicles [7]. The main advantage of ultrasonic sensors is that they are usually the cheapest of all sensor types discussed. They are very robust in adverse weather conditions and have a good record of reliability. For many years, most automobile manufacturers have used them as parking sensors. Ultrasonic sensors are also considered to be the most accurate sensors in close range applications.

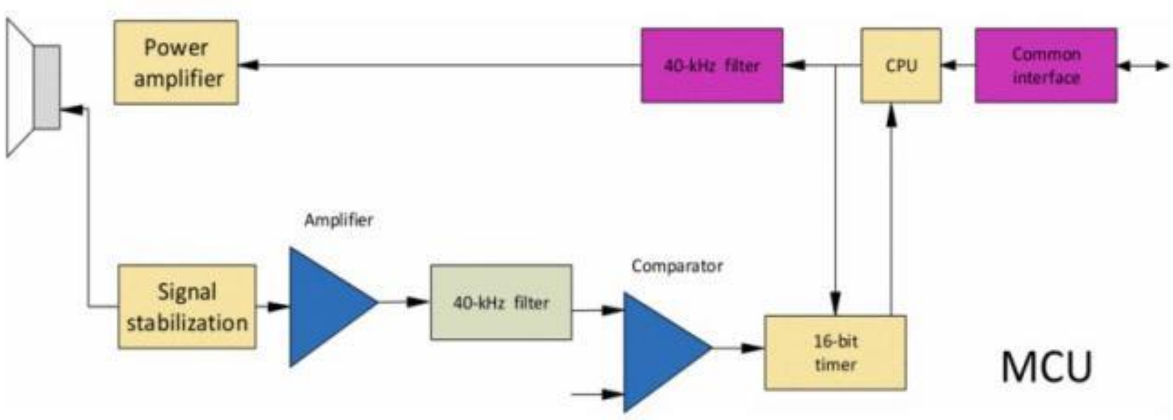

Figure 2 Block diagram of ultrasonic sensor[8].

However, the disadvantage of these sensors is that they will be seriously affected by acoustic interference. Because the sound can only propagate in the medium, the changes of environmental conditions such as temperature and humidity will greatly affect the performance of the sensor[8]. Ultrasonic sensors are selected as close -range sensors by many car manufacturers due to their low price and high reliability, but due to their limited detection range. Although ultrasonic sensors are considered excellent sensors by major automobile manufacturers, some scholars believe that when it is applied to autonomous driving, its reliability becomes less strong. The reliability of ultrasonic sensors is still a key issue, especially when it determines the safety of autonomous vehicle. This paper verifies the feasibility of three types of attacks: random deception, adaptive deception and interference attack on ultrasonic sensors. And shows that they will lead to the wrong driving decision of mobile vehicles in automatic driving[7].

Table 1. Overview of Attack and Defense Goals[7].

Situation	Decision under Attack	Attacks
w/o obstacles	stop moving	random spoofing adaptive spoofing
w/ obstacles	keep moving	jamming adaptive spoofing

After a vehicle is attacked, it is found that the vehicle is moving when it should stop, and it stops when it should be moving, which is a potential threat to safety hazards.

Ultrasonic sensors were found to be very vulnerable. By emitting sounds of specific frequencies, the car will be mistaken for an obstacle in front of the car, but the actual obstacle does not exist. If they want to avoid these attacks, these low-cost sensors need to undergo major modifications, but this is unacceptable to car manufacturers, because ultrasonic sensors themselves are widely used because they are cheap[7].

2.3 Laser Scanner

Lidar is the abbreviation of optical detection and ranging. Lidar equipment has been widely used in robotics, especially automatic driving. They provide reliable and accurate depth measurements of the surrounding environment, making them usually the first choice for environmental sensing[4]. Nowadays, the laser scanners used in autonomous vehicles on the market are more 2D laser scanners, and their shortcomings are also obvious. A laser scanner only sees parts of the object facing the scanner[9].

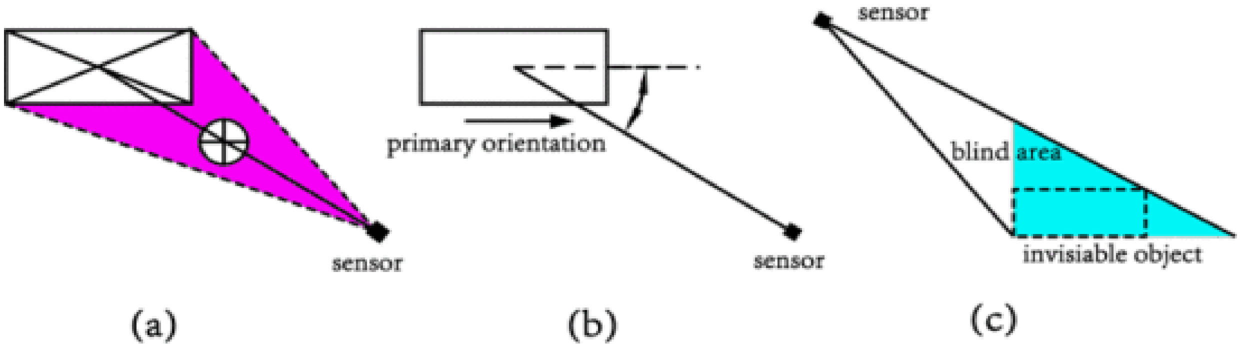

Figure 3 The procedure of fit the cluster into box model. (a) The original points of a cluster belong to a car. (b) The bounding points facing the sensor are in red. (c) Iteration end point algorithm (d) the box model for the object[9].

But for autonomous driving, a 3D laser scanner is a better choice, because compared to 2D, 3D can more comprehensively obtain more three-dimensional environmental information and feed it back to the vehicle. According to the number of layers used, laser scanners can be divided into three types: two-dimensional single-layer, 2.5-dimensional multi-layer and three-dimensional (3D) dozens of layer laser scanners. Two dimensional laser scanners, such as sick lms-111, use a single layer and provide the contour of environmental horizontal slices, but in some cases, a single slice is not enough to identify the environment. The 3D laser scanner uses more layers to provide a full range of environmental contours. The amount of information provided by the 3D scanner is sufficient for environmental recognition. Examples of 3D scanners include velodyne HDL 64e and 3DL. Nowadays, the application of 3D scanner in the automatic driving vehicle is becoming more and more popular. Unfortunately, one obvious weakness of 3D scanners is that they must be installed on the top of the vehicle. Therefore, its installation destroys the vehicle design and becomes the main obstacle to commercialization[10]. The information obtained by 2D is limited and cannot provide comprehensive information about the surrounding environment for autonomous driving. However, due to the problem of the installation location, the more powerful 3D laser scanner cannot be widely used in autonomous vehicles.

2.4 Radars

The main reason for the success of automotive radar is its physical principle, which provides unique performance characteristics at a reasonable cost. These include vehicle integration independent of environmental conditions (light, weather), directly measured spatial parameters and Doppler velocity, multi field of view capability and design compatibility. Radar works when other sensors fail. It can virtually observe the vehicle (perspective effect) by using the reflection between the road surface and the vehicle floor, so as to make invisible objects visible[11].

Automotive radar includes many different radars, such as microwave radar, lidar and so on. Common functions of autonomous vehicles on the market include adaptive cruise, obstacle detection, etc., which are all based on radar. The radar's ability to deal with complex weather and its reasonable cost determine its success. Mutual interference between vehicle radars is a challenging problem to be solved. The use of radar for autonomous vehicle is increasing rapidly. With the increasing number of vehicles equipped with automotive radar, up to 10 automotive radar units are deployed per vehicle, and the probabilities of mutual interference between automotive radar units increases[12]. Since many functions on the vehicle are implemented based on radar, the number of radars on each vehicle is also very large, and the mutual interference between radars has become a problem that automobile manufacturers must consider. For example, if two autonomous vehicle are driving side by side on a high speed, if the radars influence each other, causing the radar to misjudge the surrounding environment, the consequences are unimaginable.

3. CONCLUSION

There are more than one human senses. For example, in the daytime, people can observe the environment through vision, but at night, in an environment without light, other senses such as hearing, smell, and touch will give people perception. Autonomous vehicle should have more sensors to ensure that the car can have a comprehensive perception of the surrounding environment in various environments.For example, the camera is easily deceived by the environment and easily damaged by strong light. Ultrasonic sensors are easily attacked by sound sources of specific frequencies. 3D laser scanners need to be installed on the top of the vehicle, and radars are likely to affect each other. Tesla is continuously reducing the sensors on autonomous vehicles, and this phenomenon is also being hotly discussed by scholars. But this article believes that any autonomous vehicle that wants to reach the L5 level or L4 level should be equipped with two or more types of sensors. For different environments, some sensors may fail or false alarms, which will cause traffic accidents. Different sensors can deal with different environments, so that mutual assistance between sensors can better realize safe autonomous driving. However, due to the limitation of personnel and knowledge, this article cannot judge which kinds of sensors can cooperate with each other to better realize automatic driving. This is also a problem worthy of more in-depth exploration. In subsequent research, qualified scholars can judge which sensor combination should be selected for autonomous vehicles through the cooperation of different sensors and their performance in complex road conditions.In addition, the issue of car safety should also be considered. Perpetrators may use strong light, sound waves and other methods to attack the vehicle's sensors. Auto manufacturers should consider this issue and update the sensors.

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