Proceedings of CONF-MLA 2025 Symposium: Intelligent Systems and Automation: AI Models, IoT, and Robotic Algorithms
DOI: 10.54254/2755-2721/2025.LD28563

The Application of Sensors and Other Systems in Modern Driverless Cars

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Abstract. With the rapid development of science and technology, electronic information technology is widely used in various fields, and the field of driverless cars is no exception. Man-made driving mode depends on the driver's technology and road knowledge, and it will be affected by the environment, technical experience and the driver's physical condition, and it will face some traffic safety problems. The application of electronic information technologies in autonomous vehicles enables enhancements to the vehicle's environmental perception capabilities, thereby allowing the vehicle to adapt flexibly to complex road scenarios during autonomous driving operations. This review article will combine examples and literature to analyze the different sensors mainly used in driverless cars, and summarize the types and functions of sensors, SLAM algorithm, CAD model and the use of integrated monitoring system. This paper elaborates on the challenges encountered by diverse sensors in the application of autonomous vehicles, and explores the specific application of electronic information technologies in autonomous vehicles. The research aims to enhance the environmental perception capability of autonomous vehicles regarding road environments, mitigate traffic risks, and facilitate the realization of vehicle-road coordination.

Keywords: Robotic, Localization, Sensor, SLAM, Monitoring and control system

1. Introduction

In recent years, alongside advancements in artificial intelligence technology, autonomous vehicles have undergone rapid development. To ensure precise environmental awareness, autonomous vehicles are typically outfitted with a diverse array of sensors. The integration of multi-sensor technology has become the research focus, mainly including camera, lidar, millimeter-wave radar, Inertial Measurement Unit,IMU) and wheel odometer. The core of multi-sensor technology lies in leveraging the unique advantages of each sensor to achieve comprehensive perception of the surrounding environment.

Simultaneous localization and mapping (SLAM) technology is one of the important technologies in this field. In tunnels, underground parking lots, high-rise buildings and sheltered environments, the positioning information is usually weak [1], and self-driving cars cannot accurately obtain their own positioning information. SLAM technology can obtain its own relative positioning information in unknown environment and rebuild the surrounding environment [2], which can effectively solve the above problems.

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This paper analyzes the research status of multi-sensor fusion, summarizes its existing problems and technical difficulties, and puts forward suggestions for its future development and research direction.

2. The development and the basic overview of robots' senosr

Fundamentally, sensors are a category of input devices that read or measure physical properties from their surroundings, detect or sense heat, light, sound, and motion, and subsequently generate corresponding responses [3]. Most of the passive sensors are self-powered; they sense the data without actually manipulating the environment by active probing while active sensors actively probe the environment. Transceiver, microcontroller external memory, and power supply are some common components that we might find in a sensor [4]. The use of multi-robot systems for carrying one or more sensors around the environment represents a solution that has received a significant attention and can also provide some extraordinary advantages as sensors can be used to solve many problems in robotics such as robot path planning, localization mapping, and sensing in robots.

The rapid development of computer technology started from the 1970s provided a wide range of possibilities for user to upgrade their robotic sensors. Apart from that, non-contact sensors began to emerge. The introduction of these technologies enabled robots to finally perceive a wider range of external dynamic environmental information and accomplish more complex tasks. Over the course of two decades, these technologies have gradually matured.

Following content will discuss each important sensor with practical examples and real case.

2.1. Ultrasonic sensor

The driverless car is very popular at present. They typically rely on a variety of expensive sensors. For the safety wise considerations, various types of sensors are installed throughout the whole vehicle, used to ensure the safety of drivers, passengers as well aspedestrain, Table 1 below shows some related sensors [5].

Table 1. Common types of sensor

Sensor Type	Physical Input	Localization Role
Ultrasonic	Sound waves	Distance measurement to obstacles (e.g., walls)
Infrared(IR)	Light/Heat radiation	Proximity detection & object avoidance
Accelerometer	Acceleration forces	Track movement direction & speed changes
Gyroscope	Angular velocity	Measure rotation & orientation
Optical Encoder	Wheel rotation pulses	Calculate distance traveled (odometry)

It employ multiple ultrasonic sensors in all directions to detect a wide range of possible obstacles in front of or at the back of the vechicle to enable safe operation of such vehicles in pedestrian areas [6]. Send out an ultrasonic wave, calculate the time it takes for it to bounce back, then multiply this time by the speed. Calculate distance based on this time delay [7].This constitutes the fundamental operational algorithm for this category of sensors (Figure1). This operation algorithm is quite simple and effective [3].

However, the performance of this types of sensors may vary in different environments. They might perform better in a stable conditions. Meanwhile, microprocessors process the data received from cameras and sensors and send signals to actuators to perform physical actions. Those controll

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structure will be able to prevent some of the collisions with unknown obstacles by deploying a reduced safe velocity ensuring a sufficiently large safety distance, if the detected value is not within the safe range , after the system localized the location of this vehicle. The ultrasonic sensors has already been proved useful.

Figure 1. Distance measurement schematic diagram

In contrast, infrared sensors— which share considerable similarities with this technology—detect thermal radiation and are frequently employed for proximity sensing and obstacle avoidance, particularly under low-illumination conditions [7]. Ultrasonic and infrared are both commonly used for obstacle detection, but how they operate is based on different principles.

2.2. Accelerometers

Beyond this, for autonomous vehicles, parameters such as the vehicle's speed and other motion states also merit consideration. A closer look at the sensors that can help us monitor these aspects is necessary. Accelerometers are sensors on in-service trains, placed on the axle-box, bogie, and car-body. In simple terms, the function of Accelerometers is to detect the vehicle's acceleration in the ABS system, preventing wheels from locking up, and also helps optimize engine performance [8].

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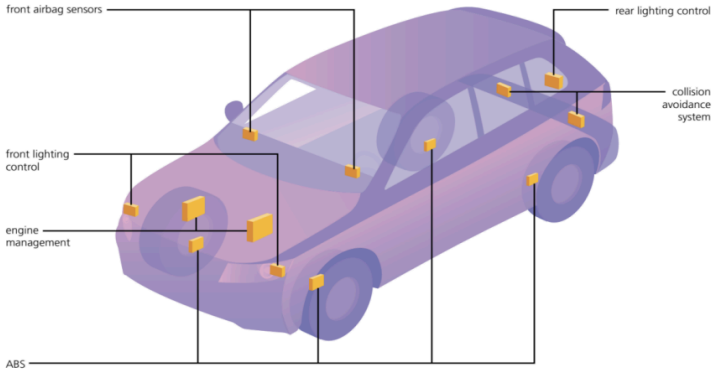

Figure 2. Sensors on a modern car

Figure2 above shows various sensors on modern cars [5]. Among them, the ABS anti-collision system is the one most closely related to safety and accelerometers. The ABS system has been installed on wheeled vehicles to prevent the wheels from locking during braking, thereby ensuring maneuverability and improving braking performance [9]. Its method is to control the slip rate of the wheels. By maintaining the slip rate at the optimal value that varies with the road surface, slip control maximizes the braking force, thereby improving braking efficiency. During braking, braking torque is applied to the wheels to reduce the angular velocity, causing the vehicle to skid.

In addition to the ABS system in accelerometer, another type of inertial measurement unit that can also be well applied in robot measuring is IMU. This is a device that perceives the motion state of a robot through its accelerometer and a gyroscope. By measuring linear acceleration, angular velocity, and attitude variations, this device operates via a mechanism analogous to that of an accelerometer. It furnishes motion control and navigation support for the robot, facilitates the robot in maintaining balance, and aids in the execution of complex movements. Besides the modern driverless vehicles analyzed in the previous context, micro medical robots incorporate IMUs into smaller robot systems to achieve in-body navigation and provide support for minimally invasive surgeries [10].

However, currently, these types of technology has been replaced by other technologies in some other fields.

3. SLAM(Simultaneous Localization and Mapping)

SLAM, an acronym for Simultaneous Localization and Mapping, also enables robots to achieve localization; however, SLAM is specifically applied in unknown environmental maps, implying that the system must perform certain estimations while concurrently constructing the map. As the robot acquires environmental information, it can adapt to dynamic changes and estimate its spatial position even in the absence of a pre-existing map [11]. SLAM is performed to guarantee consistency in both temporal and spatial dimensions, providing accurate input for subsequent processing [12].

It uses built-in lasers or cameras to “see,” just like human eyes. While localizing, it builds a map by drawing what it sees and measuring distances to obstacles. A flow chart (Figure 3)looks like this: Robot → Sensor → Map → Localization → Action. Hence, fixed paths are no longer needed; layouts can change and the robot adapts.

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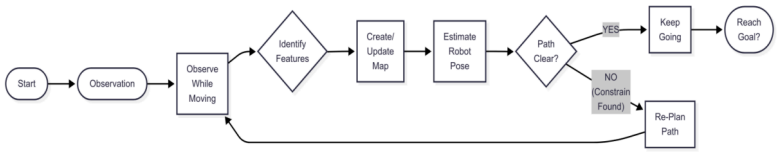

Figure 3. SLAM algorithm

Sometimes, SLAM system is also combined with some of the sensors in helping robots to locate themselves. The cooperative calibration between these is also unignorable.

Specifically, the SLAM system can receive outside environmental data from various sensors as the basis for the construction of the environment's map and the following localization.

Secondly, through algorithms, the data received from various sensors is then integrated to compensate for the limitations of individual sensors (such as the shortcomings of some sensors mentioned above), and enhance data reliability. Dynamic adaptation and optimization is also worth mentioning, as sensors will provide real-time feedback on the changes on the environment, and the SLAM system adjusts its mapping and localization strategies dynamically, aiming to ensure accuracy in complex environments.

4. Monitor and control system

Sensors are used in both monitoring and control applications. There is a subtle difference between how these two methods work. Both monitoring and control systems will send signals to the microprocessor or computer at the beginning of processing. These signals are then converted to digital format if necessary, using an analogue to digital converter (ADC). The computer or microprocessor then analyzes the data received by checking it against stored values [12].

In a monitoring system, if the new data is outside the acceptable range, a warning message is sent to a screen or an alarm is activated without any other following action. The microprocessor or computer has no effect on what is being monitored, so it is simply 'watching' the process but not preventing. This system is designed to give users a warning if any deviations are detected.

On the other hand, in a control system, if the data is outside the acceptable range, the computer or microprocessor sends signals to control the robot's motors. The next set of input from the system will be affected by the previous output from the sensors, creating a feedback system loop. This system actively adjusts the process to maintain desired conditions, ensuring that the system operates within specified parameters in a reasonalble algorithm.

Table 3. Comparision of two systems

	Monitoring System	Control System
Data Flow	Sensor → Microprocessor → Display/Alarm	Sensors →Microprocessor → actuators (eg:breaks) → feedback systems → take action
Output	Displays thermal imaging or sounds alarm	Perform a deceleration or braking action
Environmental impact	-	Changing the state of motion of the vehicle

Taking the aforementioned autonomous vehicle as an example, the monitoring system may only display the distance to an obstacle; in contrast, the control system—equipped with a feedback

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mechanism—can directly execute physical actions to bring the vehicle to a halt or reinitiate its movement. The specific step comparison is shown in Table 3.

5. Conclusion

In conclusion, this paper presents an overview of diverse sensor types applicable to robotic localization, along with their integrated applications with associated systems such as SLAM. It also synthesizes the classification and characteristics of these sensors in conjunction with relevant literature.

However, it is undeniable that there are some research deficiencies and gaps in this review article. This paper is mainly reviewed, using the literature review method, and does not include empirical and real-life evidence to confirm the relevant research. In the future, the scope of actual measurement will be expanded, the comprehensive analysis of multi-sensor data will be integrated, the number of references will be increased, and the level of views will be further improved

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