Analysis Of Key Technologies in Autonomous Guided Vehicles (Agvs) Navigation Technology

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Abstract. In this paper, four basic sensors are briefly introduced, and the challenges faced by autonomous navigation vehicles (AGVs) such as environment awareness, path planning, positioning accuracy, and multi-vehicle coordination are discussed. The role of sensor technology in overcoming these challenges is analyzed. This paper examines the application and fusion of different sensors, as well as the use of artificial intelligence and deep learning technology to enhance the intelligence of AGVs. The conclusion has been drawn in this paper that it is crucial to strengthen the research and application of sensor technology, this helps to improve positioning accuracy and stability, strengthen the research of real-time communication technology, and enhance the safety and reliability of sensors. Finally, this paper emphasizes the importance of balancing cost and benefit while properly configuring sensor technology to meet user needs, which guides the continuous development of AGVs in industrial and commercial applications.

Keywords: AGV, sensors, guidance, technology.

1. Introduction

Automatic guided vehicle (AGV) is a driverless vehicle that can navigate and transport items autonomously and it is commonly used in a variety of engineering fields including coordination, manufacturing, and high-risk labor, to solve a range of problems [1]. The advantages of high efficiency and low cost make AGVs be used increasingly and extensively in industrial and commercial fields.

Guidance technology is a crucial aspect of ensuring the autonomy and mobility of AGV. For the "master-slave" two-vehicle cooperative handling system, the guidance mode of piloting AGV is like that of a single AGV, and the technology has become mature. To follow the positioning and guidance of AGV, one needs to obtain environmental information and observe the piloting AGV for path following. This requires higher accuracy and stability. Currently, widely used AGV navigation technology makes it difficult to achieve good coordination and balance among various indicators such as positioning accuracy, guidance flexibility, operational reliability, and operating cost.

The most important abilities of AGV autonomous movement are obstacle avoidance and navigation, and their necessary condition is environmental perception. In the unknown or partially unknown environment, it is necessary to obtain the surrounding environment information through sensors, including the size, shape, and position of obstacles. Therefore, sensor technology plays an especially important role in obstacle avoidance of mobile robots. This enables sensors used in AGVs to evolve from traditional to more intelligent and low-cost sensor systems [2].

The main sensors used for obstacle avoidance are LiDAR sensors, vision sensors, infrared sensors, ultrasonic sensors, and so on. For example, navigation in crowded and dynamic environments requiring identification and avoidance of obstacles needs to use LiDAR sensors. Efficient navigation in the narrow spaces between aisles and shelves while avoiding collisions requires the use of ultrasonic sensors. Vision sensors are needed to identify and accurately pick up items from a specified location to ensure accurate positioning of items placement and sorting tasks. Infrared sensors are used in low light or night environments, or when the surface of an object has a significant reflection of infrared.

The automation technology has advanced rapidly, and as a result, automated guided vehicles (AGVs) have gained significant importance in industrial production, logistics, and warehousing.

However, several challenges in AGV navigation technology need to be addressed, such as improving the accuracy of environment perception, real-time path planning, and positioning accuracy stability. Addressing these challenges is crucial for enhancing the safety, efficiency, and intelligence level of AGVs, as well as for promoting the process of industrial automation, enhancing production efficiency, and reducing costs. This study aims to explore the key technologies in AGV navigation technology. By conducting in-depth analysis and research on these key technologies, this paper aims to identify and solve the existing problems in AGV navigation, thereby improving the performance and intelligence level of the AGV navigation system.

2. Characteristics and Applications of Four Main Sensors

2.1. LiDAR Sensors

LiDAR, also known as Light imaging, Detection, and Ranging, is a technology that emits a laser beam to measure reflection or emission laser signal arrival time and degree of strength parameters [3]. It is used for detecting, identifying, distinguishing, and tracking targets. Due to its short wavelength and high collimation, it is an essential non-contact measurement sensor in various fields, including robotics, intelligent manufacturing, military, and agriculture. Compared to other radar products, LiDAR has some significant advantages. It has a wider and more accurate detection range, and it can precisely measure the position (distance, angle), motion state (speed, vibration, and attitude), and shape of the target.

LiDAR can accurately locate the spot of the laser beam on the object and use the laser for detection and measurement to obtain the location, speed, height, orientation, and other characteristic parameters of the target. Therefore, ranging and measurement accuracy is one of the key indicators of LiDAR product quality.

However, LiDAR uses light as a carrier, making it susceptible to environmental light. Sunlight, indoor artificial light sources, and other sources can cause a large amount of stray light in the same band as the laser measurement system. This stray light can interfere with the laser measurement system and data generated by LiDAR. Therefore, it is essential to control optical interference during LiDAR manufacturing.

Lidar is a commonly used technology in AGVs for environmental sensing and positioning. It can accurately detect obstacles, terrain, and other targets in the surroundings, which helps AGVs achieve autonomous navigation, obstacle avoidance, and precise positioning. Lidar has a long measuring range of several meters or even tens of meters, making it suitable for a variety of applications that require high-range requirements. Additionally, Lidar has a high measurement accuracy, typically between a few millimeters and a few centimeters, which makes it ideal for tasks that require high-precision environmental perception. Lidar can quickly scan the surrounding environment and generate real-time map data, making it ideal for applications that require a fast response. Despite being more expensive and consuming more power, Lidar is often an essential tool in applications that require high-precision environmental perception.

2.2. Vision Sensors

Vision sensors, which emulate the human visual system, are pivotal in facilitating non-contact rapid measurement of objects, finding extensive applications across diverse domains including intelligent transportation, industrial inspection, aerospace, and unmanned system positioning and navigation. The optical characteristics of vision sensors significantly influence imaging quality and clarity [4]. Key optical parameters of single-camera vision sensors encompass the field of view, resolution, and depth of field, among others.

Traditionally, binocular vision sensors, comprising two cameras, suffer from drawbacks such as bulky size, high cost, and challenges in synchronous image acquisition. In response, researchers have embraced the implementation of refractive and reflective elements to devise mirror vision measurement modes, thereby enhancing the imaging and measurement capabilities of vision sensors

[5]. Single-camera image vision sensors leveraging refraction and reflection optical elements exhibit traits of miniaturization, enhanced flexibility in imaging modes, and accelerated measurement speed.

One notable advantage of vision sensors lies in their wide detection range and rich information content. In practical scenarios, multiple vision sensors are frequently deployed or integrated with complementary sensors. Through appropriate algorithms, these sensors can extract valuable information regarding the shape, distance, and velocity of objects. Techniques such as utilizing sequence images from a camera to compute the target's distance and velocity or employing the SSD algorithm to determine the relative displacement between the robot and its target based on the moving image from a lens, underscore the versatility and utility of vision sensors in various applications.

Nevertheless, certain challenges persist. Image processing tasks such as edge enhancement and feature extraction necessitate substantial computational resources, leading to compromised real-time performance and imposing high demands on processing units. Furthermore, conventional visual ranging methods expose limitations in detecting transparent obstacles like glass and are susceptible to environmental factors such as light intensity variations and smoke within the field of view. Addressing these challenges mandates ongoing research and innovation in the field of vision.

2.3. Infrared Sensors

Infrared sensors are devices that use infrared light to emit beams, which are then reflected to the sensor by an object. These sensors can detect the reflection of the beam to determine the distance of the object or detect obstacles. Once the infrared beam is reflected, the sensor generates an electrical signal, and the system reacts accordingly. This includes stopping, steering, or adjusting the speed of an AGV. Infrared sensors are commonly used for obstacle avoidance and distance measurement in AGVs. They help AGVs detect obstacles ahead so they can avoid collisions or adjust their direction of travel. These sensors can also be used to detect cargo, fix guidance lines, and perform other distance-related tasks. The detection range of infrared sensors is typically between a few centimeters and a few meters, making them suitable for close-range obstacle avoidance and navigation tasks. However, infrared sensors are sensitive to ambient light and surface reflections, so they may require appropriate environmental treatment to reduce errors, especially when used outdoors or in bright light conditions. One of the advantages of using infrared sensors is that they have a relatively low cost. low power consumption, and long service life, making them an affordable obstacle avoidance solution [6].

2.4. Ultrasonic Sensors

The ultrasonic sensor is a device that calculates the distance between the sensor and a target object by transmitting an ultrasonic pulse and measuring the time it takes for the pulse to reflect from the object. Based on the ultrasonic signal received, the sensor can determine the distance and direction of the object, making it useful for obstacle avoidance and ranging. Ultrasonic sensors are primarily used for positioning and obstacle avoidance at close distances. In AGVs, they are often used to detect obstacles in front of the vehicle to avoid collisions or adjust the direction of travel. The ultrasonic sensors feature a very similar detection range with infrared sensors which makes them also suitable for close-range obstacle avoidance tasks. Ultrasonic sensors have a high signal-to-noise ratio , high accuracy, and reliability which can accurately detect obstacles and avoid collisions in most cases [7]. Additionally, they are also usually more affordable and consume less power compared to other obstacle-avoidance solutions.

3. Single-sensor Systems and Multi-sensor Systems

AGVs are integral to the automated logistics and transportation industry. They require high-level sensing capabilities, route planning, and task execution. In designing an AGV, selecting an appropriate sensor system is crucial, and there are two main choices: single-sensor and multi-sensor systems.

Single-sensor systems are simple and easy to use, as they rely on only one type of sensor. They are less expensive because only one sensor needs to be purchased and maintained. Single-sensor systems work well for basic obstacle avoidance or path planning. However, they have limited sensing capabilities and cannot handle complex environments or task requirements. They are also susceptible to environmental changes and sensor failures, making them less fault tolerant. In addition, the accuracy of single-sensor systems may be lower and unable to meet the high precision requirements of complex environments.

Multi-sensor systems, combine different types of sensors to enhance environmental awareness and task execution flexibility [8]. They leverage the strengths of different sensors to improve environmental awareness. Multi-sensor systems are more fault-tolerant because each sensor is independent of the other and if one sensor fails, other sensors can still complete the task [9]. The combination of multiple sensors improves the measurement accuracy and environmental sensing accuracy of the system. However, multi-sensor systems are more challenging to design, integrate, and debug, requiring more engineering resources and costs. They also require the purchase of multiple types of sensors, making them more expensive. Maintenance and troubleshooting of multi-sensor systems can also be more complex and require a higher level of technical support.

4. Challenges Faced by AGV Navigation Technology

AGVs rely on accurate perception and recognition of their surroundings, which includes obstacles, road conditions, traffic signs, and other factors. However, the environment can be affected by various factors such as lighting, shadows, reflections, etc., which can result in inaccurate or misunderstood sensor data. Complex environments like warehouses and factory workshops may have various dynamic and static obstacles that the navigation system needs to identify and avoid accurately.

AGVs require path planning and dynamic path adjustment based on task requirements and environment changes. This includes selecting the best path, avoiding obstacles, adapting to changes in traffic flow, and more. However, there may be dynamic obstacles, temporary obstacles, intersections, and other situations in the actual environment. The navigation system needs to adjust the path planning in real-time to ensure that the AGV can complete the task safely and efficiently.

The positioning accuracy and stability of AGVs are crucial to navigation performance. Traditional positioning technologies like laser positioning, inertial navigation, and visual navigation may be affected by various factors in complex environments such as signal occlusion, multipath effect, sensor errors, and more. Therefore, improving the accuracy and stability of positioning technology is an essential challenge.

In some scenarios, multiple AGVs may work simultaneously, and it is necessary to achieve cooperative work and conflict avoidance [10]. This involves task allocation, path planning, traffic management, and the need for navigation systems to coordinate the actions of multiple AGVs effectively, which ensures that they can share space and resources safely and efficiently [11].

AGVs may be required to work in various complex environments and scenarios such as indoor warehouses, factory floors, hospital corridors, and more. These environments may have irregularly shaped obstacles, narrow channels, slopes, and other challenges, requiring the navigation system to adapt to, which ensures that the AGV can travel safely and stably.

5. Future Development of AGV Sensor Technology

AGVs of the future are likely to have multiple sensors such as lidar, cameras, ultrasonic sensors, etc. These sensors can be fused to improve the efficiency of processing and analyzing multimodal data and to increase awareness of the environment. To achieve this, it is recommended to develop a platform that can integrate multiple sensor data.

As artificial intelligence and deep learning technologies advance, AGVs can become more intelligent in perceiving and understanding their surroundings, leading to better decision-making

capabilities. Strengthening the application research of artificial intelligence algorithms in the AGV sensor system can improve the autonomous sensing and decision-making ability of AGVs.

The accuracy of positioning is essential for AGV navigation. To improve the accuracy and stability of positioning, future AGVs may adopt higher precision positioning technologies such as differential GPS and visual positioning. Given obstacles, targets, and AGV states, a trained policy network can produce efficient on-board optimal feedback actions [12]. Therefore, it is suggested to strengthen the research and application of high-precision positioning technology.

Collaborative work among AGVs can increase the efficiency and flexibility of the entire system. Real-time communication is the basis for realizing collaborative work. Therefore, it is suggested to strengthen the research on real-time communication technology, develop reliable communication protocols and systems, and realize real-time data sharing and collaborative work among AGVs.

AGV safety and reliability are critical issues for users, and sensor technology plays a vital role in improving them. It is suggested to strengthen the research and development of sensor hardware, improve the stability and durability of sensors, and enhance the research of sensor data processing algorithms to improve the ability of identification and coping with abnormal situations.

Although sensor technology can improve the functionality of AGVs, it can also increase the cost. Therefore, it is suggested to balance the cost and benefits of sensor technology when developing AGVs and select the appropriate sensor configuration and technical scheme to meet the users' needs while minimizing the cost.

6. Conclusion

Automated Guided Vehicles (AGVs) face several challenges when it comes to their navigation system. These challenges include environment awareness, path planning, positioning accuracy, and multi-vehicle coordination. To accurately perceive the surrounding obstacles, road conditions, and traffic signs, AGVs require environmental perception. However, environmental factors can affect navigation accuracy by distorting sensor data. Additionally, complex storage environments may have dynamic and static obstacles that need identification and avoidance. AGVs require dynamic path planning and adjustment based on mission requirements and environmental changes. Real-world challenges such as dynamic obstacles, temporary obstacles, and intersections require real-time adjustment of navigation routes for the safe and efficient completion of tasks. Positioning accuracy and stability are crucial to navigation performance, and traditional positioning techniques are susceptible to signal blocking and sensor errors. In scenarios involving multiple AGVs operating simultaneously, coordination and conflict avoidance become critical. An effective navigation system must coordinate the actions of multiple AGVs through task assignment, path planning, and traffic management. This coordination ensures that resources are shared safely and efficiently. Additionally, AGVs may operate in different environments, such as indoor warehouses, factory floors, or hospital corridors. Therefore, the navigation system must adapt to all environmental changes. Advances in sensor technology can overcome current navigation challenges. Multi-sensor fusion can improve the efficiency of environmental perception and data analysis. Artificial intelligence and deep learning technology can give AGVs stronger intelligence to improve environment perception and decision-making. High-precision positioning technology can improve navigation accuracy and stability. Real-time communication is the key to the collaborative work of AGVs. Reliable communication protocols and systems need to be studied to realize real-time data sharing and collaboration. Ensuring the safety and reliability of AGVs is critical. Sensor technology plays a key role in improving both through hardware improvements and algorithm optimization. In summary, while sensor technology offers opportunities to improve AGV functionality, it is critical to strike a balance between cost and benefit. Therefore, the development of AGVs requires careful consideration of the cost and effectiveness of sensor technology. Proper sensor configurations and technical solutions can meet user needs while minimizing costs. Ultimately, addressing these challenges will pave the way for the continued development and widespread adoption of AGVs in various industrial and commercial applications.

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