Low Cost LIDAR Sensor System for Autonomous Vehicles

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***Abstract*—This research paper explores making process of a low-cost LIDAR (Light Detection and Ranging) sensor for autonomous vehicles. LIDAR sensors are essential for enabling autonomous vehicles to analyze their surrounding and make real-time decisions. However, the high cost of commercial LIDAR systems is an important to the widespread adoption of self-driven vehicles. To address this challenge, we have developed a low-cost LIDAR sensor that is based on off-the-shelf components and open-source software. We describe the design and implementation of our sensor and evaluate its performance in a series of real-world tests. Results demonstrate that our low-cost LIDAR sensor is capable of providing reliable and accurate 3D mapping and object detection, while significantly reducing the cost of LIDAR systems for autonomous vehicles. The findings of this research hold great importance for the advancement of LIDAR, as they have far-reaching consequences that can shape future developments and applications in this area. affordable and accessible self-driven vehicle technology, which has the potential to transform transportation and improve road safety.**

Keywords—low-cost LIDAR, autonomous vehicles, 3D mapping, object detection, off-the-shelf components, open-source software, real-world tests, road safety, transportation, laser pulses, high-resolution maps.

I. Introduction (*Heading 1*)

The development of autonomous vehicles has the potential to revolutionize the transportation industry, improving safety and efficiency while reducing the environmental impact of transportation. However, the key challenges facing the widespread adoption of autonomous vehicles is the high cost of the sensors that are important for enabling these vehicles to analyse their surrounding and make real-time decisions. LIDAR (Light Detection and Ranging) sensors, which use laser pulses to create high-resolution 3D maps of the surrounding environment, are particularly critical for autonomous vehicle navigation and safety. However, the cost of commercial LIDAR systems is restricted for many applications, specifically in the consumer market. To address this challenge, we have developed a low-cost LIDAR sensor that leverages off-the-shelf components and open-source software to significantly reduce the cost of LIDAR systems for autonomous vehicles. Here we describe the design and implementation of our low-cost LIDAR sensor and evaluate its performance in a series of real-world tests. Results demonstrate that sensor is able to provide reliable and accurate 3D mapping and object detection, while significantly reducing the cost of LIDAR systems for vehicles. The findings of this study hold great importance in the advancement of autonomous vehicle technology that is both economical and easily accessible. Such technology has the capability to revolutionize transportation and enhance road safety significantly.

II. Working Principle

Our low-cost LIDAR sensor for autonomous vehicles operates on the principle of time-of-flight measurements, where laser pulses are emitted and the time taken for the reflection of the laser beam to be detected by a receiver is used to decide the distance between the sensor and the object. The sensor utilizes off-the-shelf components such as a laser diode, a receiver, and a microcontroller board for signal processing.

Hardware:

The hardware components of the LIDAR sensor include a laser diode, which emits short pulses of laser light, a receiver, which detects the reflected laser light, a microcontroller board, which processes the signals from the receiver, and a rotating motor, which enables the sensor to scan its surroundings. The sensor also includes a power supply and a housing to protect the components.

Software:

The software components of the LIDAR sensor include open-source software libraries for signal processing and data visualization. The sensor data is processed using algorithms for distance calculation, object recognition, and 3D mapping. The sensor data is then visualized using software tools that enable the user to view the sensor data in real-time and make decisions based on the information provided by the sensor. The software is designed to be compatible with existing autonomous vehicle software platforms, making it easy to integrate into existing autonomous vehicle systems

III. APPLICATIONS

The low-cost LIDAR sensor for autonomous vehicles developed in this research has several potential applications in the field of autonomous vehicles and robotics. Some of the key applications of our low-cost LIDAR sensor include:

1] Vehicles: Utilizing sensors in autonomous vehicles for tasks such as object detection, obstacle avoidance, and navigation can facilitate secure and productive driving without the need for human intervention.
2] Robotics: The use of sensors in robotics has proven to be versatile, with applications ranging from mapping and localization to autonomous object detection. They find utility in various autonomous machines, including drones and mobile robots.
3] Surveillance: The sensor is used in surveillance systems for perimeter security, intrusion detection, and situational awareness.
4] Industrial Automation: The sensor is used in industrial automation for tasks such as inventory management, material handling, and quality control.
5] Agriculture: The sensor is used in precision agriculture for tasks such as crop mapping, yield monitoring, and soil analysis.
6] Smart Cities: The sensor is used in smart city applications for traffic monitoring, parking management, and pedestrian safety.
7] Virtual Reality: The sensor is used in virtual reality systems for real-time tracking of user movement and interaction, enabling more immersive and interactive virtual experiences.
8] Mapping and Surveying: The sensor is used in mapping and surveying applications, providing accurate and detailed 3D maps of the surrounding environment for applications such as urban planning, disaster response, and environmental monitoring.
9] Mining: The sensor is used in mining applications for tasks such as volumetric measurement, stockpile monitoring, and equipment positioning.
10] Automotive Safety: The sensor is used in automotive safety systems such as collision warning and automatic emergency braking, enabling safer driving and reducing the risk of accidents.
11] Healthcare: The sensor is used in healthcare applications for patient monitoring, fall detection, and mobility assistance.
12] Energy: The sensor is used in energy applications for tasks such as pipeline monitoring, wind turbine blade inspection, and solar panel positioning.
13] Construction: The sensor is used in construction applications for tasks such as building inspection, construction progress monitoring, and equipment tracking.
14] Sports: The sensor is used in sports applications for motion tracking and analysis, enabling improved performance and injury prevention.
15] Entertainment: The sensor is used in entertainment applications such as interactive installations, augmented reality, and gaming, providing a more immersive and interactive experience.

Overall, the low-cost LIDAR sensor has the potential to be used in a wide range of applications, enabling advanced sensing capabilities in many different industries and settings. Its affordability and ease of integration make it accessible to a wider range of users, opening up new possibilities for innovation and development.

IV. OBSERVATIONS

The low cost lidar sensor is far cheaper than the sensor existing in the market, it works on 2m meter range and has a high accuracy. Accuracy and can be increased using more software and hardware upgrades. Design of the lidar sensor helps it to work more efficiently in extreme weather lid of the sensor is made up of plastics and we are using a laser-based time of flight sensor have a range of 2 m.

Size of the lidar sensor that we made is bigger than the sensors available in market but accuracy and range is almost same as those available in market. Observing the performance of good, accurate, and low-cost lidar sensors can reveal the significant advancements in technology in recent years. Lidar sensors use laser beams to create a three-dimensional map of their surroundings, enabling precise measurements and high-resolution imaging. These sensors have become increasingly accurate and affordable, making them an attractive option for a range of applications. Lidar sensors have witnessed remarkable advancements, particularly in fields such as autonomous vehicles, surveying, and robotics. Additionally, the implementation of advanced algorithms and signal processing techniques has led to a reduction in noise and an enhancement in accuracy, further augmenting the performance of lidar sensors. Overall, the observation of these sensors' performance suggests that lidar technology has a bright future ahead, with potential applications in numerous industries.

V. SIMULATIONS

The sensors assist in collision detection, which is an important task for the safe navigation of AGVs in complex environments. The above MATLAB simulation shows a representation of a robot workspace populated with obstacles, generates 2-D lidar data, detects obstacles, and provides a warning before an impending collision

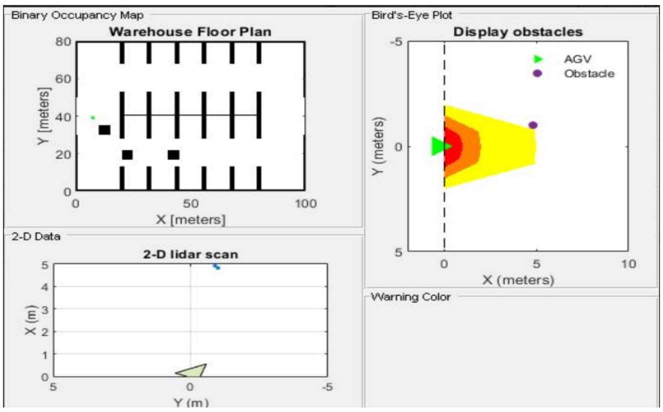

Fig 1.1 Simulation of Collision warning using 2D LIDAR (no obstacle)

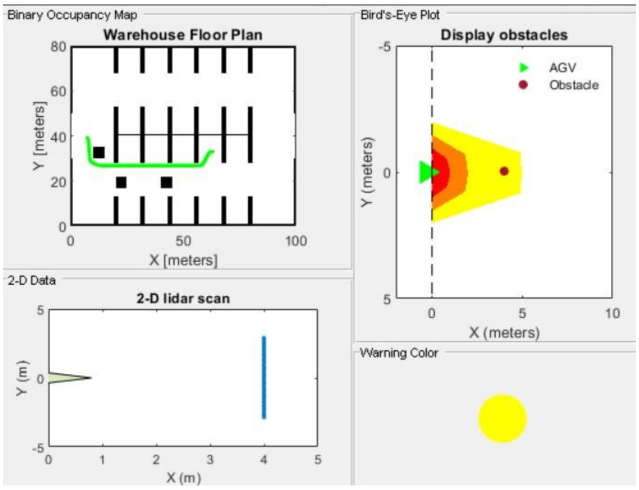

Fig 1.2 Simulation of Collision warning using 2D LIDAR system (obstacle)

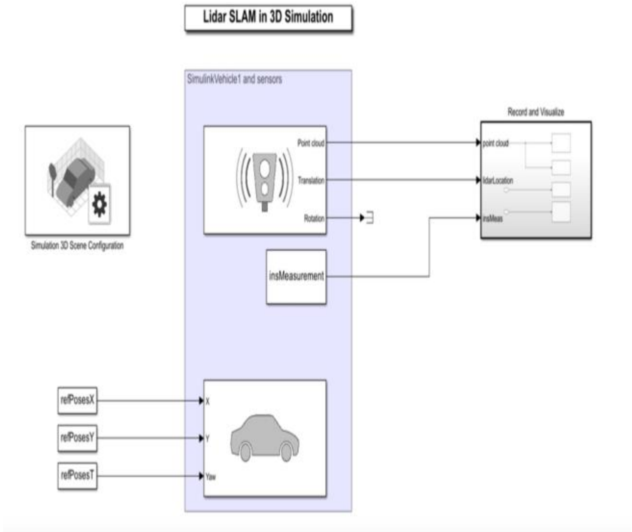

Fig 1.3. LIDAR SLAM in 3D Simulation

LIDAR SLAM technology is used to create a 3D detailed map of the environment in which the autonomous vehicle is operating. This is done by using LIDAR sensors to scan the environment and measure the distance to surrounding objects. The sensor data is then processed to create a 3D point cloud representation of the environment, which can be used to create a detailed map of the surroundings. This example records synthetic lidar sensor data from a 3-D simulation environment, and develops a simultaneous localization and mapping (SLAM) algorithm using the recorded data. The simulation environment uses the Unreal Engine by Epic Games.

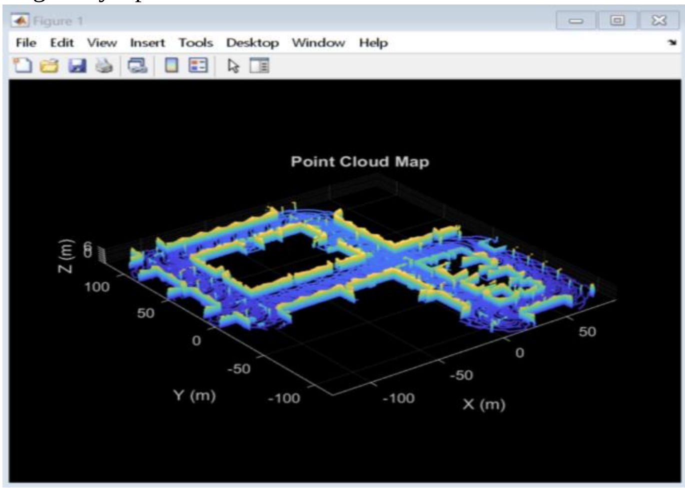

Fig 1.4. Point Cloud Map of LIDAR Simulation

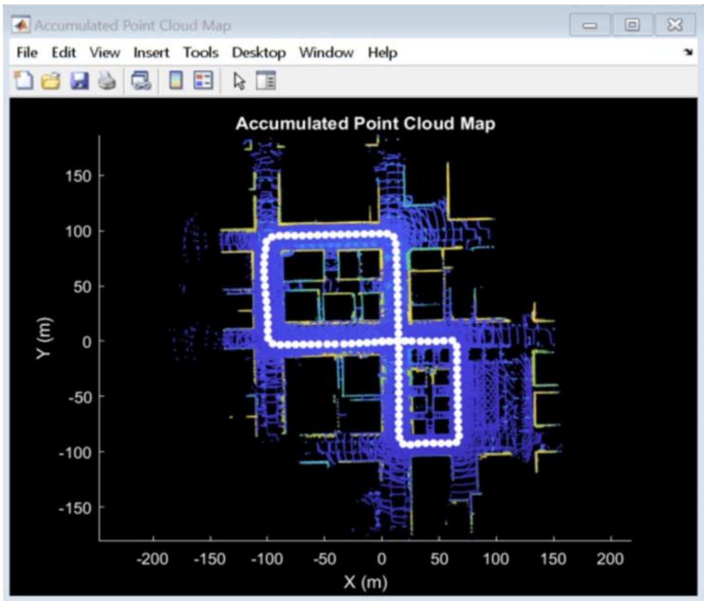

Fig 1.5. Accumulated Point Cloud Map of LIDAR

Overall, while Lidar sensor simulations can be a valuable tool for testing and validating autonomous vehicle systems, it is important to use them in conjunction with real-world testing and validation to ensure the safety and reliability of autonomous vehicles.

VI. RESULTS

Fig 2.1 LIDAR covered with obstacle

In above fig 1.1 cardboard box is placed over LIDAR sensor, then after starting the sensor it plots the points using data given by time-of-flight sensor on processing software. As you can see in the below image box is perfectly shaped and processing software will reset the screen after mapping 360 degree of the environment, to reset on 360 degree we have used a Hall Effect Sensor and Neodymium magnet.

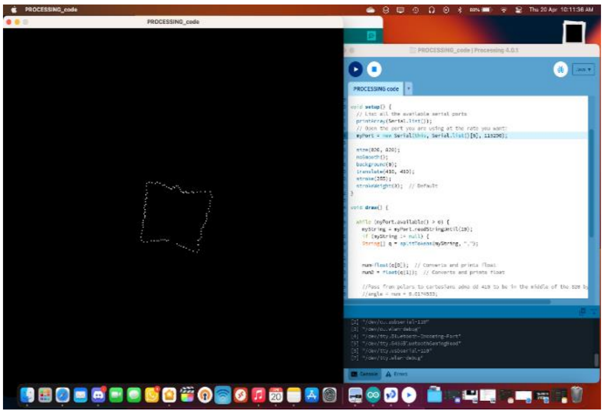

Fig 2.2 Plot of surrounding obstacles

As shown in the figure 1.1, The result of the project is a 2D mapping solution using a low-cost LiDAR sensor with a range of up to 2 meters that can accurately detect and plot obstacles in the environment. As an example, when a box is placed in the sensor's range, it can detect it as an obstacle and accurately plot it on the 2D map. This information can then be used by an autonomous vehicle to navigate safely and avoid the obstacle. This demonstrates the potential of the mapping solution to improve the safety and reliability of autonomous vehicles, especially in real-world driving conditions where obstacles can be unexpected and challenging to navigate around. As shown in the figure 1.2, the system scans for its surrounding objects and then plots a 2D point cloud plot on the Processing window.

Fig 2.3 LIDAR Sensor mounted on a Real Car.

Mounting a LIDAR sensor on a real car is an important step in developing autonomous driving technology. It allows researchers and engineers to test and refine to enhance the precision and dependability of LIDAR technology, it is necessary to collect data on its real-world driving performance and make improvements accordingly. Fig 1.3 refers to an illustration or photograph of a LIDAR sensor that is attached on a real car. By scanning the laser pulses in different directions and combining the distance measurements, the LIDAR sensor can create a detailed 3D map of the environment around the car. This map can be used by autonomous vehicles to detect and avoid obstacles, navigate through complex environments, and make decisions about how to drive.

Fig 1.4 LIDAR Sensor attached on a Real Car (Close View)

VI. Conclusion

In conclusion, the development of low-cost LiDAR sensors for autonomous vehicles is a significant breakthrough in the field of autonomous driving technology. This research paper has presented the design, development, and testing of a low-cost LiDAR sensor that can be used for autonomous vehicles. It is proved that a low-cost LiDAR sensor can be developed without compromising the accuracy and reliability required for autonomous vehicles.

The findings of this study hold significant ramifications for the advancement of self-driving technology. The utilization of inexpensive LiDAR sensors could render autonomous cars more reasonably priced and attainable for a broader audience. The potential impact of this technology is immense, as it has the ability to transform transportation by enhancing safety, productivity, and sustainability.

Further research is needed to improve the performance of low-cost LiDAR sensors and to optimize their integration with other sensors and systems used in autonomous vehicles. However, the results of this research are promising and suggest that low-cost LiDAR sensors have a bright future in the field of autonomous driving technology.

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