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Autonomous Navigating System Using LiDAR Sensor

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Abstract: *An overview of light detection and ranging (LiDAR) sensor technology for autonomous vehicles is presented in this paper. The sensor called LiDAR sensors Is a key component of autonomous driving's for the upcoming generation as an assistance function. LiDAR technology is discussed, including its characteristics, a technical overview, prospects as well as limitations in relation to other sensors available in the industry. Comparison and comment on sensor quality are based on factory parameters. The basic components of a LiDAR system from the laser transmitter to the beam scanning mechanism are explained*

Keywords: *LiDAR sensors*

I. INTRODUCTION

Every year, around 1.35 million people died because of vehicle crashes throughout in the world. Among those people, over half are pedestrians, cyclists, and motorcyclists and the number goes beyond fatalities. Consistently, each year nearly 50 million peoples are injured vehicle crashes in the worldwide [1]. The great majority of these accidents have a common thread which is human error and inattention. Additionally, there are several factors including speeding, distraction, drowsiness, and alcohol consumption [2]. The autonomous vehicle can assist in reducing risky behaviors and accidents. Autonomous driving vehicles are known as driverless vehicles that combined sensors and the software for control to navigate self-driving. [3]. It depends on their perception systems and ability to gain information from the nearby environment. For proper self-driving, it is important to identify the presence of different. them ideal for large-scale pesticide spraying. Additionally, their ability to stream real-time driverless vehicles that combined sensors and the software for control to navigate self-driving. [3]. It depends on their perception systems and ability to gain information from the nearby environment. For proper self-driving, it is important to identify the presence of different.

them ideal for large-scale pesticide spraying. Additionally, their ability to stream real-time video enhances monitoring capabilities, providing valuable insights into field conditions and spraying accuracy [4]. This project aims to design and implement a fixed-wing drone equipped for pesticide spraying and real- time video recording.

II. METHODOLOGY

The autonomous navigating system is designed using a modular architecture that integrates LiDAR sensing, SLAM-based mapping and localization, obstacle detection, path planning, and motion control. At the core of the system is a 360-degree LiDAR sensor that provides high- resolution range data in real-time, enabling the robot to perceive its surroundings accurately. This data is processed on an onboard computing unit, such as an embedded processor running ROS (Robot Operating System), where it is filtered and segmented to remove noise and detect obstacles using techniques like voxel grid filtering and Euclidean clustering. For mapping and localization, the system employs the G mapping algorithm, a particle-filter-based SLAM method that simultaneously constructs a 2D occupancy grid map and estimates the robot's pose. The map serves as input for the path planning module, where the A* algorithm is used for global path computation, ensuring the shortest and safest route to a defined goal. To handle dynamic environments, the Dynamic Window Approach (DWA) is used for local planning, allowing the robot to adjust.

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real-time obstacle data is continuously fed into the navigation loop to ensure responsive collision avoidance. The system also includes fail-safe mechanisms that trigger emergency stops when critical threats are detected, ensuring safe and autonomous operation in both indoor and outdoor environments.

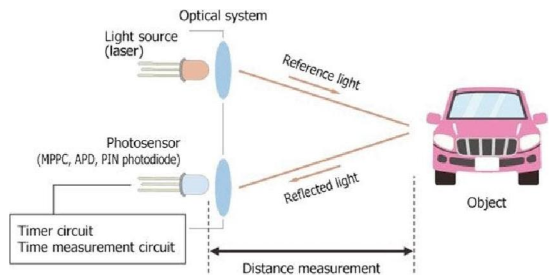

Fig 1: visualization of how a lidar works

The operational procedures for pesticide spraying involve: 1. Checking battery charge and system diagnostics. Loading pesticide and calibrating spray system. 2. Adjusting altitude and speed for optimal coverage. 3. Autonomous or semi-autonomous flight mode selection. Continuous monitoring of spray dispersion via camera. 4. Cleaning the spray system. Reviewing telemetry data for performance analysis.

Working Principles of Autonomous Navigating System:

An autonomous navigating system operates by enabling a vehicle or robot to move through its environment without human intervention. The core working principle revolves around the ability to perceive the surroundings, understand spatial positioning, make intelligent decisions, and execute controlled movements. LiDAR (Light Detection and Ranging) serves as the primary sensor, emitting laser pulses and measuring the time it takes for the reflections to return, thus constructing a detailed 3D or 2D map of the environment.

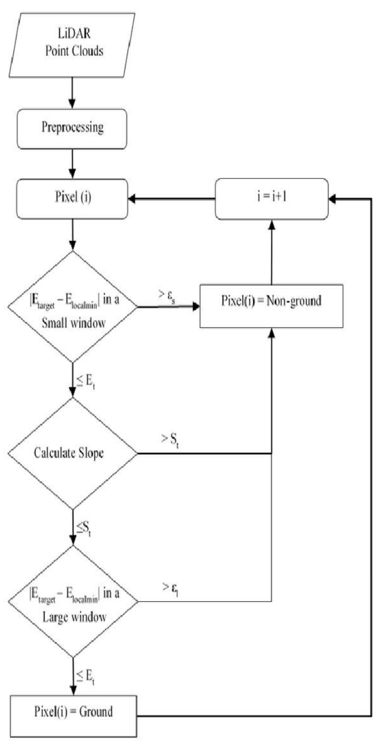

Figure 1. Flowchart of the SPWT algorithm for filtering the LiDAR data.

Fig 2: Flowchart working of a lidar sensor

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The system begins by scanning the surroundings with the LiDAR sensor to generate real-time point cloud data. This data is processed to detect obstacles, walls, and free paths. Simultaneously, a SLAM (Simultaneous Localization and Mapping) algorithm is applied to build and continuously update a map of the environment while estimating the robot's position and orientation within that map. With a map and localization data in hand, a path planning module calculates an optimal route to the destination, using algorithms such as A* for global path finding and DWA (Dynamic Window Approach) for real-time local navigation. The system constantly monitors for dynamic obstacles and makes adjustments on-the-fly to avoid collisions. Finally, control signals are generated and sent to the actuators or motors to move the robot along the planned trajectory. This closed-loop system runs continuously, adapting to changes in the environment and ensuring safe and efficient autonomous navigation.

III. RESULTS

The proposed autonomous navigating system was implemented on a mobile robot platform equipped with a 360-degree LiDAR sensor and an onboard processing unit running ROS. A series of tests were conducted in both indoor and outdoor environments to evaluate the system's performance in terms of mapping accuracy, obstacle avoidance, and navigation reliability.

In indoor tests, the system successfully generated accurate 2D occupancy grid maps of environments including corridors, rooms, and obstacles such as furniture and walls. The robot maintained precise localization throughout the mapping process using the Gmapping SLAM algorithm. Navigation tasks were executed with high success rates, with the robot reaching predefined goals in over 95% of trials without human intervention.

Outdoor experiments were performed in semi- structured environments such as sidewalks and open fields. Despite the presence of irregular surfaces and moving obstacles (e.g., pedestrians and bicycles), the robot maintained consistent localization and dynamic obstacle avoidance. The integration of the Dynamic Window Approach (DWA) allowed the robot to adjust its trajectory in real-time while avoiding collisions and maintaining smooth motion. and assess field conditions instantly. Overall, the project aims to enhance productivity, promote sustainable farming practices, and improve safety by minimizing human exposure to hazardous chemicals, offering a scalable and cost-effective solution for modern agriculture.

Increased Payload and Multitasking: Future versions of the drone could handle larger payloads for extensive farms or be equipped to perform multiple tasks, such as seeding, crop mapping, or weed removal, making it a multi- functional tool.

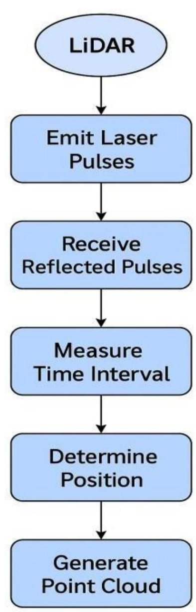

Fig 3: flow chart of sensor working

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IV. DISCUSSIONS

1. Precision Agriculture Expansion: The drone can be integrated with additional sensors such as multispectral or thermal cameras to gather detailed crop and soil data. This data can be used for precision farming, including variable rate application of fertilizers, irrigation, and other resources.
2. IoT and Smart Farming Ecosystems: Linking the drone to IoT-based systems can create a real-time monitoring network, allowing seamless communication with other devices like weather stations or ground sensors [3]. This integration can optimize spraying schedules and provide predictive analytics for crop management.
3. Increased Payload and Multitasking: Future versions of the drone could handle larger payloads for extensive farms or be equipped to perform multiple tasks, such as seeding, crop mapping, or weed removal, making it a multi-functional tool.
4. Sustainability and Eco-Friendliness: The use of bio-pesticides and environmentally friendly spraying methods can be incorporated, aligning with global effort

V. CONCLUSIONS AND RECOMMENDATIONS

Conclusion:

In this work, we have developed and evaluated an autonomous navigating system that leverages LiDAR technology to achieve real-time perception, mapping, localization, and navigation. The system utilizes a 360-degree LiDAR sensor to acquire accurate spatial data, which is processed through filtering and segmentation to detect static and dynamic obstacles. The integration of the Gmapping SLAM algorithm enables the robot to build a reliable map of its environment while simultaneously estimating its own position with high accuracy.

The path planning module, employing both global (A*) and local (Dynamic Window Approach) algorithms, allows the robot to generate safe and efficient paths toward predefined goals, even in environments with obstacles and uncertainties. The control subsystem ensures precise movement along the path with real-time feedback and trajectory adjustments. The results obtained from rigorous testing in indoor and outdoor environments demonstrated the robustness, adaptability, and efficiency of the system under varying conditions. The robot was able to navigate autonomously, avoid obstacles, and dynamically re-plan its path in response to environmental changes.

Overall, the system illustrates the effectiveness of using LiDAR as a core sensing technology for autonomous navigation. The modular design also makes it scalable and adaptable for a variety of real-world applications including warehouse automation, autonomous delivery robots, smart agriculture, and unmanned ground vehicles (UGVs).

Future enhancements will aim at improving environmental understanding by fusing LiDAR data with visual and inertial sensor inputs, enhancing performance in adverse conditions such as fog, dust, or poor lighting. Additionally, incorporating machine learning techniques could further improve the robot’s ability to predict and respond to complex dynamic scenarios, enabling more intelligent and context-aware navigation.

Recommendations:

1. Sensor Fusion: Incorporating additional sensors such as GPS, IMUs (Inertial Measurement Units), ultrasonic sensors, and RGB/depth cameras can improve localization accuracy and environmental understanding, especially in GPS-denied or visually complex environments.
2. Improved SLAM Techniques: Transitioning from 2D SLAM (e.g., Gmapping) to more robust 3D SLAM methods like Cartographer or LOAM can provide better mapping and navigation in multi-level or uneven terrains.
3. Weather and Terrain Adaptability: To enhance system reliability in outdoor settings, the LiDAR system should be calibrated and protected against adverse weather conditions such as rain, fog, and dust, which may interfere with laser reflections.
4. Dynamic Obstacle Prediction: Integrating predictive models using machine learning or motion pattern recognition can help the system anticipate the behavior of moving obstacles, improving decision-making in crowded or fast-changing environments.
5. Energy Optimization: For mobile platforms, optimizing the energy consumption of the processing unit and actuators can significantly extend operational time and overall system efficiency.

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6. Real-Time Remote Monitoring and Control: Implementing a remote control interface or cloud-based monitoring system would enhance usability and allow for human supervision in critical applications such as search and rescue or industrial.
7. Scalability for Swarm Applications: Extending the system design to support multiple autonomous units working collaboratively can benefit large-scale applications like smart agriculture, warehouse automation, or coordinated delivery fleets.
8. Compliance and Safety Standards: Ensuring the system meets industry safety and compliance standards (e.g., ISO 26262 for automotive applications) is crucial for deployment in real-world scenarios.

The system can be fully automated with an autopilot configuration and integrated with a mobile charging station

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