Department of Electrical Engineering and Computer Science

Howard University

Washington, DC 20059

EECE 404 Senior Design II

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Team Name: DroneSense

Project Name: Drone Obstacle Avoidance System

Final Project Report:

90/100

DroneSense

By:

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Abstract:

"Autonomous LiDAR drones, equipped with Light Detection and Ranging (LiDAR) technology, are changing the game in data collection" (*Autonomous Lidar drone mapping*). The increasing use of drones in various fields such as surveying, delivery, and inspection, introduces critical safety challenges, especially in complex and unpredictable environments. Traditional drone operation depends heavily on human reflexes and manual control, often leading to accidents and property damage due to limited situational awareness. This project proposes an autonomous Drone Obstacle Avoidance System that enhances flight safety and operational efficiency by integrating lidar-based environmental sensing and real-time path correction. By enabling autonomous navigation, the system significantly reduces the likelihood of collisions and human error, paving the way for safer deployment of drones in both civilian and industrial applications. The system is designed with regulatory compliance in mind, including FAA and FCC standards, while being optimized for varying environmental conditions.

The drone system was tested in both simulated and real-world environments using Gazebo and Mission Planner. In both of these paths, the drone was successful in demonstrating autonomous flight and obstacle avoidance. The drone is able to transition between flight modes such as Auto, ALT_HOLD, Guided, and many more which allow for flexible control over deployment. The drone also is connected to a raspberry pi which allows it to be intergrated with various paths of code. This project will allows us to reduce human supervision due to the autonomous supervision while complying many safety standards.

Problem Statement:

Controlling a drone requires quick reflexes, especially if pilots are unfamiliar with the environment. Improper control causes accidents, injury, and property damage. The drone system will enable autonomous obstacle avoidance, allowing the drone to detect obstacles and adjust its speed and trajectory each time it encounters an obstacle. The system will allow drones to work in more complex environments and improve safety by reducing drone accidents

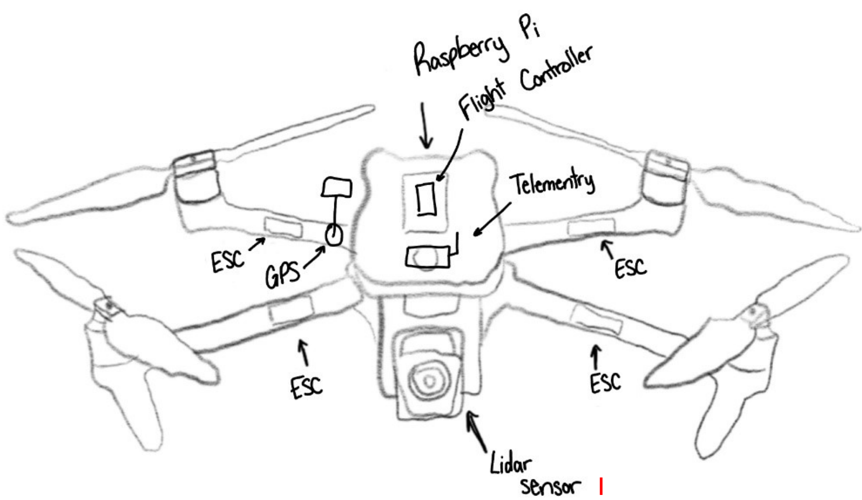
Design Requirement:

The Drone Obstacle Avoidance System allows drone operators to be more safe and efficient by reducing human error, improving reaction time, and allow for autonomous movement in complex environments. The drone will utilize lidar sensors to detect nearby obstacles and automatically adjust its speed and flight path. Key components of our drone includes a f450 drone frame with landing gear, a TFmini S Lidar Sensor with 12m range, a M8N GPS module, raspberry pi 5, a buck converter, 30A electric brushless motor controller (ESCs), Pixhawk flight controller, 3s LiPo battery 2200mAh 11.1V 35C, motors and propellors. In regards to the sensor, the "TFmini-S is a short-range single-point laser radar with three advantages: low cost, small size, and low power consumption. It has multiple interfaces to meet the needs of different customers. As an upgraded version, TFmini-S maintains its compact and lightweight design, has higher performance, and is suitable for a wider range of applications" (*TFmini-S 12 m small laser ranging module*). The system will also use radio telemetry system so that the drone can still communicate and be monitored by the control center laptop. To meet the demands of various weather conditions and flight rules, the drone design must comply with the FAA and FCC regulations, noise levels, privacy rules where camera could be involved, and have enough power and capable of stable flight. There are many rules for recreational flyers from the FAA. This includes recreational flyers keeping their drones within their line of sight, and staying below 400 ft in uncontrolled airspaces (*Recreational Flyers & community-based organizations* 2025).

-10 Deficiency in patent-style description and the details of the structure and operation

Solution Design:

To develop the drone obstacle avoidance system, our team explored and generated multiple solution designs based on our design matrix, which evaluated each design on functionality, vision, cost and flight time. Each idea focused on enhancing safety and autonomous navigation. We analyzed multiple options, such as multiple lidar sensors, a 360-degree lidar sensor, and ultrasonic sensors, to reduce interference and implement autonomous movement. Each design was fairly evaluated, with Jeremy's solution design scoring the highest using the design matrix. Ultimately, the selected design equips the drone with a lidar sensor that allows it to detect nearby obstacles and automatically adjust its speed autonomously.



Side View

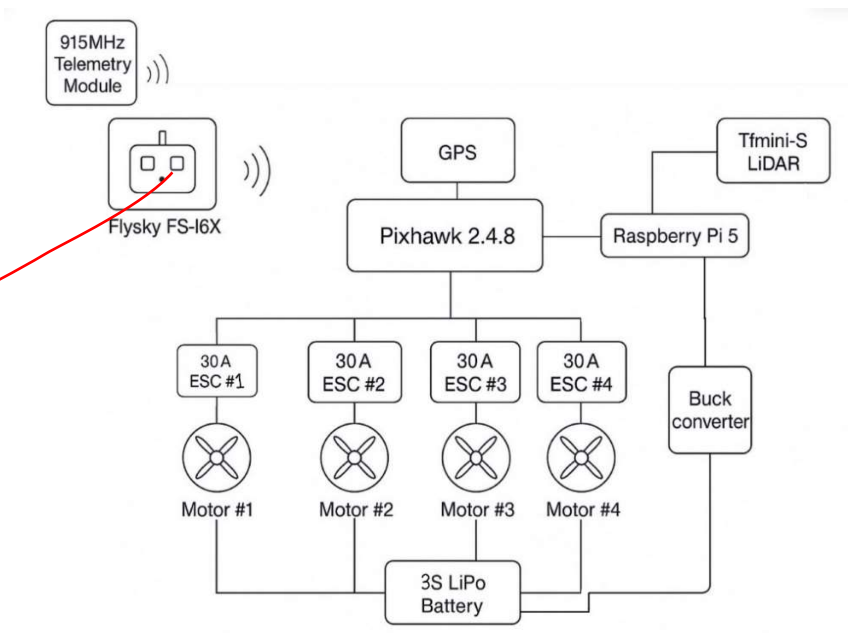
This picture shows the solution design that was used for the project.

Project Implementation:

To build our autonomous drone with obstacle detection capabilities, we followed a structured but flexible approach inspired by Agile methodology. The project was executed over several weeks, beginning in a simulated environment and gradually progressing to full hardware integration for real-world testing. Our first goal was setting up the foundation. We began by downloading all the necessary software such as Gazebo, PX4, and QGroundControl to simulate drone behavior in a virtual environment. Once the software was ready, we configured the simulated drone and populated its surroundings with a variety of virtual obstacles to mimic real-world conditions. With this environment established, we made the drone operational in the simulation and integrated a basic obstacle detection algorithm that used simple machine learning techniques to avoid collisions. Once we had a functioning simulation, we moved into enhancing the drone's sensing capabilities by integrating LIDAR and camera-based object detection. This phase allowed the drone to perceive its surroundings more accurately and respond in real time. We also refined our machine learning algorithm during this period, making it more effective at identifying and maneuvering around obstacles with greater precision. With these improvements, we enabled the drone to fly autonomously in the simulation, continuously adjusting the virtual environment to further test its adaptability. After the virtual testing phase, we transitioned to building and integrating physical components. We finalized the simulation code to run on a Raspberry Pi, preparing it for use as the drone's onboard processor. We then assembled the drone's physical frame and connected key hardware elements including the flight controller, battery, transmitter, and receiver. In the final stage, we integrated the microcontroller, GPS unit, Raspberry Pi, and power module to form a cohesive and fully autonomous drone platform.

Project Implementation Process:

The drone obstacle avoidance system was conducted over multiple sprints, each focusing on incremental development and integration of the drone's obstacle avoidance system. The following subsections will detail the work completed in each sprint supported by screenshots and figures to illustrate the process.



This picture shows the component-level schematic that was used for the project.

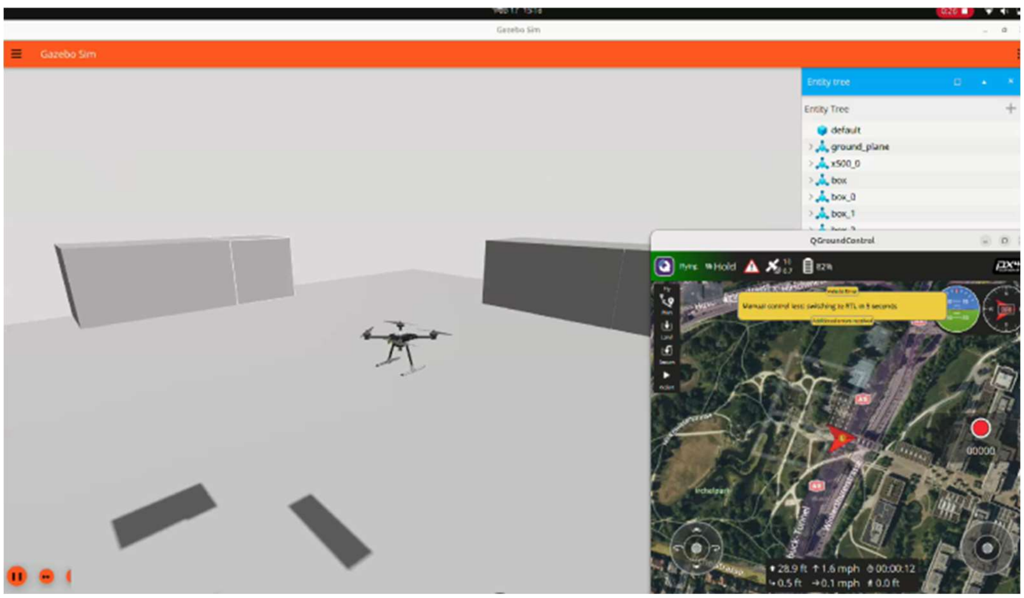
Sprint 1: Basic Obstacle Avoidance in a Simulated Environment

The first sprint aimed to establish a foundation for obstacle detection by developing and testing a basic algorithm within a simulated environment. The tasks were planned over three weeks.

In week 1, the team installed and configured simulation software, including Gazebo to create a virtual environment for testing the drone.

During week 2, the drone model based on the F450 frame was integrated into the Gazebo environment. Multiple obstacles, such as walls of varying sizes, were added to simulate real-world scenarios.

In week 3, the team implemented a basic flight control algorithm to enable the drone to navigate the simulated environment. The algorithm was then tested by flying the drone through the obstacle-filled environment.



This picture shows the drone successfully flying in the Gazebo environment.

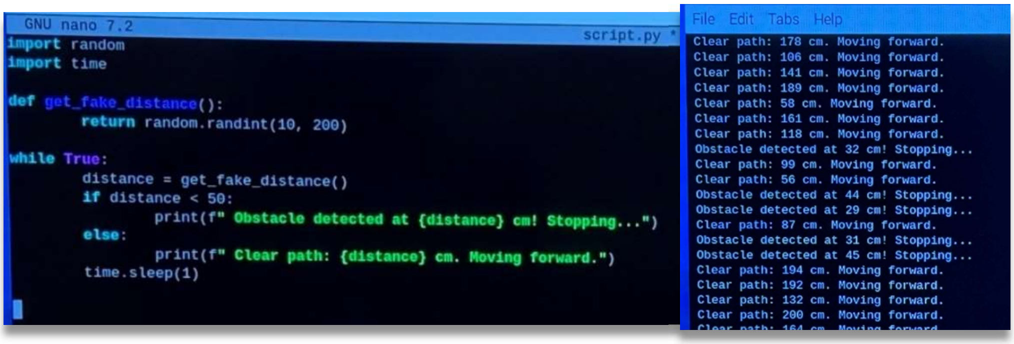
Sprint 2: Software integration with Hardware components

The second part of the sprint focused on transitioning from simulation to hardware integration, incorporating the LIDAR sensor for object detection.

In week 1, the Tfmini- S LIDAR sensor was physically integrated with the Raspberry Pi5 which served as the onboard computing platform. Software drivers were developed to process the LiDAR data.

In week 2, the algorithm was refined to improve its performance. The algorithm was optimized to execute avoidance maneuvers such as engaging the drone in ALTHOLD, LOITER and AUTO mode when detecting an obstacle.

In week 3, the drone was configured for autonomous flights using the Flysky transmitter and receiver. The team tested the integrated system in a controlled environment ensuring the LiDAR data were correctly processed by the Raspberry Pi and communicated to the Pixhawk flight controller.



This picture shows the simulated lidar sensor data and its terminal output.

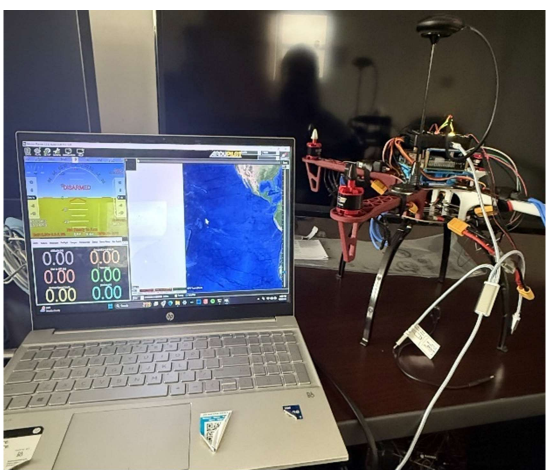
Sprint 3: Fully Integrated Drone and Real-world Testing

Sprint 3 aimed to complete the drone's assembly and conduct real world testing to validate its autonomous navigation and detection capabilities.

In week 1, the team finalized the Gazebo simulation to mirror the physical drone's configuration. The Raspberry Pi was configured to handle real time data processing from the LiDAR and GPS module.

In week 2, the F450 frame was assembled and all hardware components were mounted including the Pixhawk 2.4.8 flight controller, 3S LiPO 2200mAh battery, 30A ESCs, brushless motors, and the Flysky FS-16x receiver. The 915 MHz 100mW RC telemetry kit was installed to enable real-time communication between the drone and the ground station.

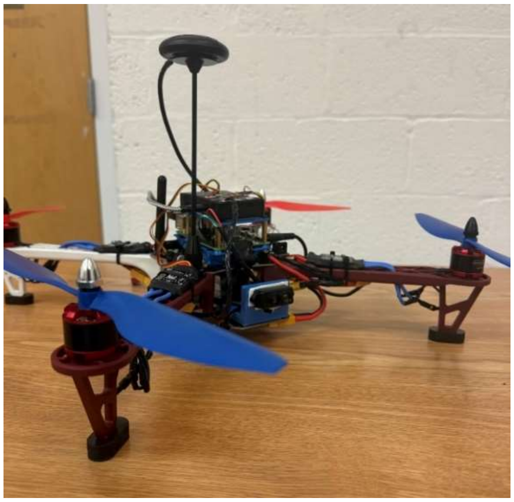
In week 3, the GPS module was integrated to provide precise positioning data, enhancing the drone's ability to navigate complex environments. The fully assembled drone was tested in a controlled outdoor environment, where it successfully detected obstacles while maintaining stable flight.



This picture shows the Mission Planner software used to program the Pixhawk flight controller.

Conclusion:

Over the course of this project, our team successfully implemented an autonomous Drone Obstacle Avoidance System that enhances operational safety and efficiency in complex environments. By integrating a TFmini S Lidar Sensor with a Raspberry Pi 5 and Pixhawk flight controller, the system allows real-time detection and avoidance of obstacles, significantly reducing the dependence on human reflexes and minimizing the risk of collisions. Through design evaluation and implementation, we demonstrated how autonomous systems can improve drone navigation reliability while adhering to FAA and FCC regulations. Our solution balances performance, cost, and environmental adaptability, making it a practical foundation for future expansion for industrial drone applications. The structured engineering approach we followed—from requirement analysis to system integration—resulted in a fully functional prototype capable of adjusting its flight path based on real-time environmental input. This project not only addresses a critical safety challenge in modern drone use but also sets a precedent for scalable and regulatory-compliant autonomous drone systems. Future iterations can explore additional sensor fusion and advanced path-planning algorithms to further enhance autonomy and environmental interaction.



This picture is the completed product of the drone obstacle avoidance system.

References

Benewake. (n.d.). TFmini-S 12 m small laser ranging module. https://www.benewake.com/TFminiS/index.html

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