

LiDAR Micro Drone for Proximity Sensing

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Abstract:

The LiDAR Micro Drone is an advanced and compact unmanned aerial vehicle (UAV) designed for intelligent navigation, obstacle detection, and environmental monitoring. It employs LiDAR (Light Detection and Ranging) technology to measure distances by transmitting laser pulses and calculating the Time of Flight (ToF) of reflected signals, enabling real-time distance mapping and efficient obstacle detection during flight. The ESP32-S3 microcontroller provides high-speed dual-core processing, low power consumption, and built-in Wi-Fi and Bluetooth 5 communication, making the system highly efficient and reliable. Additional sensors, including the MPU6050 gyroscope and accelerometer for flight stabilization and the BMP388 barometric pressure sensor for altitude control, are fused with RTOS-based firmware for simultaneous sensor processing and motor control. The drone supports autonomous navigation, automatic collision avoidance, and real-time wireless monitoring via ESP-NOW. Experimental results confirm successful obstacle detection across a sensing range of 0.2 m to 8 m, stable indoor flight performance, and effective wireless data transmission. The proposed system delivers a compact, low-cost, and intelligent solution for safe UAV navigation and proximity sensing in indoor and complex environments.

Keywords—LiDAR, micro drone, ESP32-S3, proximity sensing, obstacle avoidance, autonomous navigation, Time of Flight, IoT, embedded systems, RTOS

I. INTRODUCTION

Unmanned aerial vehicles (UAVs) have become increasingly important tools across surveillance, environmental monitoring, disaster management, smart agriculture, and industrial inspection. Among these, micro drones present unique operational advantages due to their compact size and ability to navigate confined or hazardous spaces where larger platforms cannot function effectively.

The LiDAR Micro Drone addresses a critical gap in the existing landscape of low-cost aerial platforms. Most budget drone systems lack real-time obstacle detection and proximity sensing capabilities,

increasing the risk of collision and physical damage. Conventional camera-based sensing further fails in low-light, smoky, or dusty environments. This project proposes an intelligent LiDAR-based micro drone powered by the ESP32-S3 microcontroller to overcome these limitations.

The system integrates the TF-Luna LiDAR sensor for obstacle detection, the MPU6050 gyroscope and accelerometer for flight stabilization, and the BMP388 barometric pressure sensor for altitude maintenance. Together with RTOS-based firmware and wireless communication via ESP-NOW, the proposed drone achieves autonomous navigation and real-time proximity sensing in a compact, low-cost

form factor suitable for educational and research applications.

II. LITERATURE REVIEW

A comprehensive review of existing research on UAVs, LiDAR systems, embedded microcontrollers, and autonomous drone navigation was conducted to identify current advancements, limitations, and research gaps in drone obstacle detection systems.

U. Seidaliyeva et al. (2025) reviewed the role of LiDAR technology in UAV detection and surveillance systems. The paper covers LiDAR fundamentals, sensor types, and data processing methods including clustering and deep learning techniques. The authors concluded that LiDAR provides highly accurate 3D environmental data, improving UAV detection, tracking, and classification performance.

X. Liu et al. (2025) presented a micro-UAV swarm system for indoor autonomous operations integrating localization, communication routing, object detection, and deep reinforcement learning for intelligent decision-making. The authors concluded that advanced sensing and control algorithms enhance localization accuracy, tracking efficiency, and obstacle avoidance in micro-UAV swarm systems.

M. V. N. Mude (2025) discussed recent advancements in microcontroller technology including low-power architectures, AI integration, and IoT connectivity that improve system efficiency and performance. The author concluded that modern microcontrollers play a major role in IoT, automation, and intelligent applications.

L. Zhuang, X. Zhong, L. Xu, C. Tian, and W. Yu (2024) reviewed Visual SLAM techniques used in UAV localization and perception systems, covering sensor configurations, data processing methods, and real-time mapping algorithms for autonomous navigation. The authors concluded that Visual SLAM is an essential technology for accurate UAV mapping and navigation in complex environments.

III. WORKING METHODOLOGY

The proposed LiDAR Micro Drone is equipped with a TF-Luna LiDAR-based proximity sensing unit for obstacle detection and safe navigation. The LiDAR sensor continuously emits laser pulses and measures reflected signals using the Time of Flight (ToF) principle to calculate the distance between the drone and surrounding obstacles.

The overall system architecture consists of nine functional layers: Sensing, Data Acquisition, Processing, Decision-Making, Flight Control, Motor Driver and Actuation, Communication, User Interface, and Power Management. All sensor data is transmitted to the ESP32-S3 onboard controller, which acts as the central processing unit of the entire system.

The driving force is that, all the drone & flight need precised control over for every millisecond, that's why we've choosen ESP32-S3- Zero processor with Dual-core. And to completely utilize both cores at every second, simultaneously, we've used RTOS - Real Time Operating System to process all the data side-by-side, as Core 0 for sensor fusion and Core 1 for motor controls without a single delay.

The sensing layer comprises the TF-Luna LiDAR sensor for obstacle distance measurement via ToF, the MPU6050 for acceleration, tilt, and rotational data (pitch, roll, yaw), and the BMP388 for atmospheric pressure and altitude measurement. UART communication is used for the TF-Luna LiDAR while I2C is used for the MPU6050 and BMP388 sensors.

Upon power-on, the LiDAR sensor begins scanning the surroundings, measuring obstacle distances in real time. The measured distance data is sent to the ESP32-S3 controller, which analyzes the readings using an obstacle avoidance algorithm. If an obstacle is detected within the predefined safety threshold, the controller automatically adjusts the drone's movement to prevent collision. The obstacle avoidance logic determines whether the drone

should move left, right, backward, stop, or land based on the detected proximity.

Flight stabilization is achieved through a PID control algorithm executed on the ESP32-S3, using MPU6050 data to maintain pitch, roll, and yaw balance, generating PWM signals to dynamically adjust motor speeds. SI2302 MOSFET motor drivers translate these PWM signals into speed commands for the four 8520 coreless brushed motors, which drive the propellers to generate thrust and lift. For wireless communication, the ESP32 transmits processed sensor data and drone status to an RC controller or mobile application via ESP-NOW, enabling real-time monitoring of obstacle distance, altitude, orientation, and battery level.

The firmware is developed using PlatformIO IDE with RTOS (Real-Time Operating System), enabling dual-core utilization: Core 0 handles sensor fusion while Core 1 manages motor control, achieving simultaneous processing at the microsecond level. The drone frame was designed using Autodesk Fusion 360 for a lightweight and compact 3D-printed structure. The entire system is powered by a 1S 800 mAh LiPo battery (3.7 V), with the TP4056 module managing safe USB charging and overcharge protection.

IV.EXPERIMENTATION AND TESTING

Comprehensive testing was conducted to validate performance, stability, obstacle detection capability, and wireless communication efficiency of the LiDAR Micro Drone system. Various hardware and software modules were tested individually and collectively to ensure reliable operation and safe flight performance.

The TF-Luna LiDAR sensor was tested for real-time distance measurement accuracy across its full 0.2 m to 8 m sensing range, with obstacle detection accuracy verified at multiple distances and consistent response times in indoor environments. The MPU6050 was validated for accelerometer and

gyroscope reading accuracy, tilt angle measurement, and drone stabilization performance. The BMP388 was tested for air pressure sensing capability and altitude measurement accuracy during flight.

Flight stability testing evaluated drone balancing during takeoff, landing, and hovering, with PID control parameters tuned for smoother operation. Obstacles were placed at varying distances and directions to verify automatic response, stop/change-direction logic, and collision prevention. Battery performance (1S LiPo), wiring integrity, MOSFET switching, and protection components (Schottky diodes and resistors) were also individually validated. System integration testing combined all sensor, controller, motor, and communication modules and conducted multiple trial runs for reliability analysis under different environmental conditions.



V.RESULT AND DISCUSSION

The proposed LiDAR Micro Drone system was successfully designed, implemented, and tested for real-time proximity sensing and obstacle avoidance. The TF-Luna LiDAR sensor accurately measured distances between the drone and surrounding obstacles, enabling effective collision detection. The ESP32-S3 efficiently processed sensor data and controlled motor outputs through the obstacle avoidance algorithm.

The MPU6050 provided stable orientation and balancing data while the BMP388 maintained

altitude during flight. Wireless communication via ESP-NOW enabled real-time monitoring of sensor readings and drone status on the RC controller and mobile application. The experimental results confirmed successful performance in real-time obstacle detection, stable flight control, effective wireless data transmission, basic autonomous navigation, and collision avoidance in short-range indoor environments.

During testing, minor challenges including sensor noise, response delay, and flight balancing issues were observed. These were addressed through calibration, noise filtering using averaging and smoothing techniques, and tuning of flight control parameters. The lightweight frame design and low-cost component selection made the system compact and economical for educational and research deployment. Overall, the project demonstrated that the proposed LiDAR Micro Drone system is effective for proximity sensing, safe navigation, and real-time environmental monitoring applications.

VI.CONCLUSION

This paper has described the development of a LiDAR Micro Drone for real-time proximity sensing and autonomous obstacle avoidance. The integration of the TF-Luna LiDAR sensor with the ESP32-S3 dual-core controller enabled accurate distance measurement and efficient obstacle detection during flight. Additional sensors — MPU6050 and BMP388 — improved drone stability and altitude control, resulting in smoother and safer flight performance.

The obstacle avoidance algorithm successfully reduced collision risks by automatically responding to nearby obstacles within the safety threshold. Wireless communication using ESP-NOW technology allowed smooth real-time data transmission for monitoring and control. The system is made using simple, affordable electronic components and free software tools, making it

practical and suitable for educational institutions, research laboratories, and small-scale industries of any size.

VII.FUTURE SCOPE

Integration of AI and machine learning can be implemented for intelligent obstacle classification and adaptive path planning beyond simple threshold-based avoidance.

Addition of a GPS module can enable outdoor navigation, geo-fencing, and autonomous waypoint-based path planning for extended mission coverage.

Development of 3D mapping and SLAM-based (Simultaneous Localization and Mapping) navigation systems will enable the drone to operate autonomously in complex and unmapped environments without fixed line tracking.

Integration of camera modules for image processing, object tracking, and visual inspection can extend the drone's applications to surveillance, search-and-rescue missions, and industrial inspection.

Development of swarm drone communication and cooperative navigation systems can allow multiple micro drones to collaborate on large-area mapping, inspection, and monitoring tasks.

Optimization of battery management systems and integration of higher-capacity LiPo batteries or wireless charging solutions can significantly extend flight duration and operational efficiency.

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