Autonomous Drone with Obstacle Detection and Avoidance

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Abstract - *An Autonomous Drone is an unmanned aerial vehicle (UAV) that can perform tasks without continuous human control. This project focuses on developing an* ***Autonomous Drone with Obstacle Detection and Avoidance*** *to improve flight safety and reduce accidents. The system uses* ***ultrasonic sensors*** *to detect nearby obstacles such as walls, trees, and buildings. The* ***Arduino Nano*** *processes the sensor data and sends commands to avoid collisions. The* ***KK2.4 flight controller*** *helps maintain drone stability, while* ***BLDC motors and ESCs*** *provide proper thrust and movement control. If an obstacle is detected within a fixed distance, the drone automatically changes its direction or stops to avoid collision. This project demonstrates a low-cost and efficient solution for safe autonomous navigation. It can be useful in surveillance, agriculture, disaster management, and industrial inspection.*

Key Words: Autonomous Drone, UAV, Obstacle Detection, Obstacle Avoidance, Arduino Nano, Ultrasonic Sensor, Flight Controller, BLDC Motor, ESC, Autonomous Navigation.

1. INTRODUCTION

An Autonomous Drone is an unmanned aerial vehicle (UAV) that can fly and perform operations without continuous human control. In recent years, drones have become very useful in different fields such as surveillance, agriculture, disaster management, military operations, aerial photography, and industrial inspection. Due to their ability to reach difficult areas quickly, drones are becoming an important part of modern technology.

One of the major problems faced during drone flight is collision with nearby obstacles like trees, walls, buildings, poles, and moving objects. These collisions can damage the drone and reduce its efficiency. To solve this problem, obstacle detection and avoidance systems are used to improve flight safety and reliability.

This project, “Autonomous Drone with Obstacle Detection and Avoidance,” is designed to develop a drone that can detect obstacles and automatically change its path to avoid collisions. The system uses ultrasonic sensors to measure the distance between the drone and nearby objects. An Arduino Nano processes the sensor data and sends commands for obstacle avoidance. The KK2.4 flight controller is used to maintain flight stability, while BLDC motors and ESCs provide the required thrust and speed control for smooth flight.

When an obstacle is detected within a fixed distance, the drone automatically stops or changes direction without manual control. This helps in safer navigation and reduces the chances of accidents. The main aim of this project is to build a low-cost, lightweight, and efficient autonomous drone system that can improve safety and support smart navigation in real-world applications.

2. PROBLEM STATEMENT

Traditional drones require continuous human monitoring and manual control during flight, which increases the possibility of crashes and accidents when obstacles are present in the flight path. In environments containing trees, buildings, walls, or other objects, the lack of automatic obstacle detection can affect flight safety and operational reliability. Advanced obstacle avoidance systems available in modern drones are often expensive and complex. Therefore, there is a need to develop a low-cost, lightweight, and efficient autonomous drone system capable of detecting.

3. OBJECTIVES

The main objective of this project is to design and develop an autonomous drone that can detect obstacles and avoid collisions during flight without continuous human control. The drone uses ultrasonic sensors to identify nearby objects such as walls, trees, buildings, and other obstacles. When an obstacle is detected within a certain distance, the system automatically changes direction or stops to prevent accidents.

- To design and develop an autonomous drone system that can operate with minimum human intervention.

- To detect nearby obstacles such as walls, trees, buildings, and other objects during flight using ultrasonic sensors.

- To avoid collisions automatically by changing the drone's direction or stopping its movement when an obstacle is detected.
- To improve flight safety and reliability by reducing accidents caused by human error or limited visibility.
- To provide a smart drone solution that can be used in areas like surveillance, agriculture, disaster management, and industrial inspection.

4. LITERATURE SURVEY

Many researchers have worked on autonomous drones for obstacle detection, navigation, and flight stability. Earlier studies mainly focused on using stereo vision systems, laser sensors, GPS, IMU, ultrasonic sensors, and image processing for safe drone movement. Some researchers developed vision-based navigation systems, while others used ultrasonic sensors and microcontrollers for low-cost obstacle detection. Flight controllers and PID algorithms were also used to improve drone stability and autonomous movement.

Although these systems showed good performance, many existing models are costly, complex, and require advanced processing systems. Some methods also face limitations in real-time obstacle detection, short-range sensing, and lightweight implementation. Therefore, this project focuses on developing a low-cost, lightweight, and efficient autonomous drone with obstacle detection and avoidance using ultrasonic sensors, Arduino Nano, and a flight controller for safe and stable navigation.

4.1. Comparative Analysis of Previous Research:

Author/ Year	Main Focus	Research Gap
Y. Kim et al. (2021)	Autonomous UAV navigation	Limited short-range obstacle detection
A. Patel et al. (2022)	Drone flight stabilization	Required advanced controllers and expensive setup
M. Sharma et al. (2023)	Smart drone path planning	High power consumption and complex algorithms
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5. PROPOSED SYSTEM

The proposed system of Autonomous Drone with Obstacle Detection and Avoidance is designed to provide safe and stable drone flight by automatically detecting obstacles and avoiding collisions. The system mainly consists of Flight Controller (KK 2.1.5), RC Receiver, PWM Receiver, Electronic Speed Controller (ESC), BLDC Motors, Ultrasonic Sensor, and Arduino Nano. These components work together to control drone movement, maintain stability, and perform obstacle avoidance.

The RC Receiver receives control signals from the remote controller and sends them to the PWM Receiver. The PWM signals are then transferred to the Flight Controller (KK 2.1.5), which is responsible for maintaining the balance, orientation, and stability of the drone during flight. The flight controller processes the movement commands and sends output signals to the Electronic Speed Controllers (ESCs).

The ESCs control the speed of the BLDC motors, which generate the required thrust for lifting and moving the drone in different directions. Proper speed control of the motors helps the drone maintain smooth and stable flight.

For obstacle detection, an Ultrasonic Sensor is used to continuously measure the distance between the drone and nearby obstacles such as walls, trees, and buildings. The sensor sends this distance data to the Arduino Nano. The Arduino Nano processes the sensor input and checks whether any obstacle is within a predefined safe distance. If an obstacle is detected, the Arduino Nano generates commands to stop forward movement or change the direction of the drone to avoid collision.

Thus, the proposed system provides a low-cost, lightweight, and efficient solution for autonomous drone navigation by combining flight stabilization and real-time obstacle detection for safer operation.

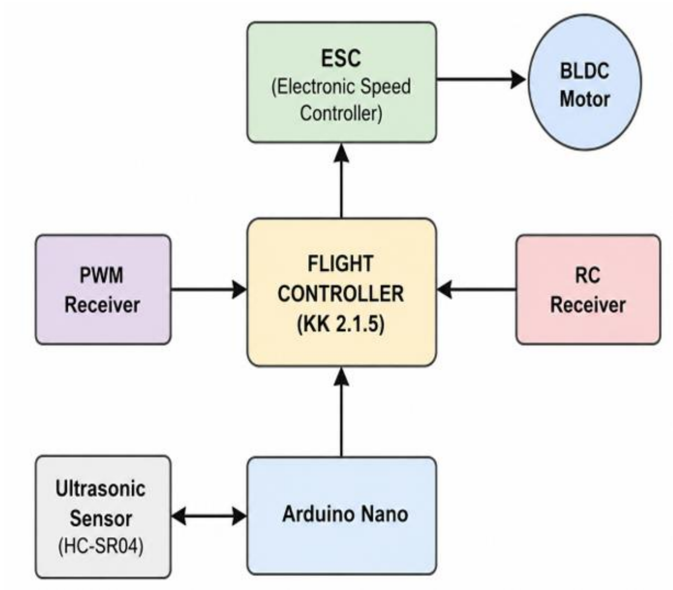

Fig.1. Block Diagram: Autonomous Drone with Obstacle Detection and Avoidance

6. METHODOLOGIES

The methodology of Autonomous Drone with Obstacle Detection and Avoidance is based on obstacle sensing, signal processing, flight control, and automatic navigation. The system is developed by integrating hardware components such as Ultrasonic Sensor, Arduino Nano, RC Receiver, PWM Receiver, Flight Controller (KK 2.1.5), ESC, and BLDC Motors to achieve safe and stable drone operation.

First, the RC Receiver receives control signals from the remote controller and passes them to the PWM Receiver. These signals are then sent to the Flight Controller (KK 2.1.5), which manages the drone's balance, orientation, and flight stability. The flight controller sends output commands to the Electronic Speed Controllers (ESCs).

The ESCs regulate the speed of the BLDC motors, which generate the thrust required for lifting and moving the drone. By controlling motor speed, the drone can move in different directions and maintain smooth flight.

For obstacle detection, the Ultrasonic Sensor continuously measures the distance between the drone and nearby objects. The sensor sends this data to the Arduino Nano, where the distance is processed and compared with a predefined safety threshold.

If the detected obstacle is within the unsafe range, the Arduino Nano automatically sends commands to stop forward movement or change the drone's direction to avoid collision. If no obstacle is detected, the drone continues its normal flight path.

Finally, the complete system is tested under different obstacle conditions to check the accuracy of detection, stability of flight, and automatic avoidance performance. This methodology helps in developing a low-cost, lightweight, and efficient autonomous drone system for safe navigation and collision avoidance.

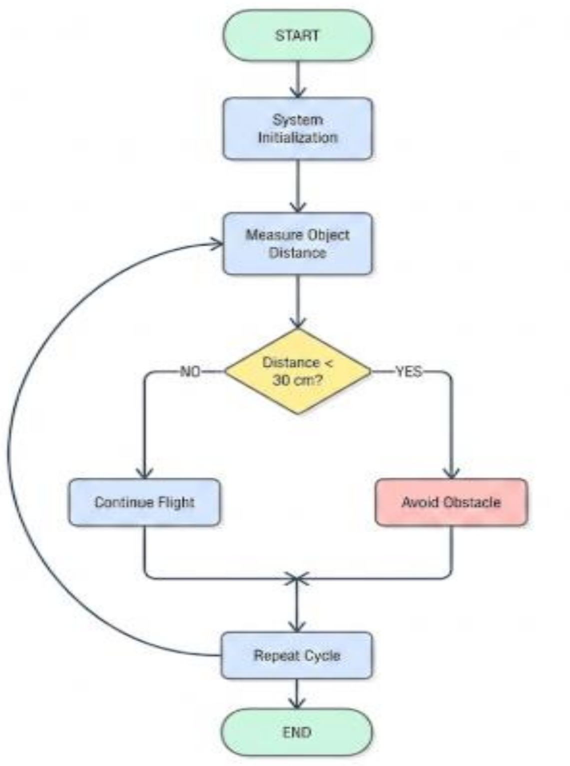

Fig.2. Flowchart of Autonomous Drone with Obstacle Detection and Avoidance

7. Hardware Design:

The hardware design of the Autonomous Drone with Obstacle Detection and Avoidance project is developed by combining different electronic and mechanical components to achieve stable flight and automatic obstacle detection. The main hardware used in this system includes KK2.4 Flight Controller, Arduino Nano, Ultrasonic Sensor (HC-SR04), BLDC Motors, Electronic Speed Controller (ESC), Drone Frame, and Li-Po Battery.

The **KK2.4 Flight Controller** is the main control unit of the drone that helps maintains flight stability, balance, and orientation during operation. It processes control signals and ensures smooth movement of the drone in different directions.

The **Arduino Nano** is used for obstacle detection and avoidance. It receives input from the ultrasonic sensor, processes the distance data, and sends commands for automatic action when an obstacle is detected.

The **Ultrasonic Sensor (HC-SR04)** is mounted on the drone to detect nearby obstacles. It continuously measures the distance between the drone and objects like walls, trees, and buildings by using ultrasonic waves.

The **BLDC Motors** provide the required thrust to lift and move the drone. These motors are efficient, lightweight, and suitable for stable drone operation.

The **Electronic Speed Controllers (ESCs)** are connected between the flight controller and BLDC motors. Their main function is to control the speed of the motors according to the signals received from the flight controller. This helps in maintaining proper balance and movement.

The **Drone Frame** acts as the structural body of the drone. It supports all hardware components such as motors, sensors, battery, and controllers, while maintaining lightweight strength and stability.

The **Li-Po Battery** is used as the power source for the complete drone system. It provides sufficient power to the motors, sensors, Arduino Nano, and flight controller for proper operation.

Thus, the hardware design provides a compact, lightweight, and efficient drone system capable of stable flight and automatic obstacle avoidance.

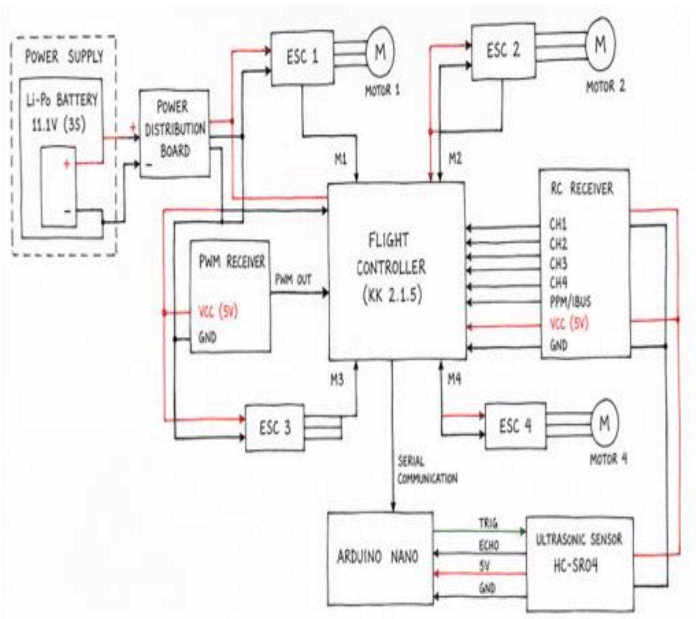

Fig.3. Schematic of Autonomous Drone with Obstacle Detection and Avoidance

7.1. Software Tools:

Layer	Technology	Purpose
Programming Layer	Embedded C	Used for coding obstacle detection and avoidance logic
Development Layer	Arduino IDE	Used for writing, compiling, and uploading code
Sensor Processing Layer	HC-SR04 Sensor Library	Used for distance measurement and sensor interfacing
Flight Control Layer	KK2.4 Firmware	Maintains drone stability and flight control
Communication Layer	Serial Communication	Transfers data between Arduino and monitoring system
Control Layer	PWM Signal Processing	Controls motor speed through ESCs
Monitoring Layer	Serial Monitor	Displays distance and obstacle status for debugging

Logic Processing Layer	Obstacle Avoidance Algorithm	Detects obstacles and changes drone direction
Testing Layer	Hardware Calibration	Used for ESC calibration and flight testing
System Integration Layer	Embedded System Integration	Coordinates hardware and software operation

8. IMPLEMENTATION

The implementation of the Autonomous Drone with Obstacle Detection and Avoidance project is carried out by integrating hardware components and programming for automatic obstacle detection and safe drone movement. The system is designed to provide stable flight along with real-time collision avoidance.

First, the drone structure is built using a drone frame, where all components such as KK2.4 Flight Controller, Arduino Nano, Ultrasonic Sensor (HC-SR04), BLDC Motors, ESCs, and Li-Po Battery are properly mounted and connected. The frame provides support and balance for the complete drone system.

The KK2.4 Flight Controller is connected to the BLDC motors through Electronic Speed Controllers (ESCs). The flight controller is configured to maintain the drone's stability, balance, and orientation during flight. The ESCs regulate motor speed based on control signals, while the BLDC motors generate thrust for lifting and movement.

The Arduino Nano is programmed to handle obstacle detection and avoidance. The HC-SR04 ultrasonic sensor is connected to the Arduino Nano to continuously measure the distance between the drone and nearby obstacles. The sensor sends distance data to the Arduino for processing.

A predefined safe distance is set in the program. When the detected obstacle is beyond the safe range, the drone continues normal flight. If an obstacle is detected within the unsafe range, the Arduino Nano sends control signals to stop forward motion or change the flight direction to avoid collision. This allows automatic obstacle avoidance without continuous human control.

Finally, the complete system is tested in different flight conditions to verify obstacle detection accuracy, flight stability, and automatic navigation performance.

The implementation shows that the drone can successfully detect obstacles and perform safe movement with a low-cost and efficient design.

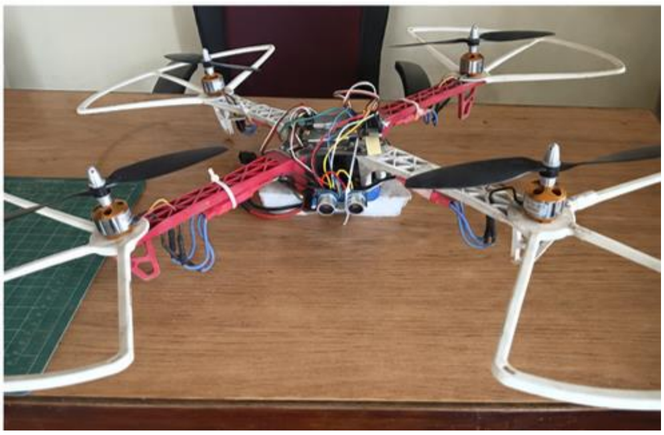

Fig 8.1. Complete Autonomous Drone setup

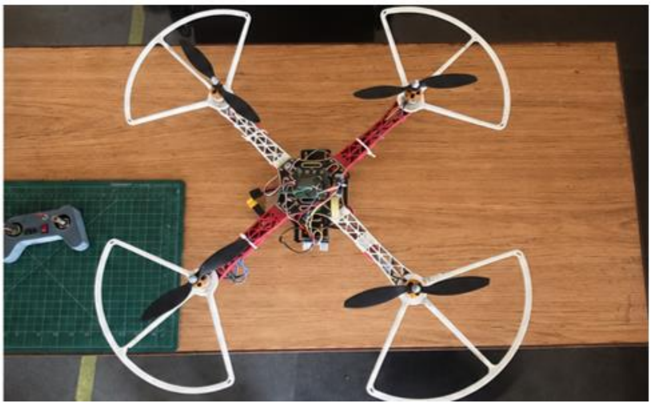

Fig 8.2. Top view of Drone Setup

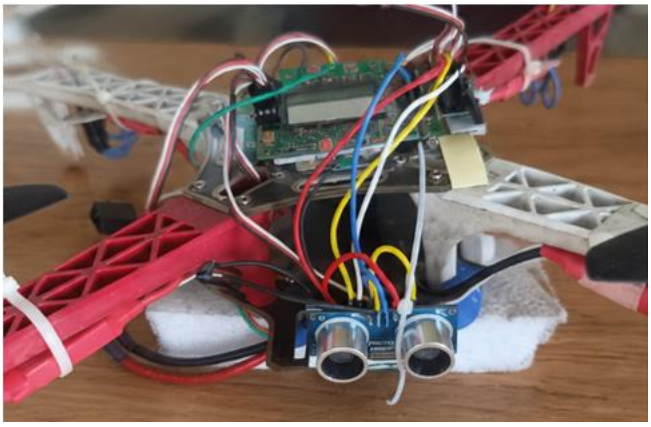

Fig 8.3. Close-up of Electronics & Sensors

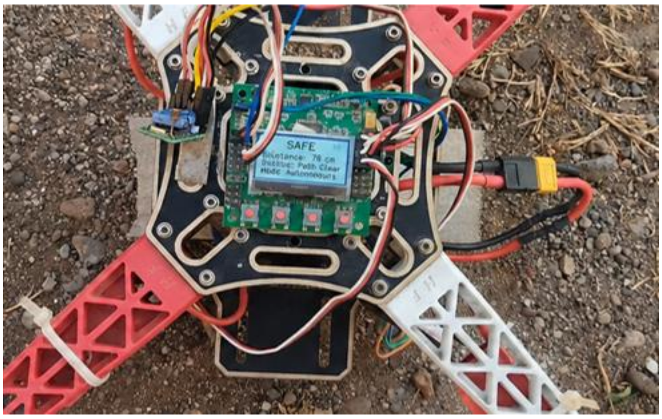

Fig. 8.4. LCD display – Real-time status

9. RESULT

The result of the Autonomous Drone with Obstacle Detection and Avoidance project shows that the developed drone system successfully performed obstacle detection and automatic collision avoidance during flight. The HC-SR04 ultrasonic sensor was able to continuously detect nearby obstacles such as walls, objects, and barriers within a predefined distance range.

The Arduino Nano effectively processed the sensor data and generated control signals for obstacle avoidance. When an obstacle was detected within the unsafe range, the drone automatically stopped forward movement or changed its direction to avoid collision. If no obstacle was detected, the drone continued normal flight operation.

The KK2.4 Flight Controller maintained proper balance and flight stability, while the BLDC motors and ESCs provided smooth thrust and controlled movement. The overall system showed stable performance during testing under different obstacle conditions.

From the implementation and testing, it was observed that the proposed system improved drone safety, reduced the chances of collision, and supported autonomous navigation without continuous human control. Therefore, the project successfully achieved a low-cost, lightweight, and efficient drone system for safe obstacle detection and avoidance.

Fig.9.1. Flight Test – Forword Movement

Fig.9.2. Idle zone – NO Obstacle detect

Fig 9.3. Back Idle zone – Obstacle detect in front side

10. CONCLUSION

The “Autonomous Drone with Obstacle Detection and Avoidance” project was successfully designed and implemented to achieve stable drone flight along with automatic obstacle detection and collision avoidance capability. The project integrated various hardware components such as the KK2.4 flight controller, Arduino Nano, ultrasonic sensor, ESCs, BLDC motors, and drone frame to develop an efficient autonomous drone system.

The ultrasonic sensor continuously detected nearby obstacles and provided real-time distance measurements to the Arduino Nano. Based on the sensor data, the obstacle avoidance algorithm generated appropriate control actions to prevent collisions. The KK2.4 flight controller-maintained flight stability by controlling the speed and orientation of the BLDC motors through ESCs. The system successfully performed obstacle detection and direction-changing operations during flight, improving overall operational safety.

The project achieved its main objectives of developing a low-cost, lightweight, and reliable autonomous drone system. The use of ultrasonic sensors provided a simple and economical solution for short-range obstacle detection. The system reduced the dependency on continuous human monitoring and demonstrated the ability to perform safe navigation in environments containing obstacles.

Although the system has certain limitations such as limited sensing range and basic obstacle avoidance capability, it provides a strong foundation for future developments in autonomous aerial systems. Advanced technologies such as GPS navigation, computer vision, artificial intelligence, and LiDAR sensors can be integrated in the future to improve navigation accuracy and autonomous performance. Overall, the project successfully demonstrated the working of an autonomous drone capable of real-time obstacle detection and avoidance.

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