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PROJECT REPORT

On

“MINI DRONE WITH PROXIMITY ALERT”

Submitted in partial fulfillment of the requirements for the award of the Degree

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In

ELECTRONICS AND COMMUNICATION ENGINEERING

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ABSTRACT

The Mini Drone with Proximity Alert is an advanced autonomous drone system designed to enhance safety and obstacle avoidance in dynamic environments. This project utilizes an Arduino Pro Mini microcontroller to integrate a network of ultrasonic sensors, ensuring real-time detection of obstacles in the drone's flight path. When obstacles are detected within a predefined proximity, the system processes the sensor data and triggers alert mechanisms such as LED indicators, buzzers, or automated flight adjustments to avoid collisions. Lightweight materials and efficient electronic component placement ensure portability and optimal battery life, making the drone suitable for various indoor and outdoor applications. The drone's software is developed using the Arduino IDE, featuring custom algorithms for sensor data processing, proximity detection, and autonomous navigation. Additionally, the drone offers mobile application integration via Bluetooth communication, enabling remote monitoring and control, as well as real-time telemetry feedback, including proximity alerts and battery status. Field tests demonstrate the drone's reliability in avoiding obstacles and maintaining safe flight paths, highlighting its potential use in surveillance, search-and-rescue operations, and educational purposes. The Mini Drone with Proximity Alert provides an innovative solution for safe drone operation in complex and confined environments.

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CHAPTER 1

INTRODUCTION

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INTRODUCTION

1.1 Introduction

The evolution of drone technology has revolutionized various industries, from surveillance and agriculture to entertainment and scientific research. Among the many types of drones, micro drones stand out due to their compact size, versatility, and affordability. These small-scale unmanned aerial vehicles (UAVs) are capable of performing a wide range of tasks in constrained environments where larger drones may be impractical. This report focuses on the development and functionality of a micro drone equipped with cutting-edge components such as the Arduino Pro Mini, F3 EVO flight controller, LiDAR module, buzzer, LEDs, propellers, and specialized drone motors. The Arduino Pro Mini serves as the brain of the drone, offering a lightweight and compact microcontroller platform with sufficient processing power to manage flight dynamics, sensor integration, and other operational tasks. This modularity allows developers to tailor the drone for specific applications, whether it is for indoor navigation, educational purposes, or exploratory projects. Combined with the F3 EVO flight controller, the system achieves stable and responsive flight, leveraging advanced algorithms for precise control and navigation. Key to the enhanced capabilities of this micro drone is the integration of a LiDAR module. LiDAR (Light Detection and Ranging) is a technology that enables the drone to measure distances to objects with high accuracy, making it suitable for obstacle avoidance, mapping, and autonomous navigation. Such advanced functionality is critical for applications in environments where human intervention is limited or undesirable.

Additionally, the inclusion of a buzzer and LEDs enhances the operational safety and usability of the drone. The buzzer serves as an alert mechanism, signaling low battery levels, connectivity issues, or other system notifications. LEDs not only improve visibility during flight, especially in low-light conditions, but also offer customizable patterns for communication and aesthetic purposes. The propulsion system, comprising propellers and lightweight drone motors, is meticulously designed to ensure efficient flight performance. The choice of materials and aerodynamic design of the propellers, combined with the powerful yet energy-efficient motors, allows the drone to achieve optimal thrust-to-weight ratio, stability, and maneuverability. This micro drone represents a harmonious blend of advanced hardware and innovative design principles. Its versatility makes it a valuable tool for diverse fields, including robotics research, surveillance, disaster management, and recreational activities. Through this report, the design, construction, and functionality of the drone are thoroughly explored, offering insights into the practical applications and future potential of micro UAVs. By utilizing readily available components and open-source platforms, this project also serves as a stepping stone for hobbyists and professionals alike, fostering further advancements in drone technology.

Mini drones, also known as small unmanned aerial vehicles (UAVs), are rapidly gaining recognition as versatile, cost-effective tools in a wide range of industries. Unlike their larger counterparts, mini drones are characterized by their compact size, ease of operation, and the ability to perform complex tasks with high precision. These drones typically weigh less than 2 kilograms and are equipped with lightweight sensors and cameras, which enable them to execute a variety of functions such as aerial photography, surveillance, environmental monitoring, and data collection. The simplicity of their design and affordability make them attractive not only for recreational use but also for commercial, industrial, and even military applications.

One of the key advantages of mini drones is their ability to access hard-to-reach areas, making them invaluable in applications where human intervention may be difficult, dangerous, or time-consuming. For example, mini drones have been used extensively in agriculture for crop monitoring and pest control, in environmental science for wildlife tracking and forest management, and in disaster relief for search and rescue operations. With further advancements in technology, the scope of these applications is expected to expand, driving the demand for more sophisticated and capable mini drones.Mini drones are typically equipped with various sensors, cameras, GPS systems, and sometimes additional tools such as thermal imaging devices or LIDAR (Light Detection and Ranging) technology, enabling them to gather high-quality data in real-time. The integration of communication systems such as Wi-Fi or 5G networks enhances their ability to transfer large datasets, further broadening their potential use cases. These features allow for precise mapping, monitoring, and surveying in numerous industries, such as construction, transportation, and energy, where traditional methods might be costly, time-consuming, or inefficient.

The future of mini drones holds immense promise as advancements in technology continue to shape their evolution. These developments will enhance their functionality, performance, and usability, making mini drones indispensable tools in various industries. Some of the most notable trends and developments in mini drone technology include improved battery life, greater flight stability, the integration of artificial intelligence (AI), and the development of new payload capacities.

One of the primary challenges faced by mini drones is limited battery life. Due to their compact size, mini drones are typically powered by lithium-polymer (LiPo) batteries, which offer a balance between weight and capacity. However, the current battery technology constrains flight times, often limiting them to between 20 and 40 minutes, depending on the drone's size and payload. To address this issue, researchers are exploring alternatives such as lithium-sulfur (Li-S) batteries, which promise higher energy densities and longer flight times. Additionally, the development of ultra-capacitors, which charge quickly and provide bursts of high energy, could supplement battery systems to extend flight duration during specific high-demand operations.

Another area of future development is the enhancement of flight stability and navigation systems. The integration of advanced sensors and real-time data processing technologies will enable mini drones to fly more stably in challenging conditions, such as high winds or in dense urban environments. Furthermore, GPS-based navigation systems are being complemented by vision-based navigation systems that use cameras and machine learning algorithms to detect obstacles, identify landing spots, and ensure smooth autonomous flight. The use of gyroscopic stabilization systems and the development of high-performance processors will also help to increase stability, enabling drones to execute more intricate maneuvers and more accurately follow programmed flight paths.

Artificial intelligence (AI) and machine learning are expected to play a transformative role in the future of mini drones. By incorporating AI algorithms, drones will become more autonomous, capable of making decisions based on real-time data without human intervention. For instance, AI could be used for autonomous object detection, tracking, and mapping, significantly reducing the need for remote piloting.

In swarm operations, multiple drones could communicate with one another and collaborate to complete complex tasks, such as large-scale environmental monitoring, construction site management, or precision farming. This collaborative behavior, inspired by natural systems like flocking birds, can increase the efficiency and scalability of drone operations.The future integration of AI with drone systems may also allow mini drones to self-learn from their environment, improving their flight behavior and efficiency over time. As drones become smarter, they will be able to navigate in dynamic environments, identify hazards, and even perform adaptive actions to optimize mission outcomes.The potential applications of mini drones are vast and diverse. As technology advances, mini drones are expected to become increasingly integrated into everyday life, with several industries already benefiting from their use. Below are a few key areas where mini drones are currently being applied and are expected to see growth in the coming years.

One of the most impactful applications of mini drones is in agriculture. Precision farming, which involves using technology to monitor crop health, soil moisture, and overall field conditions, benefits greatly from the deployment of drones. Mini drones equipped with multispectral cameras can capture detailed images of crops, allowing farmers to identify issues such as pest infestations, diseases, or nutrient deficiencies. This real-time data enables farmers to make data-driven decisions and optimize their resources, reducing the need for pesticides, fertilizers, and water usage, ultimately leading to more sustainable farming practices.

In the future, mini drones are likely to become even more involved in automated agricultural processes, such as planting, irrigation, and crop spraying, further improving efficiency and reducing operational costs.In disaster-stricken areas, mini drones can play a crucial role in search and rescue (SAR) operations. Their ability to fly in challenging terrain and access hard-to-reach locations allows them to assist in locating victims or gathering situational awareness in real-time.

For example, in the aftermath of earthquakes, floods, or forest fires, mini drones can be deployed to quickly assess damage, identify hazards, and search for survivors. The use of thermal imaging cameras, combined with AI-based image recognition, can significantly enhance the efficiency and effectiveness of SAR operations.

Mini drones are increasingly used for infrastructure inspections, especially in high-risk or hard-to-reach areas such as b=ridges, power lines, wind turbines, and cell towers. Traditionally, these inspections required human inspectors to perform dangerous climbing or scaffolding tasks. Mini drones, however, can quickly fly over structures, capture high-definition imagery, and provide detailed reports on the condition of the infrastructure. This capability significantly reduces costs, improves safety, and speeds up the inspection process.

In the future, drones will likely be equipped with more advanced tools, such as ultrasonic sensors or infrared cameras, to assess the integrity of structures more thoroughly. The integration of AI-powered analytics will allow for predictive maintenance, helping to identify potential issues before they lead to costly failures.

As cities grow more congested and urban infrastructure becomes more complex, mini drones have the potential to revolutionize urban mobility. Companies are exploring the use of mini drones for parcel delivery, reducing the need for traditional delivery methods, and enabling faster, more efficient transport of goods. Mini drones could be deployed to deliver medical supplies, food, or e-commerce packages, reducing traffic congestion and ensuring timely deliveries.

1.2 Problem Statement

The increasing use of drones in various applications such as surveillance, delivery, and entertainment has highlighted the need for enhanced safety and operational efficiency. Traditional drones often lack the ability to detect nearby obstacles in real time, leading to potential collisions, equipment damage, or harm to nearby individuals. This limitation becomes critical in constrained or crowded environments where manual control may not respond quickly enough to prevent accidents.

The challenge lies in developing a compact, cost-effective mini drone equipped with a reliable proximity alert system. This system should detect obstacles within its vicinity, issue timely warnings, and allow for evasive actions, thereby enhancing safety and user confidence during drone operations.

1.2.1 Solution:

To address the safety challenges associated with operating drones in constrained or crowded environments, a mini drone equipped with an advanced proximity alert system is proposed. This system utilizes a combination of sensors, such as ultrasonic, infrared, or LiDAR, to detect obstacles in real time within the drone's vicinity. The proximity alert mechanism will process sensor data to provide timely visual, auditory, or haptic warnings to the operator. Additionally, the system can be integrated with autonomous flight control algorithms to execute evasive maneuvers automatically, minimizing the risk of collisions. This solution ensures enhanced safety, improves user confidence, and expands the operational capabilities.

CHAPTER 2

LITERATURE SURVEY

CHAPTER 2

LITERATURE SURVEY

2.1 Literature Survey

This literature survey was conducted to gather comprehensive insights into the advancements and challenges of LiDAR-based obstacle detection systems, particularly in the context of mini drones and UAVs. The primary motivation behind this survey was to identify methodologies, technologies, and critical drawbacks highlighted in existing research to guide the design and development of our project. By analyzing these studies, all published in 2023, we aimed to develop a robust and efficient system that addresses the limitations of current implementations.

Sharma and M. K. Singh, in their paper "Development of LiDAR-based Obstacle Detection System for Mini Drones," published in the International Journal of Robotics and Automation (Vol. 39, No. 4, April 2023, pp. 245–252), explored the use of LiDAR sensors to navigate complex environments with high precision. Their system demonstrated real-time obstacle detection capabilities tailored for mini drones, emphasizing compactness and responsiveness. We referenced their work to implement LiDAR-based navigation in our project, focusing on their techniques for real-time data processing. However, the study highlighted significant drawbacks, including the system's susceptibility to weather conditions such as fog, heavy rain, and dust, which impaired sensor accuracy. To address this, we considered alternative configurations and protective measures for our LiDAR sensors to enhance reliability in varied environmental conditions.

In the study "Integration of LiDAR Sensors in Micro UAVs for Enhanced Obstacle Detection," published in IEEE Transactions on Aerospace and Electronic Systems (Vol. 59, No. 1, January 2023, pp. 54–62), Y. Chen, W. Zhang, and R. Li investigated advanced techniques for integrating LiDAR sensors into UAVs. This paper highlighted the importance of sensor placement, angle optimization, and data fusion techniques for reliable obstacle detection. Their findings on improving spatial resolution and optimizing coverage were instrumental in shaping the sensor arrangement in our project. They also introduced innovative methods for reducing sensor blind spots, which we adapted to increase the detection efficiency of our drone. However, the study identified a major limitation in power efficiency, with the integrated system exhibiting high energy consumption. This finding prompted us to incorporate energy-efficient components and streamlined algorithms to reduce the power burden in our system.

K. P. Reddy, S. J. Rao, and T. V. Ramesh presented their work, "Compact LiDAR Systems for Autonomous Mini Drones," at the IEEE International Conference on Intelligent Systems and Control (ISCO), held in Coimbatore, India, in 2023 (pp. 302–307). This research focused on the miniaturization of LiDAR systems to make them more suitable for compact UAVs. The authors explored the use of lightweight materials and compact hardware components, which directly influenced our selection of drone hardware to reduce overall weight. Their work also provided insights into cost-effective design strategies, enabling us to maintain a balance between performance and affordability. Despite these strengths, the study highlighted a trade-off between system miniaturization and the operational range of LiDAR sensors, which limited the detection of distant obstacles. This finding influenced our design to explore hybrid configurations, balancing compactness with extended range capabilities.

Z. Wang and M. L. Wang, in their paper "Autonomous Flight Control in Mini UAVs Using LiDAR-Based Proximity Alerts," published in IEEE Access (Vol. 11, 2023, pp. 11572–11583), focused on using LiDAR for proximity alert systems in UAVs. This research provided a comprehensive framework for integrating visual and auditory feedback mechanisms into UAVs, ensuring flight safety through real-time proximity alerts. Their work influenced our project’s development of alert systems, particularly in implementing simultaneous visual and audible signals to guide users during flight. Additionally, the study demonstrated the use of real-time data to improve response times to potential collisions. However, their research identified a critical challenge in adapting to dynamic obstacles, particularly in fast-moving and unpredictable environments. To overcome this limitation, we incorporated adaptive algorithms capable of processing rapid environmental changes and generating timely responses to ensure safe operation in dynamic conditions.

CHAPTER 3

PROPOSED WORK

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PROPOSED WORK

3.1 Methodology

The core of the drone's operation is the F3 EVO flight controller is shown in figure 3.1, which is responsible for flight stabilization and control. The controller includes an Inertial Measurement Unit (IMU) with a gyroscope and accelerometer, which continuously monitors the drone's orientation and movement. Based on this data, the flight controller adjusts the speed of the motors to maintain a stable flight posture. The mini drone operates based on the coordinated functioning of several key components: the F3 EVO flight controller, Arduino Pro Mini, LIDAR module, motors, propellers, and a power supply system. Each of these components plays a specific role in enabling the drone to fly, maintain stability, and detect obstacles. The F3 EVO receives control signals from a remote transmitter operated by the user. These signals determine the drone's movements—whether to ascend, descend, tilt forward or backward, or rotate. The flight controller processes these commands in real-time and adjusts the motor speeds accordingly. The propulsion system consists of four brushless DC motors, each paired with a propeller. The motors are controlled by Electronic Speed Controllers (ESCs), which receive Pulse Width Modulation (PWM) signals from the flight controller. By varying the duty cycle of the PWM signals, the ESCs regulate the speed of the motors, enabling precise control of the drone's movement. When the throttle is increased, the ESCs ramp up the motor speeds, causing the propellers to generate more thrust and lift the drone into the air. For lateral movement, the flight controller adjusts the relative speeds of the motors on either side, tilting the drone in the desired direction.

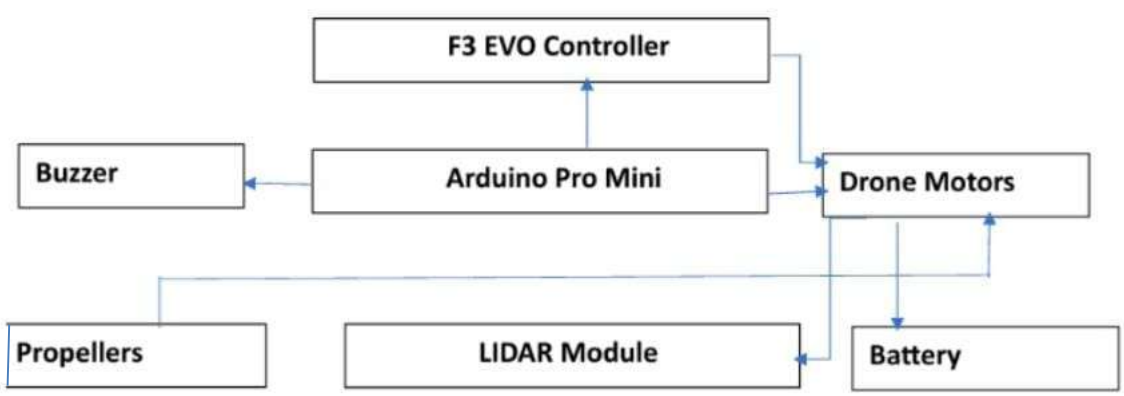

Fig 3.1 Block diagram of Mini Drone

Obstacle Detection and Avoidance

A key feature of this mini drone is its obstacle detection and avoidance capability, which is achieved using a LIDAR module. The LIDAR emits laser pulses and measures the time taken for the pulses to reflect back from an object. This time-of-flight data is converted into distance measurements. The LIDAR module communicates with the Arduino Pro Mini via an I2C or UART interface. The Arduino processes the distance data and compares it against a predefined threshold. If an obstacle is detected within this threshold, the Arduino triggers an alert using a buzzer and sends a signal to the flight controller to take corrective action, such as slowing down or changing direction.

Power Supply System

The drone is powered by a 3-cell (3S) Lithium Polymer (Li-Po) battery with a capacity of 1000-1500 mAh. The battery provides a high discharge rate necessary for driving the motors and powering the electronics. A Power Distribution Board (PDB) is used to distribute the power from the battery to the ESCs and the Arduino Pro Mini. The PDB ensures that each component receives the appropriate voltage and current for efficient operation.

Communication System

The drone communicates with the remote controller via a radio frequency (RF) module integrated into the flight controller. The RF module operates at a standard frequency of 2.4 GHz, ensuring reliable communication over a reasonable distance. The user sends commands to the drone using a transmitter, and the flight controller interprets these commands to control the motors.

3.1.1 Mini Drone Development

Component Assembly

The assembly process begins with mounting the motors on the drone's frame. The ESCs are connected to the motors and secured in place. The propellers are then attached to the motors, ensuring proper orientation for lift generation.

Next, the F3 EVO flight controller is mounted at the center of the frame, where it can accurately measure the drone's orientation without interference. The Arduino Pro Mini and LIDAR module are positioned on the front of the frame to enable effective obstacle detection.

The PDB is installed near the center of the frame, and the battery is mounted beneath the drone to maintain a low center of gravity, improving stability.

Wiring and Connections

The motors are connected to the ESCs, which are in turn connected to the PDB for power supply. The ESCs also receive control signals from the F3 EVO flight controller.

The LIDAR module is wired to the Arduino Pro Mini using I2C or UART, depending on the module specifications. The Arduino is powered via the PDB and communicates with the flight controller through a serial interface.

The buzzer is connected to a digital output pin on the Arduino. When triggered, the Arduino sends a high signal to the buzzer, producing an audible alert.

Software Configuration

- **Flight Controller Firmware:** The F3 EVO is flashed with Betaflight firmware, a popular open-source firmware for flight controllers. Using the Betaflight Configurator software, the IMU is calibrated, flight modes are configured, and PID tuning is performed to optimize flight stability.
- **Arduino Programming:** The Arduino Pro Mini is programmed using the Arduino IDE. The code includes:

- Initialization of the LIDAR module and I2C/UART communication.
- Continuous reading of distance data from the LIDAR.
- Comparison of distance values with a predefined threshold.
- Activation of the buzzer and sending of signals to the flight controller when an obstacle is detected.

Testing and Debugging

The testing phase begins with bench testing of individual components:

- **Motor and ESC Testing:** The motors are tested to ensure they respond correctly to varying throttle levels.
- **LIDAR Testing:** The LIDAR module is tested by placing objects at different distances and verifying the accuracy of the readings.
- **Arduino and Buzzer Testing:** The Arduino is tested by simulating obstacle detection scenarios to ensure the buzzer activates correctly.

After successful bench testing, the drone undergoes flight testing in a controlled environment. Initial tests focus on stability, responsiveness, and basic maneuverability. Subsequent tests evaluate the obstacle detection and avoidance system.

Iterative Improvements

Based on test results, iterative improvements are made. This may involve adjusting the PID parameters for better stability, refining the Arduino code to improve obstacle detection accuracy, or repositioning components to optimize balance.

3.1.2 Design and Planning

Design and planning are critical initial steps in the mini drone development process. This phase involves defining the objectives, specifications, and overall architecture of the drone. Objective definition is the first step, where the purpose of the mini drone must be clearly defined. Objectives can range from recreational use to specific tasks such as aerial photography, environmental monitoring, or educational purposes. Following that, a thorough requirement analysis is conducted. This includes determining the required flight performance, such as flight time, range, speed, and maneuverability. It also involves identifying the payload capacity, including cameras, sensors, or additional modules, and incorporating safety features like collision avoidance and fail-safe mechanisms.

In the preliminary design phase, key components such as the frame, propulsion system, and power system are considered. The frame needs to be lightweight yet strong enough to support all components. Common materials for the frame include carbon fiber, aluminum, and lightweight plastics. Carbon fiber is often preferred for its high strength-to-weight ratio, but cost considerations may lead to alternatives like fiberglass or advanced composites. The choice of frame geometry also influences the aerodynamics and stability of the drone, with options including quadcopters, hexacopters, and octocopters depending on the intended use.

The propulsion system design involves selecting the number and type of propellers, their size, and the necessary thrust-to-weight ratio. Propeller size directly impacts lift generation, power consumption, and noise levels. Additionally, propeller material—plastic, carbon fiber, or wood—affects durability and efficiency. The choice of the motor is equally crucial, with brushless DC motors being the industry standard for their efficiency and low maintenance. The motors must provide sufficient thrust to lift the total weight of the drone, including payload, while maintaining energy efficiency.

The power system is as shown in figure 3.1 is designed by estimating battery capacity, voltage, and type (Li-Po or Li-ion) based on the desired flight time. Li-Po batteries are commonly used due to their high energy density and discharge rate, but safety considerations such as overcharge protection and proper handling are paramount.

The battery's weight significantly influences overall performance, requiring a balance between capacity and mass. Additionally, a power distribution board (PDB) is integrated to ensure efficient power delivery to all components.

Software system requirements are also identified during this phase. This includes outlining the flight controller's capabilities, communication protocols, and autonomous navigation features. Open-source platforms like ArduPilot and PX4 are considered for their flexibility, support community, and customization options. Risk assessment is carried out to analyze potential risks such as hardware failure, software bugs, environmental factors, and human error, along with mitigation strategies like redundancy, regular maintenance, and user training.

Lastly, a project timeline and budget are established. The timeline includes milestones for each phase of development, such as component procurement, initial assembly, software integration, and testing. The budget encompasses costs for hardware, software, testing, iterations, and unforeseen contingencies. A Gantt chart or similar project management tool can be employed to track progress and ensure timely completion.

3.1.3 Hardware Selection and Integration

Hardware selection and integration ensure that the physical components of the mini drone meet the design requirements and work seamlessly together. The frame and propellers are chosen based on the material's strength and weight properties. Carbon fiber is often selected due to its high strength-to-weight ratio. However, cost constraints may necessitate alternatives like aluminum or high-grade plastics.

Propellers are selected to match the motor specifications, ensuring optimal thrust and efficiency. The number of blades and pitch angle are critical factors in determining lift and thrust. Typically, two-blade propellers are favored for efficiency, while three- or four-blade designs may be used for higher thrust in limited spaces. Propeller guards can be added to enhance safety, especially for indoor or close-proximity operations.Motors play a crucial role in the drone's performance. Brushless DC motors are typically preferred because of their efficiency and long lifespan. The selection of motors is based on their KV rating (RPM per volt), thrust, and compatibility with the frame and propellers.

High-KV motors provide greater RPM, suitable for smaller propellers and faster drones, whereas low-KV motors are ideal for larger, more stable designs. Each motor requires an electronic speed controller (ESC) to regulate its speed. Modern ESCs often include features like regenerative braking and active freewheeling, improving performance and efficiency.

The flight controller serves as the drone’s brain, responsible for stabilizing and controlling it. A suitable flight controller is selected based on its processing power, built-in sensors (gyroscope, accelerometer), and support for autonomous flight modes. Options such as Pixhawk, NAZA, and CC3D are popular for their reliability and feature sets. Advanced controllers also include barometers, magnetometers, and even onboard GPS for enhanced functionality. The power system includes selecting the right type of battery, usually Li-Po, which provides high energy density and discharge rates. The capacity of the battery is chosen to achieve the desired flight time while balancing weight constraints.

Various sensors are integrated into the drone, such as altitude sensors for stable altitude maintenance, GPS modules for navigation and autonomous flight, and camera modules for photography or video capture. Cameras range from standard HD models to thermal and multispectral options, depending on the application. A communication module is selected to facilitate data transmission between the drone and the ground station. The communication system must support the required range and frequency, with common options including 2.4 GHz radio modules and Wi-Fi-based systems.

Long-range drones may require more advanced solutions like 900 MHz or 1.2 GHz modules. The final step involves assembling all components according to the design, ensuring proper connections, secure mounting, and adequate cable management. Careful consideration is given to minimizing interference between components, especially in high-frequency communication systems.

3.1.4 Software Development

The software development phase involves writing the code that will control the drone and its various components. Firmware is developed or customized for the flight controller to handle tasks such as stabilization, motor control, and sensor data processing. Flight control algorithms are implemented to manage roll, pitch, yaw, and throttle control. These algorithms include the development of PID controllers to minimize errors in position and orientation, ensuring stable flight. For drones requiring autonomous features, additional algorithms are developed for waypoint navigation, obstacle avoidance, and return-to-home functionality. Advanced control algorithms such as Model Predictive Control (MPC) or adaptive controllers may be employed for specialized applications requiring high precision.

Communication protocols are implemented to facilitate data transmission between the drone and the ground station. This includes ensuring real-time telemetry data, such as battery status and position, is transmitted accurately. A user interface is developed for controlling the drone and displaying telemetry data. This interface can be a mobile app, desktop software, or a web-based application. Common frameworks for interface development include Qt, ROS (Robot Operating System), and MAVLink for communication. The software development phase concludes with extensive testing and debugging of individual modules, ensuring the system functions as intended. Advanced features such as image processing for object detection and tracking, using libraries like OpenCV or TensorFlow, can be integrated for specialized drones. Security features, including encrypted communication and authentication protocols, are also implemented to protect against potential threats.

3.1.5 Testing and Iteration

Testing and iteration are crucial to ensure the mini drone performs as expected under various conditions. Initial testing involves verifying basic functions such as motor control, sensor readings, and communication range in a controlled environment. This includes testing the drone’s ability to lift off, hover, and land smoothly. Performance testing is conducted to evaluate the drone’s flight time, range, speed, and maneuverability. Stability tests are performed under different wind conditions to measure how well the drone maintains its position and orientation.

Stress testing involves running the drone at maximum load and extreme conditions to identify potential points of failure. Safety testing is performed to verify the functionality of fail-safe mechanisms, such as return-to-home and auto-landing when the battery is low, and to ensure collision avoidance features work effectively.

Based on the test results, necessary modifications are made to both hardware and software. This iterative process continues until the desired performance is achieved. Each iteration is followed by further testing to validate the changes. Various sensors are integrated into the drone, such as altitude sensors for stable altitude maintenance, GPS modules for navigation and autonomous flight, and camera modules for photography or video capture. Cameras range from standard HD models to thermal and multispectral options, depending on the application.

3.1.6 Finalization and Deployment

Finalization and deployment involve preparing the mini drone for its intended use. The final assembly ensures all components are securely mounted and properly connected. Protective covers or coatings may be applied to sensitive components to enhance durability. Calibration is an essential step before deployment. Sensors such as the gyroscope, accelerometer, and compass are calibrated for accurate readings. Motor and ESC calibration is performed to ensure synchronized operation. Detailed documentation is prepared, including assembly instructions, user manuals, and maintenance guidelines. This documentation also covers the software architecture, codebase, and communication protocols for future reference.

If the drone is intended for specific users, training sessions are conducted to provide instruction on its operation and maintenance. The final step is deploying the drone for its intended purpose, whether for recreational use, research, or commercial applications. Post-deployment support is offered, including software updates, troubleshooting, and spare parts. By following this detailed methodology, the development of a mini drone can be executed systematically, ensuring a reliable and high-performance final product.

3.2 Components and Specifications

SI No	Components	Specifications
1	**F3 EVO Controller**  3.2.1 F3 EVO Controller	• Processor: STM32F303 MCU with a 32-bit ARM Cortex-M4 core. • IMU: Integrated MPU6050 (3-axis gyroscope and 3-axis accelerometer). • Connectivity: Supports SBUS, PPM, and DSM receivers. • Power Input: 5V via USB or external power source.
2	**Arduino Pro Mini**  3.2.1Arduino Pro Mini	• Microcontroller: ATmega328P. • Operating Voltage: 3.3V or 5V (selected based on other components). • Clock Speed: 8 MHz (for 3.3V) or 16 MHz (for 5V). • Communication: Supports I2C, UART, and SPI. • Power Consumption: Low power, suitable for lightweight applications.

3	**LIDAR Module**  3.2.3 LIDAR Module	• Operating Voltage: 5V. • Interface: I2C/UART. • Range: 0.2 m to 12 m (depending on model). • Accuracy: ±2 cm. • Power Consumption: Low (less than 100 mA).
4	**Li-Po Battery**  3.2.4 Li-Po **B**attery	• Type: Lithium Polymer (Li-Po) battery. • Configuration: 3S (3 cells in series). • Voltage: 11.1V (nominal). • Capacity: 1000-1500 mAh. • Discharge Rate: 25C to 40C (C-rating indicates the maximum current the battery can deliver). • Weight: 100-150 grams.

5	**Propellers**  3.2.5 Propellers	• Size: 5 inches (5x3 or 5x4.5, where 5 inches is the diameter, and the pitch is 3 or 4.5 inches). • Material: ABS plastic or carbon fiber for lightweight and durability. • Mounting Hole: Compatible with 5 mm motor shafts.
6	**BLDC Motor**  3.2.6 BLDC Motor	• Type: Brushless DC motors (BLDC). • KV Rating: 2300-2500 KV (KV refers to the number of revolutions per minute per volt). • Operating Voltage: 7.4V to 11.1V (2S or 3S Li-Po battery). • Maximum Current: 10A to 15A (depending on the load). • Power Output: 80W to 120W.
7	**ESC (Electronic Speed Controller)**  3.2.7 ESC	**Voltage Rating**: Range of input voltages the ESC can handle, typically in volts (e.g., 3.7V to 12V). **Current Rating**: Maximum continuous current in amps; must match motor requirements to avoid overheating. **PWM Frequency**: Controls motor speed; higher frequency offers smoother control.

3.3 Flow Chart

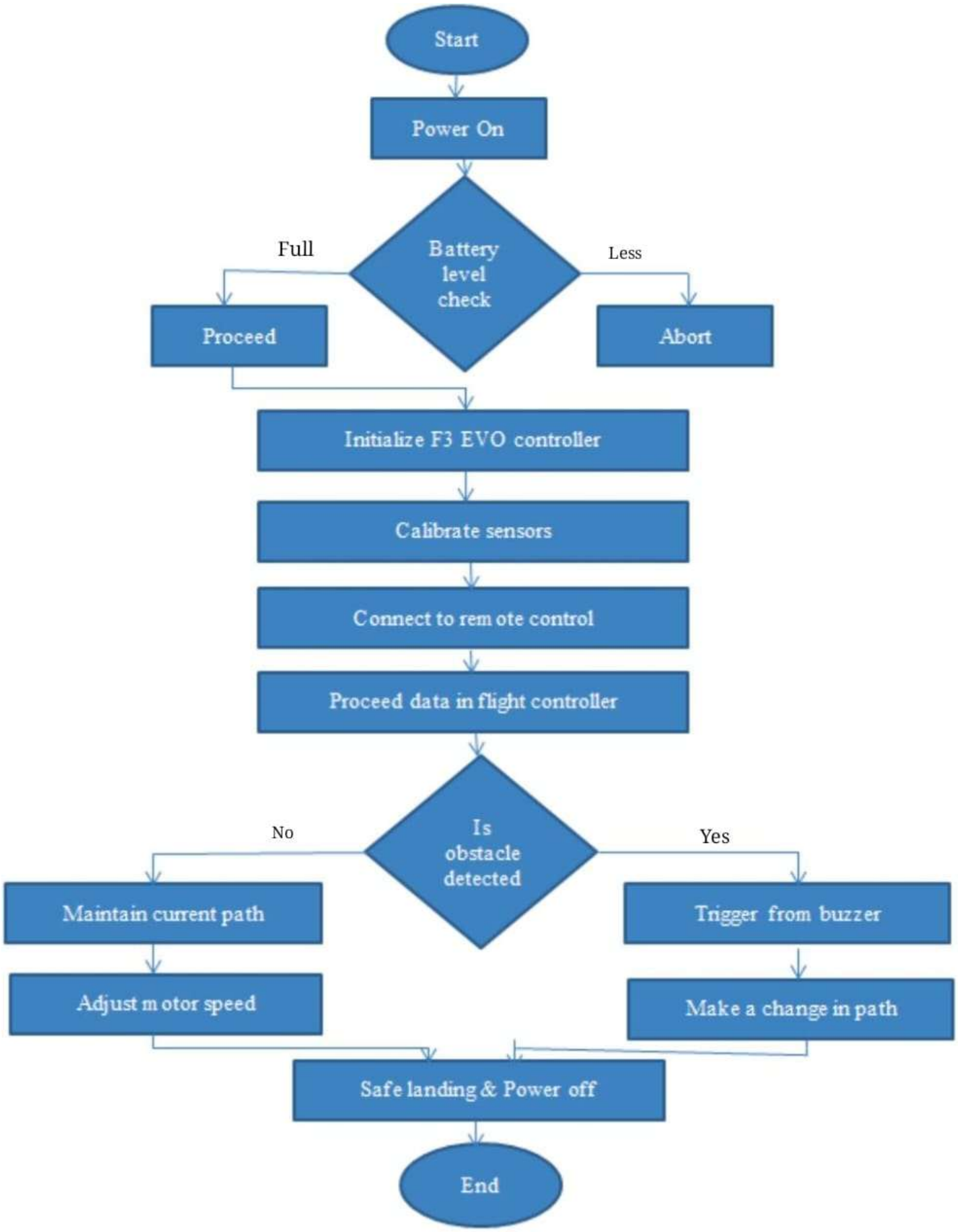

Fig 3.3 Flow Chart of Mini Drone

3.3.1 Explanation of Flow Chart

The drone system is in its initial state as shown in figure 3.3, where all components are inactive. This state ensures that the drone is ready to begin its flight sequence once powered on. Starting conditions include ensuring a fully charged battery and a clear takeoff area. When the battery is powered on, it supplies voltage to the flight controller and other components. Ensuring the battery is fully charged at the start is crucial for maximum flight time and avoiding mid-flight issues. The system performs a quick self-test to verify battery health.

The F3 EVO flight controller initializes its internal systems. This involves loading firmware, checking its onboard sensors, and ensuring that communication with peripherals is established. Proper initialization ensures smooth drone operation by setting initial parameters for flight control. Sensor calibration is essential for accurate flight control. During this step, the flight controller performs a self-check to calibrate the gyroscope and accelerometer, ensuring that any sensor drift or bias is corrected before takeoff. This step ensures that the drone remains stable during flight.The drone establishes a connection with the remote control transmitter. This connection allows the operator to manually control the drone or override autonomous operations if necessary. A secure and stable connection is critical for safety, particularly in areas with high electromagnetic interference.

Before proceeding with the flight, the system checks the battery voltage level. If the battery level is too low. It prevents takeoff to avoid dangerous mid-flight power depletion. The battery check also includes verifying the temperature of the battery pack to avoid overheating issues.

- **Yes:** If the battery level is above a predefined threshold, the drone proceeds with the flight sequence.
- **No:** If the battery level is below the threshold, the system triggers a buzzer alert and aborts the flight. This ensures the drone does not take off with insufficient power, enhancing safety.

The flight controller processes the data received from the sensors. It uses algorithms to determine the drone’s current position, orientation, and potential obstacles.

This step is crucial for real-time decision-making, ensuring that the drone reacts promptly to changes in its environment.

- **No:** If no obstacles are detected, the drone maintains its current path.
- **Yes:** If an obstacle is detected within a certain range, the system triggers an avoidance maneuver to prevent collision. The avoidance strategy involves calculating a new path while maintaining balance.

If the path ahead is clear, the drone continues on its planned trajectory. The flight controller may make small adjustments to motor speed and direction to maintain stability and optimize energy consumption. When an obstacle is detected, the flight controller initiates an avoidance maneuver. This involves calculating a new trajectory that circumvents the obstacle while maintaining stability and direction. The system ensures that the new path is safe and efficient.

The flight controller adjusts the speed of individual motors to achieve the desired maneuver. This step ensures smooth and controlled movement around obstacles. The adjustment is based on real-time feedback from the IMU and LiDAR sensors. The flight controller sends control signals to the motors and propellers based on processed sensor data. These signals dictate the drone's speed, altitude, and direction. Precise control signals ensure that the drone remains stable even during complex maneuvers.

Throughout the flight, the system continuously monitors the battery status. This step ensures that the drone is aware of any significant drop in battery level. The system also logs battery performance for post-flight analysis.

- **Yes:** If the battery level drops below a critical threshold, the system triggers a buzzer alert and initiates the landing sequence.
- **No:** If the battery level remains within a safe range, the drone continues its operation. The threshold for critical battery level is set to ensure the drone has enough power for a safe landing.

When the battery reaches a critical level, the system triggers an audio alert to inform the operator. Simultaneously, it initiates an autonomous landing sequence to prevent crashes due to power loss. The landing mode is designed to find a safe and flat surface for descent. The drone performs a controlled descent and lands safely at a suitable location. Once on the ground, the system powers off non-essential components to conserve remaining battery power. Post-landing checks include motor shutdown and final data logging. The flight sequence ends, and the drone is ready for maintenance or recharging before its next operation.

3.3.2 Design and Planning

Designing the circuit for a mini drone requires meticulous planning and a systematic approach to integrate the key components. Each part of the drone plays a critical role in ensuring flight stability, power efficiency, obstacle detection, and safety.

Design Objectives:

The primary objectives of the drone circuit design are:

- Stable Flight: Ensure that the flight controller can process sensor data and provide accurate commands to the motors for stable and smooth flight.
- Obstacle Avoidance: Enable real-time detection of obstacles using the LiDAR sensor and trigger appropriate maneuvers to prevent collisions.
- Power Efficiency: Maximize the flight time by efficiently managing power distribution and consumption.
- Safety Features: Incorporate safety mechanisms, such as low battery alerts and autonomous landing, to prevent accidents and damage.

Wiring and Connectivity:

Minimizing wire length reduces resistance and potential signal loss.

- Power Wires: Thick gauge wires should be used for connections between the battery, PDB, and ESCs to handle high current.

- Signal Wires: Shielded wires are recommended for signal connections, such as I2C and PWM, to prevent electromagnetic interference.

Power Management:

Efficient power management is vital for maximizing flight time and ensuring the longevity of components.

- Battery Selection**:** A high-capacity Li-Po battery with a suitable discharge rate should be used to meet the power demands of the motors and electronics.
- Voltage Regulation: The PDB should have built-in voltage regulators to provide stable power to the flight controller and sensors.

Safety Protocols:

Safety is a critical aspect of drone design.

- Low Battery Alert: The buzzer should be triggered when the battery voltage drops below a certain threshold.
- Autonomous Landing: The flight controller should initiate a landing procedure when the battery reaches a critical level.
- Fail-Safe Mechanisms: In case of signal loss from the remote control, the drone should either hover or return to the starting point.

Testing and Iteration:

Thorough testing is required to validate the circuit design.

- Ground Tests: Before flight, perform ground tests to check motor response, sensor readings, and power distribution.
- Flight Tests: Conduct multiple flight tests in a controlled environment to fine-tune the control algorithms and ensure reliable performance.

Planning the Assembly:

Step 1: Frame Assembly:

- Assemble the drone frame and mount the motors, flight controller, and LiDAR sensor.

Step 2: Wiring:

- Connect the motors to the ESCs and route the wires to the PDB.
- Connect the flight controller to the PDB for power and to the ESCs for control signals.
- Connect the LiDAR and buzzer to the flight controller.

Step 3: Power Connection:

- Connect the battery to the PDB using a suitable connector.

Step 4: Calibration:

- Calibrate the sensors (gyroscope, accelerometer, and LiDAR) using the flight controller software.

Step 5: Testing:

- Perform initial power-on tests to check for proper connectivity and functionality of all components.

3.3.3 Circuit Connection of the Mini Drone

The circuit connection of a mini drone as shown in figure 3.3 involves integrating key components such as the F3 EVO flight controller, LiDAR module, motors, propellers, buzzer, and battery in a manner that ensures seamless communication and efficient power distribution. Below is a detailed explanation of the connections:

Power Distribution: The rechargeable Li-Po battery serves as the primary power source. The battery is connected to the Power Distribution Board (PDB), which distributes power to the various components of the drone.

- PDB to Flight Controller: The PDB provides regulated power to the F3 EVO flight controller, ensuring stable operation.
- PDB to Motors: The PDB directly powers the Electronic Speed Controllers (ESCs), which are responsible for driving the motors.

Flight Controller Connections: The F3 EVO flight controller acts as the central processing unit and is responsible for interpreting sensor data and controlling the motors.

- ESC Connections: Each ESC is connected to a specific motor port on the flight controller. These connections allow the flight controller to send PWM signals to control motor speed.
- Gyroscope and Accelerometer: These sensors are typically built into the flight controller and directly communicate with its processor.
- LiDAR Module: The LiDAR sensor is connected to the flight controller via an I2C or UART interface, depending on the specific model used. This connection enables the controller to receive distance data for obstacle detection.

Remote Control Receiver: The remote control receiver is connected to the flight controller through designated input channels. These channels receive signals from the transmitter, allowing the operator to manually control the drone when necessary.

- Binding Process: The receiver must be bound to the remote control transmitter before operation. This ensures a secure communication link.

Buzzer Connection: The buzzer is connected to a dedicated port on the flight controller. The controller triggers the buzzer in response to specific events such as low battery alerts or system errors.

- Alert Mechanism: Different buzzer tones indicate different statuses, such as initialization completion, low battery, or critical battery level.

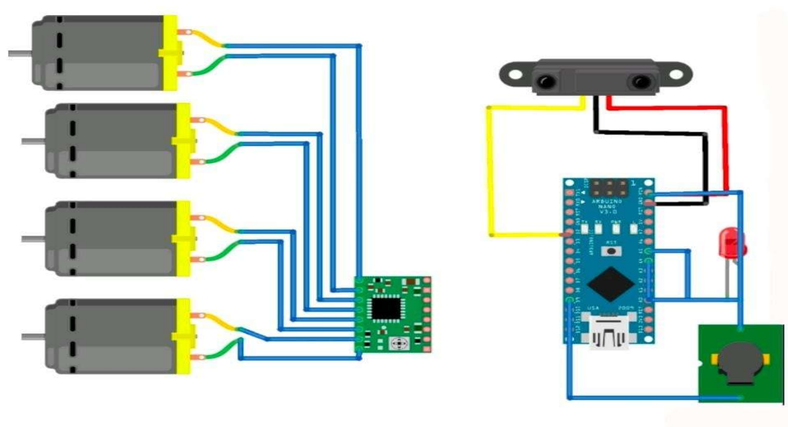

Fig 3.3 Circuit diagram of mini drone

Motor and Propeller Setup: The motors and propellers are critical for generating thrust and enabling flight.

- Motor Connections: Each motor is connected to an ESC, which in turn is connected to the PDB and flight controller. The ESCs receive signals from the controller to adjust motor speed.
- Propeller Configuration: Proper placement of propellers is essential to ensure stable flight. The propellers must be oriented correctly to generate the necessary lift and control torque.

Battery Connection: The Li-Po battery is connected to the PDB via a secure XT60 or similar connector. This connection ensures stable power delivery during flight.

3.4 Remote Controller of a Mini Drone

The remote controller (RC) is a critical part of a mini drone system, enabling a user to manually control the drone's movements and access various flight modes. The RC communicates wirelessly with the drone via radio frequency (RF) signals, typically using protocols such as 2.4 GHz ISM band, PWM, or PPM signals. The RC transmits control signals corresponding to the user’s joystick and button inputs, while the drone’s onboard flight controller processes these signals to adjust motor speeds, altitude, and direction. Additionally, telemetry feedback from the drone (such as battery status or signal strength) can be sent back to the remote controller.

Steps in Remote Controller Working

- Powering ON the Controller: The remote controller is powered by a battery pack, typically rechargeable lithium-ion or AA batteries. Once powered on, the microcontroller inside the RC initializes the communication module and sensors (joysticks, switches, buttons).
- Signal Input from Joysticks
  - Throttle Control: The throttle joystick determines the drone’s altitude by adjusting the overall motor speed.
  - Yaw, Pitch, Roll Control: The other joystick provides yaw (rotation), pitch (forward/backward tilt), and roll (left/right tilt) commands.
  - Additional Switches and Buttons: These may control auxiliary functions such as flight mode switching, camera control, or return-to-home (RTH) activation.
- Signal Processing**:** The microcontroller reads the inputs from the joysticks and buttons, converts them into digital signals, and encodes them into a communication protocol (e.g., PWM, PPM, or SBUS) for transmission.
- Wireless Transmission**:** The communication module, usually a 2.4 GHz RF module, transmits the encoded control signals wirelessly to the drone's receiver. Advanced controllers may use frequency-hopping spread spectrum (FHSS) or direct-sequence spread spectrum (DSSS) to improve signal reliability and avoid interference.

- Drone Receiver Processing: The drone's receiver picks up the transmitted signal and forwards it to the flight controller (F3 EVO). The flight controller decodes the signal and adjusts the motor outputs accordingly to execute the intended movement.
- Telemetry Feedback (Optional)**:** Some advanced remote controllers feature telemetry, where data such as battery level, altitude, and signal strength is sent back from the drone to the remote controller. This feedback helps the user make informed decisions during flight.

3.4.1 Block Diagram of Remote Controller

Designing and planning the remote controller configuration for the mini drone as shown in figure 3.4 involves ensuring seamless communication between the operator and the drone, enabling efficient and safe flight operations. The remote controller must offer intuitive inputs for controlling the drone's basic flight movements, including throttle, yaw, pitch, and roll. These inputs are typically provided through joysticks, which allow the operator to make precise adjustments to the drone's altitude and direction. By having dedicated controls for each axis of movement, the operator gains full control over the drone's stability and trajectory, which is crucial for both manual navigation and collision avoidance during flight.

Auxiliary functions are essential for enhancing the drone's capabilities, such as mode switching, return-to-home (RTH), and camera control. These functions are commonly mapped to switches and buttons on the remote controller, giving the operator quick access to features that improve flight safety and efficiency. For example, the return-to-home function allows the drone to autonomously navigate back to its starting point in case of signal loss or low battery, making it a critical feature for long-distance flights. Camera controls are also integrated into the system to allow the operator to capture footage or view the drone's surroundings in real time.

The microcontroller within the remote controller plays a crucial role in processing the input signals from the joysticks, buttons, and switches. It encodes these signals into a format that can be transmitted to the drone's receiver. This microcontroller ensures that the commands are processed accurately and in real-time, providing immediate feedback to the operator. Its role extends to managing the overall operation of the controller, ensuring reliable and consistent transmission of commands to the drone's receiver for smooth flight control.

To power the entire system, a reliable power supply is required to ensure continuous operation of the remote controller and its components. The power supply must be robust enough to handle the power demands of the joysticks, switches, microcontroller, and communication module without interruption.

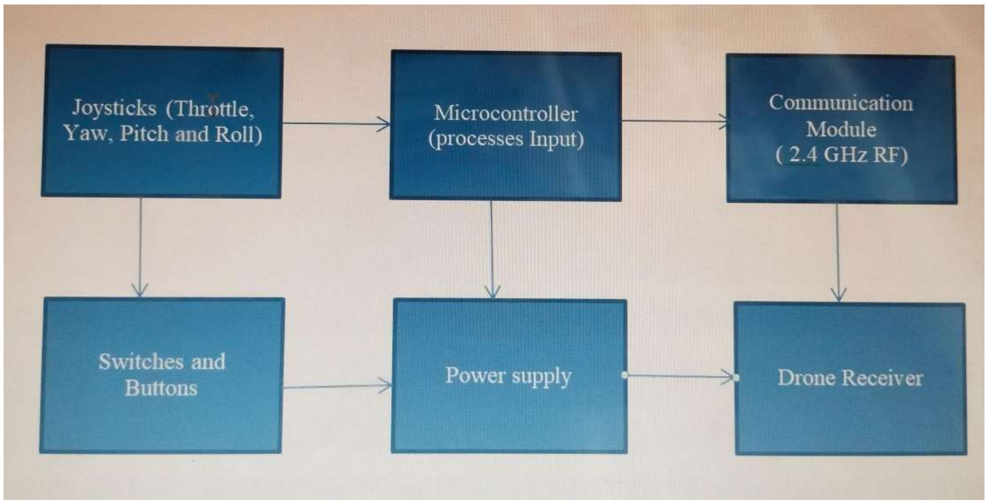

Fig 3.4 Block diagram of remote control

The communication module, typically operating at a 2.4 GHz RF frequency, transmits the encoded commands to the drone’s receiver. This communication is essential for real-time data transfer between the operator and the drone, ensuring that each command reaches the flight controller promptly. The drone's receiver, in turn, decodes the signals and relays them to the flight controller, completing the feedback loop and allowing for responsive control of the drone in various environments.

3.4.3 Hardware Selection and Integration

The hardware selection for the remote controller is crucial for achieving reliable performance. This section outlines the key components and their integration.

Key Components:

RF Transceiver Module:

- Module: NRF24L01 or similar 2.4 GHz transceiver.
- Integration: Connect the RF module to the microcontroller on the remote controller and the F3 EVO flight controller on the drone.

Microcontroller:

- Controller: An ATmega328P or ESP32 microcontroller can be used to process input from the joysticks and buttons and send data to the RF module.
- Integration: The microcontroller interfaces with the joysticks, buttons, and display, and sends control signals to the RF module.

Joysticks and Buttons:

- Joysticks: Use two analog joysticks for throttle/yaw and pitch/roll control.
- Buttons: Include buttons for takeoff, landing, and mode switching.
- Integration: Connect the joysticks and buttons to the analog and digital input pins of the microcontroller.

Display:

- Type: A 16x2 LCD or an OLED display can be used to show telemetry data.
- Integration: Connect the display to the microcontroller using I2C or SPI interface.

Battery:

- Type: A 7.4V Li-ion or Li-Po battery.

3.4.4 Software Development

The software development for the remote controller involves writing firmware for both the remote controller and the drone’s flight controller.

Firmware for Remote Controller:

The firmware handles input from the joysticks and buttons, processes the data, and sends control signals to the drone.

- Initialization: Initialize the microcontroller, RF module, joysticks, buttons, and display.
- Reading Inputs: Continuously read input from the joysticks and buttons.
- Data Processing: Convert joystick positions into PWM values for throttle, yaw, pitch, and roll.
- Data Transmission: Send the processed data to the drone via the RF module.
- Display Update: Continuously update the display with telemetry data received from the drone.

Firmware for Drone:

The firmware on the drone’s flight controller processes incoming control signals and sends telemetry data back to the remote controller.

- Initialization: Initialize the flight controller, RF module, sensors, and motors.
- Receiving Data: Continuously receive control signals from the remote controller.
- Motor Control: Convert the received signals into PWM values and send them to the ESCs.
- Telemetry Transmission: Send telemetry data (e.g., battery level, altitude) to the remote controller via the RF module.

Testing and Iteration:

Thorough testing is required to ensure the remote controller configuration works as intended.

Ground Testing:

- Test the communication link between the remote controller and the drone.
- Verify that the joysticks and buttons send the correct control signals.
- Check the display for accurate telemetry data.

Flight Testing:

- Conduct test flights in a controlled environment.
- Evaluate the responsiveness of the controls and the accuracy of the telemetry data.
- Test safety features such as return-to-home (RTH) and low battery alerts.

Iteration:

Based on the test results, make necessary adjustments to the hardware and software.

- Improve the signal range and stability by adjusting the RF module settings.
- Fine-tune the control algorithms for better flight performance.
- Enhance the display interface for better readability.

3.4.5 Finalization and Deployment

Once the system has been thoroughly tested and refined, it is ready for final deployment.

Final Assembly:

- Assemble the remote controller and drone components securely.
- Ensure all connections are properly soldered and insulated.

Final Testing:

- Perform a final round of testing to ensure everything works as expected.
- Test the system in various environments to validate its robustness.

Deployment:

- The mini drone with the remote controller can now be deployed for real-world use.
- Provide documentation and user guidelines for safe operation.

By following this detailed design and planning process, a reliable and efficient remote controller configuration for the mini drone can be achieved

3.5 Live Streaming

Live streaming using an ESP32-CAM is shown in figure 3.5 involves transmitting video feed from the ESP32-CAM module over Wi-Fi to a client device, where the video can be monitored.This process requires a combination of hardware (ESP32-CAM, WiFi module) and software (web server or streaming protocol) to facilitate smooth communication. Below is a step-by-step breakdown of how the system works.

ESP32-CAM**:** The ESP32-CAM is a low-cost, compact development board equipped with an integrated camera and Wi-Fi capabilities. The board features:

- ESP32 Microcontroller: This handles the logic and communication for the video stream.
- OV2640 Camera: The camera module captures video frames.
- Wi-Fi Connectivity: The ESP32-CAM can connect to local Wi-Fi networks for internet access or peer-to-peer communication.

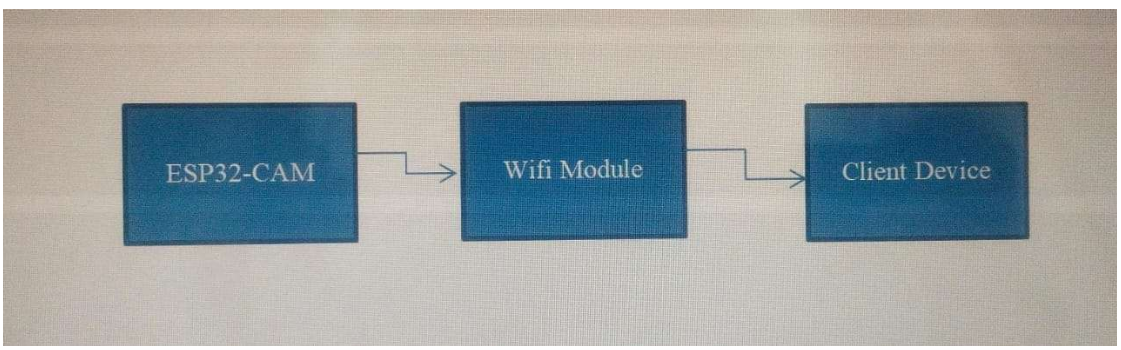

Fig 3.5 Block diagram of Live stream

Setting Up the ESP32-CAM for Live Streaming

- Camera Initialization: The ESP32-CAM initializes the camera module (OV2640), configuring it to capture video frames at a specified resolution (usually 640x480 or 320x240 for smoother streaming).
- Wi-Fi Connection: The ESP32-CAM connects to a Wi-Fi network using the onboard Wi-Fi module (ESP32's Wi-Fi capabilities). The Wi-Fi credentials (SSID and password) are configured in the software.

- Web Server Setup: The ESP32-CAM runs a small HTTP server that handles requests from client devices. It streams the captured frames over HTTP or RTSP (Real-Time Streaming Protocol) to the client device.

Streaming Protocol

- MJPEG Stream: The ESP32-CAM typically uses MJPEG (Motion JPEG) as the video streaming format. MJPEG is a compression technique where each frame is an individual JPEG image, making it easy to stream over the network. The HTTP server sends a continuous stream of JPEG images, which the client device renders as a video.

  The HTTP response contains multipart image data, which is sent to the client device in intervals (frame by frame). The browser or client device that requests the video feed continuously loads these images to create the illusion of a video.

- RTSP Stream: For higher efficiency and lower latency, the ESP32-CAM can also be configured to stream via RTSP. RTSP supports live video streaming, allowing clients to control the video feed (e.g., pause, play). This requires using additional libraries on the ESP32 and RTSP-compatible software on the client device.

Client Device (Viewer)

- Web Browser: The simplest way to view the stream is via a web browser. The client device connects to the ESP32-CAM's IP address through the local network.
- The ESP32-CAM serves the video stream, and the browser renders it in real-time. In the case of MJPEG, it simply displays the JPEG images as frames in a video-like format.
- Dedicated Software: For RTSP streams or more complex implementations, a client device can use video streaming software like VLC Media Player or an RTSP-compatible application. The software connects to the ESP32-CAM's IP address and port, receiving and displaying the video feed.

Monitoring and Interaction

- Real-time Monitoring: The client device receives the continuous video stream and displays it, allowing real-time monitoring of the camera's field of view.
- Interaction **:** Advanced setups may include the ability to control the camera or interact with the streaming process. For example, a web interface might allow zooming or changing the video resolution, while some applications can control the orientation of the camera if it is mounted on a pan-and-tilt mechanism.

Challenges and Considerations

- Latency: Live streaming involves some latency, especially when using Wi-Fi. The higher the video resolution and frame rate, the greater the potential delay. Optimizing the streaming protocol and video compression can help minimize lag.
- Bandwidth: The amount of data transmitted depends on the video resolution, frame rate, and streaming protocol. Higher resolution streams require more bandwidth, so network performance and Wi-Fi signal strength are key factors in stream quality.
- Power Consumption: The ESP32-CAM uses significant power when streaming, so it may require an external power supply or battery if used for prolonged periods.

Design and Planning

Design and planning play a crucial role in the successful implementation of a live streaming project using an ESP32-CAM module, WiFi connectivity, and an SD card. This phase focuses on outlining the project's purpose, defining technical specifications, and ensuring all necessary requirements are identified before moving on to hardware and software implementation.

- **Defining Project Objectives:**

The primary objective of this project is to create a reliable live streaming system that can capture video using the ESP32-CAM module, transmit the video feed over a WiFi network, and optionally store recorded video on an SD card for future playback. Additionally, considerations for low latency, stable connectivity, and user-friendly operation should be addressed.

- **System Architecture:**

The planned system architecture includes three major components:

ESP32-CAM Module: Responsible for capturing video and transmitting it over WiFi.

WiFi Network: Acts as the medium for live streaming, connecting the ESP32-CAM to a server or client device.

SD Card Storage: Used for local recording of video feeds.

The architecture diagram includes the ESP32-CAM connected to a power source, with WiFi enabling the connection to a remote viewing device (e.g., smartphone, computer) while the SD card stores video data locally.

- **Key Design Considerations:**

Power Supply: The ESP32-CAM requires a stable 5V power supply for reliable operation.

WiFi Coverage: Ensure the WiFi network range covers the intended area where the ESP32-CAM will be deployed.

Video Resolution: Balance resolution and frame rate to achieve an optimal trade-off between video quality and network bandwidth usage.

Data Storage: Plan the SD card capacity based on expected recording duration and video quality.

Scalability: Design for possible future expansion, such as adding multiple cameras.

- **Hardware Selection and Integration**

Hardware selection and integration involve choosing the right components for the project and ensuring they are properly assembled and connected to function as a cohesive system. In this case, the key hardware components are the ESP32-CAM module, a compatible SD card, power supply, and necessary peripherals.

Hardware Components:

ESP32-CAM Module:

The ESP32-CAM is a low-cost module with an integrated camera and WiFi/Bluetooth capabilities. Key features include:

- 2MP OV2640 camera.
- Built-in microSD card slot.
- Support for up to 160 MHz clock speed.
- GPIO pins for additional peripherals.

MicroSD Card:

A microSD card is required for local video storage. Recommended specifications:

- Capacity: 16GB or higher.
- Speed Class: Class 10 or UHS-I for faster read/write speeds.
- File System: FAT32 for compatibility with the ESP32-CAM module.

Power Supply:

A stable 5V 2A power supply is crucial to ensure the ESP32-CAM operates reliably without unexpected resets or disconnections.

Other Peripherals:

FTDI Programmer: Required for flashing the ESP32-CAM with custom firmware during the software development phase.

Jumper Wires and Breadboard: For initial prototyping and testing connections.

Mounting the Camera: Attach the OV2640 camera to the ESP32-CAM module using the provided connector. Ensure a secure fit to avoid issues during operation.

- Connecting the SD Card: Insert the microSD card into the slot on the ESP32-CAM. Ensure it is formatted correctly to FAT32 before use.

Power and Programming Connections:

- Connect the ESP32-CAM to the FTDI programmer using jumper wires.
- Ensure proper connection of TX, RX, and GND pins.
- Power the module via the VCC and GND pins.
- Initial Power-Up: Before flashing any firmware, power up the ESP32-CAM to check if the default firmware is operational and if the WiFi network is detectable.

By carefully selecting and integrating the hardware components, the system's reliability and performance can be optimized, paving the way for smooth software development.

Software Development

Software development is the heart of the live streaming project. This phase involves writing firmware for the ESP32-CAM, enabling WiFi connectivity, live video streaming, and SD card recording functionality.

Development Environment Setup:

- Arduino IDE: The Arduino IDE is a popular choice for programming the ESP32-CAM.
- ESP32 Board Support: Ensure the ESP32 board package is installed in the Arduino IDE.
- Required Libraries:
    - WiFi.h for WiFi connectivity.
    - ESPAsyncWebServer.h for handling HTTP requests.
    - SD_MMC.h for SD card operations.

CHAPTER 4

RESULT

CHAPTER 4

RESULT

4.1 Result

The mini drone system developed for this project integrates various essential components to achieve both effective flight control and real-time video streaming. The drone is equipped with a lightweight frame, efficient motors, and propellers, ensuring stable flight performance. A powerful battery system provides the necessary energy for operation, while the flight controller, equipped with necessary sensors, processes input from the remote control and adjusts the flight accordingly.

The remote control system incorporates a transmitter with joysticks and buttons for precise control over the drone's altitude, direction, and additional functionalities such as camera operation and auto-landing. Communication between the remote control and the drone is facilitated through RF or Wi-Fi modules, enabling seamless command execution. Additionally, telemetry feedback provides real-time flight status, including altitude, battery life, and speed, which can be monitored through the remote control or a connected mobile interface.

To enhance the functionality of the drone, a camera module is integrated for live streaming, providing a real-time video feed that can be transmitted to compatible devices such as smartphones or computers. The video feed is displayed through a mobile app or software, offering additional features like camera control and flight telemetry. The system's live streaming capabilities are supported by RF or Wi-Fi communication, ensuring stable video transmission for effective monitoring and remote operation.

This integrated system provides a comprehensive solution for controlling a mini drone and streaming video in real-time, offering both versatility and functionality. The implementation of these features in the project demonstrates the successful integration of hardware and software components, ensuring smooth operation and user-friendly control for various applications.

4.2 Project Prototype

Prototype Design:

The mini drone prototype as shown in fig 4.1 is designed to be lightweight and compact, ensuring maneuverability and ease of use. The structure consists of a durable frame that holds all key components securely. The drone’s design is optimized for indoor and outdoor flight, with a small footprint that allows it to fly in confined spaces. The core function of the prototype is to enable users to control the drone with a remote control and stream video footage in real time, making it suitable for surveillance, recreational use, or aerial photography.

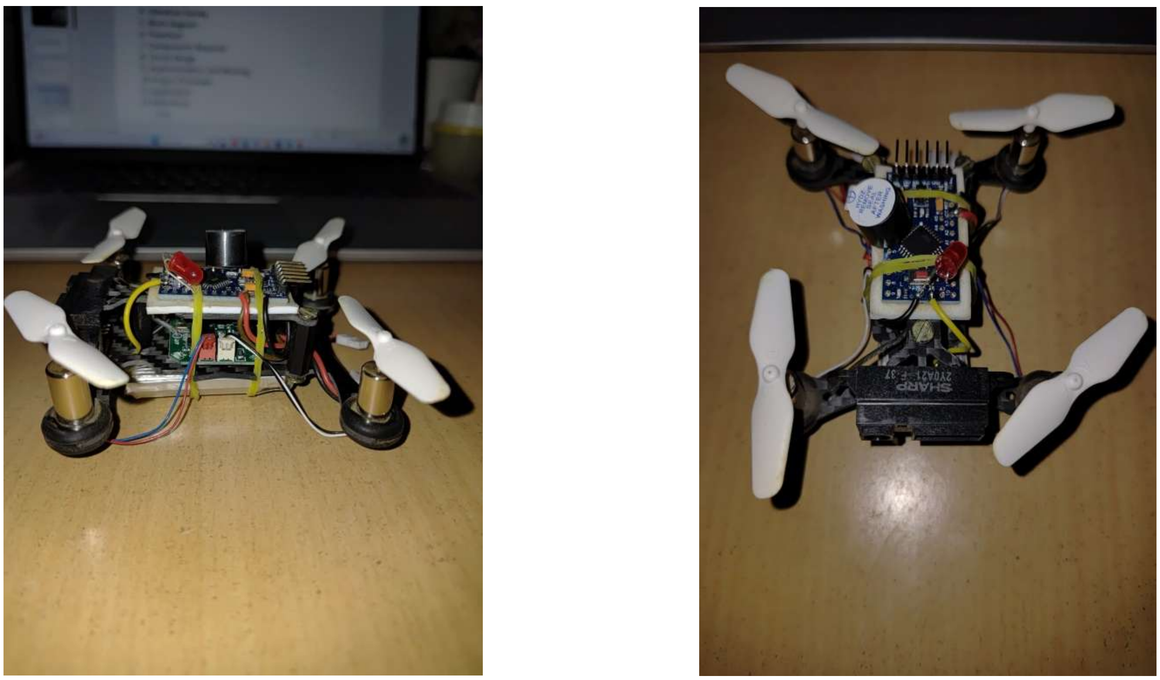

Fig 4.1 Side and Top view of the Mini Drone

Frame**:** The frame is made from lightweight yet durable material, such as plastic or carbon fiber, to reduce weight while providing structural integrity. The frame houses all electronic components, ensuring their protection during flight.

Motors and Propellers**:** Four brushless motors provide the necessary thrust for flight, paired with lightweight propellers for maximum efficiency. These components ensure stability and control during flight.

Battery**:** The prototype uses a lithium-polymer (LiPo) battery for energy storage. The battery is compact but provides enough power to support extended flight times while maintaining the drone's lightweight design.

Flight Controller**:** The flight controller is responsible for stabilizing the drone and processing input from the remote control. It contains sensors such as an accelerometer and gyroscope, which help maintain the drone's balance and orientation during flight.

Communication Module**:** The communication module is responsible for transmitting both control signals and video feed. This is achieved through RF (radio frequency) signals or Wi-Fi, depending on the configuration chosen for the project. RF is ideal for long-range communication, while Wi-Fi offers higher bandwidth for video streaming.

Telemetry Feedback**:** The drone's flight parameters (such as altitude, speed, battery status, and orientation) are transmitted to the remote control or an app on a connected device. This real-time feedback ensures the operator is always informed of the drone's current status.

Control System:

The control system allows the operator to command the drone's movement through a wireless remote control or a mobile app. The remote control as shown in fig 4.2 features joysticks for controlling the altitude and orientation of the drone. Additional buttons and switches provide control over the camera, video recording, and other functions such as auto-landing and return-to-home.

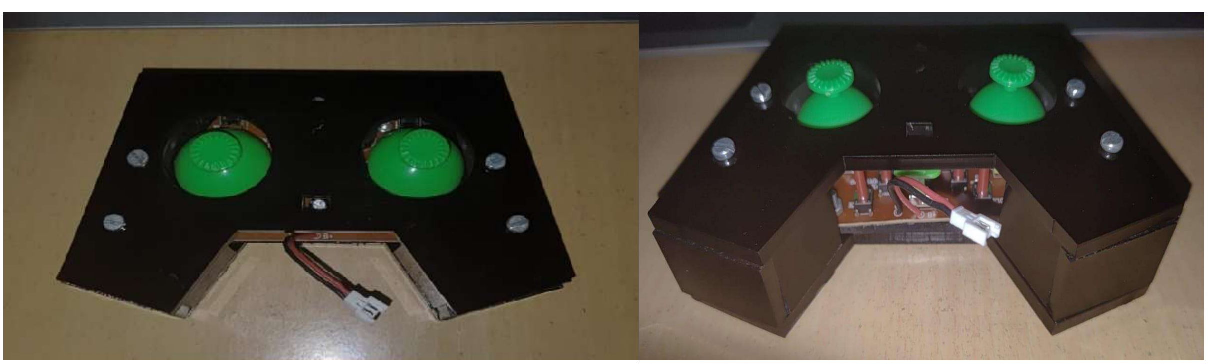

Fig 4.2 Remote Controller

In terms of software, the mobile app can also allow for flight path planning, where the operator can select waypoints or direct the drone through a touch interface. The app communicates with the drone via Wi-Fi to send commands and receive telemetry data, including live video feed and flight parameters.

4.3 Live Streaming Function:

The live streaming feature allows the video captured by the drone's camera to be transmitted to a smartphone, tablet, or computer. This is achieved through Wi-Fi or RF-based communication. The video feed can be viewed on a dedicated mobile app or software, which also provides additional functionalities such as flight telemetry, camera control, and video recording

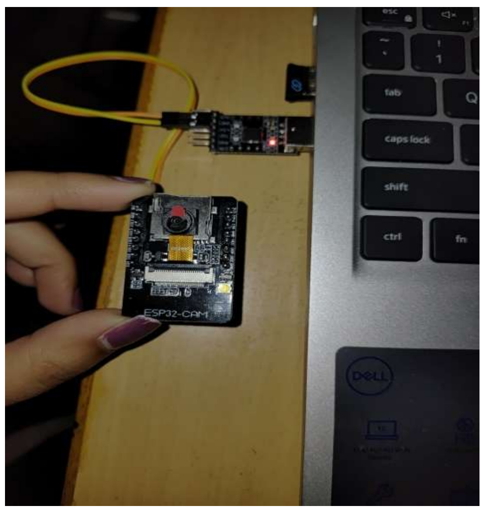

Fig 4.3 View of Connection

To facilitate live streaming, referring to figure 4.3 the system is designed with minimal latency in video transmission, ensuring that the feed remains smooth and in real-time. The camera module used in the drone provides HD resolution (720p or 1080p) for clear and detailed video, while the communication module ensures the video feed is transmitted without significant loss of quality.

CHAPTER 5

APPLICATION, ADVANTAGES AND DISADVANTAGES

CHAPTER 5

APPLICATIONS, ADVANTAGES AND DISADVANTAGES

5.1 Applications, Advantages and Disadvantages of Mini Drone.

Applications:

- Surveillance and Security: Used for monitoring properties and detecting unauthorized access with real-time alerts.
- Search and Rescue: Helps in locating missing persons by navigating difficult terrains and alerting nearby obstacles.
- Agriculture: Used for crop monitoring and spraying pesticides while avoiding obstacles like trees or power lines.
- Delivery Systems: Delivers small packages while ensuring safe navigation around objects in urban environments.
- Wildlife Monitoring: Tracks animal movements and avoids disturbances with proximity alerts in protected areas.
- Inspection of Infrastructure: Inspects power lines, wind turbines, and pipelines, preventing collisions with nearby structures.
- Photography and Videography: Captures aerial footage while avoiding obstacles like trees and buildings.
- Disaster Management: Assists in assessing damage after natural disasters while avoiding debris and obstructions.
- Military Reconnaissance: Used in military operations for gathering intelligence in complex environments while avoiding detection.
- Education and Research: Employed in universities and research institutions for studying drone technology and its applications.

Advantages:

- Enhanced Safety: Proximity alert prevents drones from colliding with obstacles, enhancing safety during operation.
- Obstacle Avoidance: Real-time proximity alerts allow the drone to navigate around barriers without human intervention.
- Cost-Effective: Mini drones are relatively affordable compared to larger drones, making them accessible for various applications.
- Compact and Portable: Small size makes it easy to transport and deploy in tight spaces or challenging environments.
- Autonomous Operation: With proximity sensors, drones can operate autonomously, reducing the need for constant human control.
- Improved Efficiency: Increased ability to navigate without crashing means fewer maintenance costs and downtime.
- Versatile Applications: Suitable for both indoor and outdoor use, with applications across different industries.
- Real-Time Alerts: Provides immediate notification of nearby obstacles, helping operators take action quickly.
- Data Collection: Can be used for gathering critical data, like environmental measurements or surveillance footage, without human risk.
- Increased Precision: Proximity alerts help mini drones maintain accuracy in navigating complex environments.

Disadvantages:

- Limited Battery Life: Mini drones typically have shorter battery lives, limiting their operational time.
- Limited Payload: Due to their small size, they may not carry heavy equipment or sensors for complex tasks.
- Environmental Limitations: Proximity sensors may be less effective in certain environments like fog or heavy rain.
- Signal Interference: Proximity sensors can be affected by electromagnetic interference or obstacles blocking the sensor's view.
- Complexity of Technology: Integrating and maintaining proximity alert systems can increase the complexity and cost of the drone.
- Limited Range: Mini drones typically have a limited range due to smaller communication modules and lower power.
- Vulnerability to Damage: Due to their size, mini drones are more susceptible to damage from collisions or harsh weather conditions.
- Regulatory Issues: Use of drones in certain areas may be restricted or regulated by laws, especially in urban or densely populated regions.
- Lack of Advanced Features: While proximity alerts are useful, mini drones may lack other advanced features like high-resolution cameras or advanced stabilization.
- Sensor Limitations: Proximity alerts are based on sensors that may not detect every possible hazard, leading to potential collisions if not properly calibrated.

5.2 Applications, Advantages and disadvantages of Live Stream.

Applications:

- Security Surveillance: Using the ESP32 CAM to stream live video for home or office security monitoring.
- Remote Monitoring: Monitoring remote locations or machinery through a live stream with real-time video feedback.
- Outdoor/Adventure Streaming: Streaming live video from outdoor events like hiking, camping, or sports activities.
- DIY Smart Home Systems: Integrating ESP32 CAM with smart home devices to stream video from various locations in a home.
- Interactive Livestreaming (Education, Gaming, etc.): Using the ESP32 CAM for live interactive lessons, tutorials, or gaming streams.
- Robotic Vision: Employing the ESP32 CAM on a mobile robot to stream video for remote control or monitoring.
- Wildlife Observation: Setting up live streaming for observing wildlife in forests, zoos, or aquariums.
- Drone Streaming: Using the ESP32 CAM for real-time video feed on drones for aerial surveillance.
- Live Event Broadcasting: Broadcasting small-scale events like weddings, performances, or conferences.
- Medical/Healthcare Streaming: Live streaming for telemedicine or real-time health monitoring of patients.

Advantages:

- Low-Cost Solution: ESP32 CAM is an affordable option for streaming compared to other dedicated streaming cameras.
- Compact and Portable: Small form factor makes it easy to set up and move around for live streaming purposes.
- Wi-Fi Connectivity: Can stream over Wi-Fi, eliminating the need for wired connections and providing flexibility in setup.
- Customizable**:** The ESP32 allows custom firmware and configuration, offering flexibility in how streaming is managed.
- Easy Integration**:** Can be easily integrated into existing IoT systems or projects for live video streaming.
- Low Power Consumption: ESP32 CAM is energy-efficient, making it suitable for battery-powered applications.
- Real-Time Feedback: Enables real-time video feedback, useful for monitoring, surveillance, and live event broadcasting.
- Scalable**:** Multiple ESP32 CAM units can be deployed for larger-scale monitoring or broadcasting setups.
- Supports Multiple Protocols: Supports streaming protocols such as MJPEG or RTSP, allowing compatibility with various platforms.
- Easy to Set Up: Simple to configure with libraries and examples available for the ESP32 CAM, making setup faster for developers.

Disadvantages:

- Limited Video Quality: The ESP32 CAM has relatively low video quality (640x480 or 1280x720), which may not meet the needs of high-definition streaming.
- Limited Processing Power: The ESP32 CAM's processing capabilities are limited, which may cause lag or lower frame rates in some streaming scenarios.
- Short Range: Wi-Fi signal range limitations might restrict streaming distances, especially in large areas or buildings with thick walls.
- Network Dependency: The quality of the stream is dependent on the Wi-Fi network's speed and stability, which may be inconsistent in some environments.
- Security Risks: Live streaming over a Wi-Fi connection can expose the device to security vulnerabilities if not properly secured.
- Low Frame Rate: Frame rates may be limited to lower values (typically 15–30 fps), affecting smoothness in fast-moving scenes.
- Storage Constraints: ESP32 CAM has limited onboard storage, so recording long streams may require additional memory or cloud storage.
- Latency Issues: Live streaming over Wi-Fi can introduce latency, which may impact real-time applications such as remote control or gaming.
- Limited Power Options: Battery-powered live streaming can be problematic for long periods, requiring frequent recharging or external power sources.
- Quality Degradation in Poor Wi-Fi Conditions: Streaming quality may degrade in poor Wi-Fi conditions (e.g., interference, low signal strength) causing buffering or dropouts.

CHAPTER 6

CONCLUSION AND FUTURE SCOPE

CHAPTER 6

CONCLUSION AND FUTURE SCOPE

6.1 Conclusion

In the intersection of live streaming and drone technology, the combination of a mini drone system and live streaming capabilities offers immense potential for both personal and professional applications. The use of components like ESP32 CAM, a compact yet powerful camera module, and a Wi-Fi module enables efficient real-time video streaming, even from remote or hard-to-reach locations. The integration of live streaming with mini drone systems transforms how we interact with aerial devices, making them an ideal choice for diverse scenarios, ranging from security surveillance and wildlife observation to adventurous activities and educational content delivery.

The advantages of such a system are clear: low-cost solutions, easy integration, portability, and the ability to perform remote monitoring and control through Wi-Fi. These strengths make it highly suitable for personal projects, research, and prototyping purposes. Whether it’s an autonomous drone surveying a site, an outdoor adventure stream, or a security drone with real-time surveillance, the potential applications of such systems are vast and expanding.

However, there are also certain limitations. As observed, the low processing power of the ESP32, limited video quality, and network dependency may restrict its performance in some applications, particularly those requiring higher resolution, smoother frame rates, or larger ranges. These factors should be considered when designing drone systems, particularly if the drone is intended for professional, commercial, or large-scale applications.

6.2 Future Scope:

The future of mini drones combined with live streaming technology is poised for exciting advancements, especially as both fields continue to evolve.

- Improved Video Quality & Transmission: As camera technology advances, future drones could incorporate higher resolution cameras (such as 4K streaming), enhanced image processing, and faster wireless communication protocols (like 5G or Wi-Fi 6) to offer better video quality and smoother streaming experiences. This could open doors for professional videography, film production, and remote inspection applications.
- Enhanced Drone Autonomy: In the coming years, mini drones will likely become more autonomous, capable of operating without much human intervention. Integration with advanced AI and machine learning could enable drones to analyze the live stream video, recognize patterns, and even make real-time decisions for surveillance, security, and environmental monitoring.
- Higher Battery Efficiency and Power Solutions: Battery technology advancements will help drones stay airborne for longer durations, which is crucial for applications like aerial surveys, long-range surveillance, and search and rescue operations. Solar-powered drones or better energy storage solutions could extend operational timeframes and reduce the need for frequent recharges.
- Edge Computing Integration: By integrating edge computing on drones, live video processing could occur on the drone itself, reducing latency and bandwidth consumption. This would allow drones to process data on-site, such as performing facial recognition, detecting objects, or analyzing environmental conditions before sending necessary data back to the user or a central server.
- Advanced Telemetry and Feedback Systems: Future drones will likely feature advanced telemetry systems with more precise real-time data transmission and feedback, enhancing control during live-streaming events, and ensuring safer operation even in challenging environments. Telemetry data such as speed, altitude, and drone health will be integrated into live streams for enhanced user experience and safety.

CHAPTER 7
REFERENCES

CHAPTER 7

REFERENCES

7.1 References

1. Sharma and M. K. Singh, "Development of LiDAR-based Obstacle Detection System for Mini Drones," International Journal of Robotics and Automation, vol. 39, no. 4, pp. 245-252, Apr. 2023.
2. Y. Chen, W. Zhang, and R. Li, "Integration of LiDAR Sensors in Micro UAVs for Enhanced Obstacle Detection," IEEE Transactions on Aerospace and Electronic Systems, vol. 59, no. 1, pp. 54-62, Jan. 2023.
3. K. P. Reddy, S. J. Rao, and T. V. Ramesh, "Compact LiDAR Systems for Autonomous Mini Drones," in Proceedings of the IEEE International Conference on Intelligent Systems and Control (ISCO), Coimbatore, India, 2023, pp. 302-307.
4. Z. Wang and M. L. Wang, "Autonomous Flight Control in Mini UAVs Using LiDAR-Based Proximity Alerts," IEEE Access, vol. 11, pp. 11572-11583, 2023.
5. J. Liu, X. Gao, and H. Xu, "Real-Time Collision Avoidance for Mini Drones Using LiDAR Technology," in Proceedings of the IEEE International Conference on Robotics and Automation (ICRA), Xi'an, China, 2022, pp. 784-789.
6. S. Thakur and R. Gupta, "LiDAR-Enabled Navigation System for Miniature Drones," Journal of Intelligent and Robotic Systems, vol. 104, no. 3, pp. 457-467, Mar. 2023.
7. M. S. Alam, "Lightweight LiDAR Integration for Mini UAVs with Proximity Detection," IEEE Sensors Journal, vol. 23, no. 6, pp. 4402-4409, Jun. 2023.
8. P. R. Pal and A. Gupta, "Adaptive LiDAR-Based Obstacle Detection for Mini Drones in Complex Environments," in Proceedings of the IEEE International Conference on Advanced Robotics (ICAR), Tokyo, Japan, 2023, pp. 592-598.
9. R. Patel and S. Sharma, "LiDAR-Driven Micro UAVs: Enhancing Navigation and Safety Features," IEEE Transactions on Industrial Electronics, vol. 70, no. 3, pp. 2850-2858, Mar. 2024.