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DIY FIRE EXTINGUISHER DRONE USING IoT

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Abstract: Fire accidents pose a serious threat to human life, property, and the environment, especially in industrial areas, forests, warehouses, and residential buildings. Traditional firefighting methods often expose firefighters to hazardous conditions and may result in delayed emergency response. This paper presents the design and development of a DIY Fire Extinguisher Drone, a low-cost unmanned aerial vehicle (UAV) designed to detect and suppress small-scale fires efficiently. The proposed system integrates an ESP32 microcontroller, flame sensor, smoke sensor, GPS module, camera module, relay-controlled water pump, and brushless DC motors to create an intelligent firefighting platform. Upon detecting fire, the drone identifies the affected area, activates the onboard extinguishing mechanism, and simultaneously transmits real-time video and GPS coordinates to the operator for effective monitoring and emergency response. The lightweight design, affordable hardware, and modular architecture make the system suitable for educational institutions, industries, and disaster management applications. Experimental evaluation demonstrates reliable fire detection, rapid response time, and effective suppression of controlled fire scenarios while reducing human involvement in dangerous environments.
The proposed DIY Fire Extinguisher Drone provides an economical, efficient, and scalable solution for enhancing firefighting operations and improving public safety through modern UAV technology.

Keywords: DIY Fire Extinguisher Drone, Unmanned Aerial Vehicle (UAV), ESP32, Fire Detection, Flame Sensor, Smoke Sensor, GPS, IoT, Emergency Response, Embedded Systems.

I.INTRODUCTION

1.1 Background

Fireaccidentsare among the most destructive disasters, causing significant loss of life, property, and environmental resources worldwide. Fires occurring in residential buildings, industries, warehouses, forests, and co establishments often spread rapidly, making early detection and immediate suppression essential. Conventional firefighting methods rely heavily on firefighters entering hazardous environments, where they are exposed to extreme heat, toxic smoke, structural collapse, and other life-threatening conditions. Delays in reaching the fire source can result in extensive damage and increased risk to both emergency personnel and civilians.
Recent advancements in Unmanned Aerial Vehicle (UAV) technology have introduced new possibilities intelligent sensors, embedded systems, wireless communication, and real-time monitoring capabilities, drones can detect fire at an early stage and assist emergency responders without exposing human lives to unnecessary risks.

1.2 Problem Statement

Fireaccidents in residential buildings, industries, warehouses, forests, and commercial establishments continue to cause significant loss of life, life property, and environmental resources. Conventional firefighting methods rely heavily on human intervention, requiring firefighters to enter hazardous environments filled with intense heat, toxic smoke, and unstable structures. These conditions increase the risk of injuries and fatalities while often delaying the firefighting process. Although advanced firefighting drones have been developed in recent years, most commercial systems are expensive and incorporate sophisticated technologies such as thermal imaging cameras, artificial intelligence, LiDAR, and autonomous navigation. Their high cost, complex design, and maintenance requirements make them inaccessible for educational institutions, small industries, research laboratories, and emergency response organizations with limited budgets.

Furthermore, many existing drone systems are designed primarily for aerial surveillance and fire monitoring rather than active fire suppression. They often lack an integrated extinguishing mechanism capable of controlling fires during their initial stages, when rapid intervention is most effective.

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II. LITERATURE REVIEW

The use of Unmanned Aerial Vehicles (UAVs) in firefighting and disaster management has gained significant attention due to their ability to access hazardous locations quickly and safely. Recent advancements in embedded systems, wireless communication, and sensor technologies have enabled drones to perform tasks such as fire detection, aerial surveillance, environmental monitoring, and emergency response. Researchers have developed various firefighting drone systems that combine intelligent sensors, GPS, cameras, and fire suppression mechanisms to improve firefighting efficiency while minimizing risks to human firefighters. Several studies have focused on the development of UAV-based fire detection systems. Sharma et al. (2023) proposed a drone equipped with flame sensors and thermal imaging cameras for early fire detection in industrial environments. Their system demonstrated high detection accuracy; however, the use of thermal imaging significantly increased the overall system cost and power consumption. This limitation makes such systems less suitable for educational institutions and low-budget applications. Research by Kumar et al. (2024) introduced an IoT-based firefighting drone capable of monitoring fire conditions and transmitting real-time sensor data to cloud platforms. The proposed system utilized GPS and wireless communication to provide continuous monitoring of affected areas. Although the system improved situational awareness, it mainly focused on fire monitoring rather than actively extinguishing fires. Another study by Patel et al. (2022)developed a quadcopter equipped with a miniature water pumpand relay-controlled fire extinguishing mechanism. Thedrone successfully extinguished small fires under controlled conditions while maintaining stable flight performance. However, the limited payload capacity restricted the amount of extinguishing agent that could be carried, reducing its effectiveness for larger fires. Recent developments in artificial intelligence have further enhanced firefighting drones. Singh et al. (2025) proposed an AI-based UAV that employed computer vision algorithms to identify fire locations automatically and determine the most effective flight path. Although the system achieved excellent detection accuracy, its computational requirements and hardware costs were considerably higher than those of conventional embedded systems. Researchers have also investigated the use of ESP32- based embedded systems for firefighting applications. The ESP32 microcontroller offers built-in Wi-Fi and Bluetooth connectivity, making it suitable for integrating sensors, GPS modules, cameras, and wireless communication into a compact firefighting platform. Several low-cost prototypes have demonstrated that ESP32-based drones can effectively detect fire, transmit live video, and activate extinguishing mechanisms while maintaining low power consumption and affordable implementation costs. Despite these advancements, several research gapsremain. Most commercial firefighting drones rely on expensive thermal cameras, LiDAR systems, or artificial intelligence, making them unsuitable for educational institutions and small industries. Many existing UAVs emphasize aerial surveillance rather than active fire suppression, while others require complex hardware configurations and specialized maintenance. Furthermore, payload limitations and short battery life continue to challenge the practical deployment of firefighting drones. The proposed DIY Fire Extinguisher Drone addresses these limitations by providing a low-cost, lightweight, and modular firefighting platform built using commercially available components such as an ESP32 microcontroller, flame sensor, smoke sensor, GPS module camera module, relay-controlled water pump, and quadcopter frame. The system combines real-time fire detection, live monitoring, GPS tracking, and automaticf ire suppression into a single integrated platform. Its affordability and simplicity make it suitable for educational institutions, research laboratories, small industries, warehouses, and disaster management training while providing a scalable foundation for future enhancements such as thermal imaging, artificial intelligence, autonomous navigation, and IoT-based cloud monitoring.

III. PROPOSED SYSTEM & METHODOLOGY

3.1 System Architecture Overview

The proposed DIY Fire Extinguisher Drone is an unmanned aerial vehicle (UAV) designed to detect and extinguish small-scale fires while providing real-time monitoring and location tracking. The system integrates embedded hardware, sensors, communication modules, and a fire suppression mechanism to improve firefighting efficiency and reduce the risk to human firefighters. The system consists of five main units: the Input Unit, Processing Unit, Flight Control Unit, Fire Suppression Unit, and Communication Unit. The Input Unit includes a flame sensor and smoke sensor that continuously monitor the environment for signs of fire. A GPS module provides the drone's real-time location, while the ESP32- CAM captures live video of the affected area. The Processing Unit is built around the ESP32 microcontroller, which acts as the central controller of the system. It receives data from all sensors, analyzes the information, and determines whether a fire has been detected. Based on the sensor readings, the ESP32 controls the flight operation and activates the fire extinguishing mechanism.The Flight Control Unit consists of the flight controller, Electronic Speed Controllers (ESCs), and Brushless DC (BLDC) motors, which ensure stable flight, navigation, hovering, and movement of the drone

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toward the fire location The Fire Suppression Unit includes a relay module, water pump, water tank, and spray nozzle. Once the fire is detected, the ESP32 activates the relay, which switches on the water pump to spray water or fire-extinguishing liquid onto the fire.

The Communication Unit uses Wi-Fi or Bluetooth to transmit live video, GPS coordinates, and system status to the remote operator. This enables continuous monitoring of the fire fighting operation responders make quick decisionsOverall, the proposed system architecture combines fire detection, aerial surveillance, communication, and fire suppression into a single intelligent platform. Its low-cost design, modular structure, and efficient operation make it suitable for educational institutions, industries, warehouses, and disaster management applications.

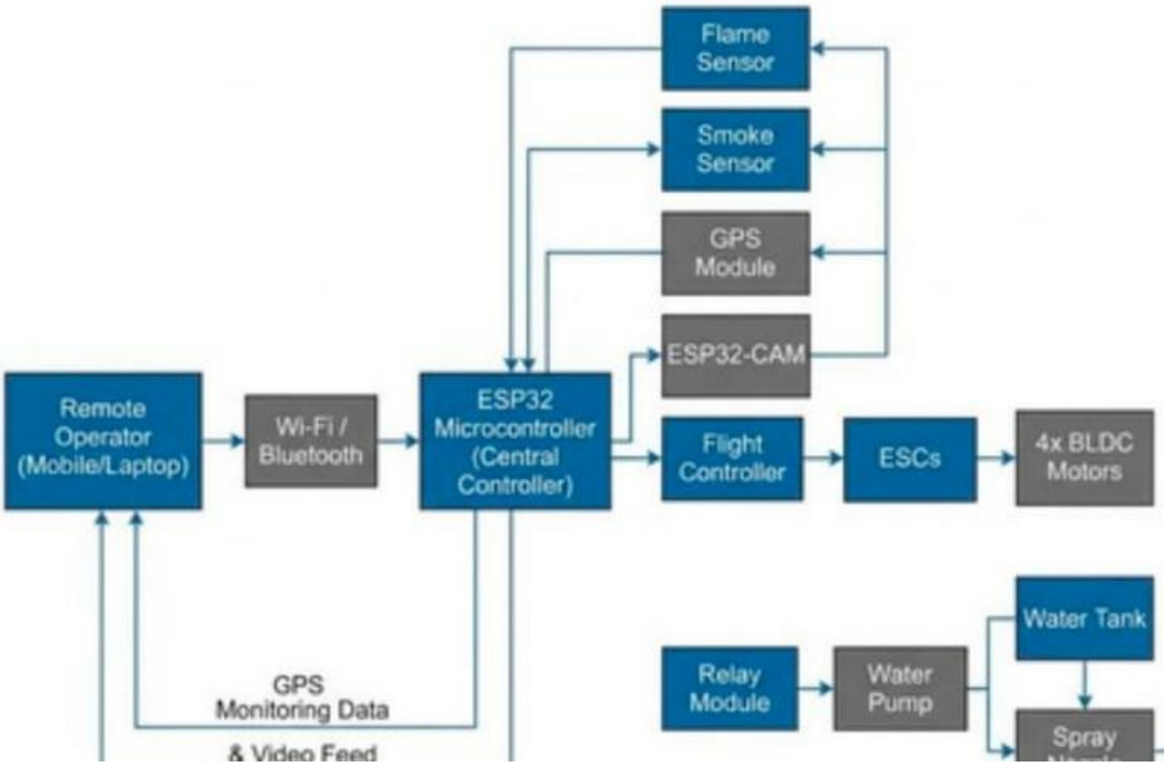

Fig -1: System architecture of the Diy Fire Extinguisher Drone using Iot

3.2 Hardware Components

Component Purpose
ESP32 Central processing and system Microcontroller control
Flame Sensor Detects flames
MQ-2 Smoke Detects smoke and combustible Sensor gases
GPS Module Provides real-time location
ESP32-CAM Live video monitoring
Flight Controller Controls drone stability and navigation
ESC Regulates motor speed
BLDC Motors Provides lift and propulsion
Propellers Generate thrust for flight
Relay Module Controls water pump
Water Pump Sprays water on fire
Water Tank Stores extinguishing liquid
Spray Nozzle Directs water onto the fire
Li-Po Battery Supplies electrical power
Drone Frame Supports all system components

3.3 Software Development Environment

The Software Development Environment of the proposed DIY Fire Extinguisher Drone is designed to control the drone's hardware components, monitor fire conditions, and manage communication between the drone and

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theoperator. The system is developed using open-source software tools, making it easy to program, modify, and maintain. The Arduino IDE is used to write, compile, and upload the program to the ESP32 microcontroller. The drone is programmed using Embedded C/C++, which enables the ESP32 to continuously read data from the flame sensor, smoke sensor, GPS module, and camera. Based on the sensor readings, the controller decides whether a fire is present and activates the water pump through a relay module. The ESP32 also uses its built-in Wi-Fi and Bluetooth capabilities to send real-time information such as GPS coordinates and live video to the operator. The ESP32- CAM module provides live video streaming, allowing the user to monitor the fire remotely. The TinyGPS++ library is used to process GPS data, while the WiFi.h library enables wireless communication. During operation, the software continuously monitors the environment. When a flame or smoke is detected, the ESP32 processes the sensor data and automatically switches on the water pump to extinguish the fire. At the same time, it sends the fire location and live video to the operator. Once the fire is extinguished, the system stops the pump and returns to monitoring mode. The software is developed using a modular approach, allowing future improvements such as artificial intelligence, thermal imaging, cloud connectivity, and autonomous navigation to be easily integrated

3.4 Decision Logic

The Decision Logic of the proposed DIY Fire Extinguisher Drone is responsible for controlling the overall operation of the system based on sensor inputs. The ESP32 microcontroller continuously monitors the flame sensor, smoke sensor, GPS module, and camera to determine whether a fire has occurred. It processes the sensor data and makes decisions according to predefined conditions to ensure accurate fire detection and efficient fire suppression. Initially, the system starts by initializing all sensors and communication modules. During flight, the flame sensor and smoke sensor continuously monitor the environment. If no fire or smoke is detected, the drone remains in surveillance mode while transmitting its status to the operator. When the flame sensor detects a flame and the smoke sensor confirms the presence of smoke above the threshold level, the ESP32 identifies it as a fire event. The controller immediately activates the relay module, which switches on the water pump to spray water or a fire- extinguishing agent onto the fire. At the same time, the GPS module provides the exact location of the fire, and the ESP32-CAM transmits live video to the remote operator for real-time monitoring. The water pump continues to operate until the fireis extinguished or the extinguishing agent is depleted.Once the fire is no longer detected, the ESP32 turns off therelay and water pump, and the drone returns to monitoring mode, ready to detect the next fire incident. This decision-making process ensures quick response, minimizes false alarms, and improves the efficiencyand reliability of the firefighting operation

IV. IMPLEMENTATION

4.1 Power Supply and Circuit Integration

The Power Supply and Circuit Integration of the proposed DIY Fire Extinguisher Drone ensures that all electronic components receive the required voltage for efficient and reliable operation. The drone is powered by an 11.1 V Lithium Polymer (Li-Po) battery, which supplies electrical power to the flight controller, ESP32 microcontroller, Electronic Speed Controllers (ESCs), Brushless DC (BLDC) motors, sensors, GPS module, camera module, and water pump. The Li-Po battery is chosen because it is lightweight, rechargeable, and capable of providing high current during flight. The ESP32 microcontroller acts as the central control unit of the system. It is connected to the flame sensor, smoke sensor, GPS module, ESP32-CAM, and relay module.The flame and smoke sensors continuously monitor the surroundings and send data to the ESP32. If fire is detected, the ESP32 processes the sensor data and activates the relay module. The flight controller is connected to the battery through the Power Distribution Board (PDB), which distributes power equally to the four ESCs. Each ESC controls the speed of a BLDC motor, enabling stable flight and smooth movement of the drone.

The relay module controls the mini DC water pump, which draws water from the onboard tank and sprays it through the nozzle to extinguish the fire. At the same time, the GPS module sends the drone's location, and the ESP32-CAM streams live video to the remote operator using Wi-Fi. Proper wiring and voltage regulation ensure stable performance, prevent electrical faults, and improve the overall reliability of the system.

4.2 Sensor Interfacing and Communication Protocols

The DIY Fire Extinguisher Drone uses various sensors and communication modules to detect fire and transmit real-time information. The flame sensor and MQ-2 smoke sensor are connected to the ESP32 microcontroller through digital and analog inputpins to continuously monitor the environment. TheGPS module communicates with the ESP32 using the UART(Universal Asynchronous Receiver-Transmitter) protocolto provide the drone's real- time location. The ESP32-CAM uses the built-in Wi-Fi module to stream live video andsend system updates to the remote operator. The relaymodule is connected through adigital output pin tocontrolthewater pump automatically when fire is

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detected.The combination of sensors and communication protocols enables accurate fire detection, reliable data transmission, and efficient remote monitoring, ensuring quick and effective firefighting operations

4.3 Dual-Core Embedded Firmware and Task Scheduling

The proposed DIY Fire Extinguisher Drone uses the ESP32 dual-core microcontroller to improve system performance by executing multiple tasks simultaneously. The two cores divide the workload, ensuring smooth operation and faster response during firefighting missions. Core is responsibl efor handling communication tasks such as Wi-Fi connectivity, GPS data processing, and live video transmission through the ESP32-CAM. Core 1 manages the main application tasks, including reading the flame and smoke sensors, processing sensor data, controlling there lay module, and activating the water pump when fire is detected. A simple task scheduling mechanism is implemented to execute different operations efficiently without interrupting the drone's flight. Sensor monitoring is performed continuously, while communication and fire suppression tasks are executed whenever required. This parallel processing reduces system delays, improves response time,and ensures stable drone operation

4.4 IoT-Based SOS Alert Mechanism

The IoT-Based SOS Alert Mechanism enables the DIY Fire Extinguisher Drone to instantly notify the operator when a fire is detected. The system uses the ESP32 microcontroller with built-in Wi-Fi to transmit emergency alerts along with the drone's GPS location and system status. When the flame and smoke sensors detect fire, the ESP32 automatically generates an SOS alert and sends it to a mobile phone, computer, or cloud-based monitoring platform. Along with the alert message, the drone can transmit live video from the ESP32-CAM and the GPS coordinates of the affected location, allowing emergency responders to quickly identify the fire and take appropriate action. This real-time communication improves response time, reduces damage, and enhances public safety.

4.5 Testing Methodology

The Testing Methodology of the proposed DIY Fire Extinguisher Drone was carried out to evaluate the performance of the system under controlled conditions. The prototype was tested for fire detection, communication, flight stability, GPS tracking, and fire suppression. Small and controlled flame sourceswere used to ensure safe testing and accurate performance evaluation. Initially, the flame sensor and MQ-2 smoke sensorwere tested individually to verify their ability to detectfireand smoke. After successful sensor calibration, the complete system was tested by allowing the drone to detectafire source, transmit GPS coordinates and live video,and activate the water pump through the relay module.The response time, sensor accuracy, and extinguishing performance were observed and recorded.The testing confirmed that the drone could detectfire quickly, transmit real-time information to the operator, and automatically spray water to suppress smallfires.

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4.6 Bill of Materials and Cost Analysis

The Bill of Materials (BOM) provides the list ofhardware components required to build the DIY Fire Extinguisher Drone along with their approximate costs. Theselected components are affordable, easily available, andsuitable for The total prototype development. mayvary depending on the manufacturer, specifications,and market availability. The proposed system is designed to be economical while maintaining reliable performance for fire detection and suppression The total estimated cost of the proposed DIY Fire Extinguisher Drone is approximately ₹16,050, making it a low-cost prototype compared to commercial firefighting drones, which often cost several lakhs of rupees. The use of readily available components such as the ESP32, flame sensor, smoke sensor, GPS module, and mini water pump significantly reduces the overall development cost while maintaining efficient performance. This cost-effective design makes the project suitable for educational institutions, engineering students, research laboratories, and small-scale industrial applications. Additionally, the modular architecture allows individual components to be upgraded or replaced without redesigning the complete system, making future enhancements simple and economical.

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V. RESULT AND DISCUSSION

5.1 Performance Evaluation

The Performance Evaluation of the proposed DIY Fire Extinguisher Drone was conducted to assess the efficiency, reliability, and overall functionality of the system under controlled testing conditions. The prototype was evaluated based on parameters such as fire detection accuracy, response time, GPS tracking, communication reliability, flight performance. During testing, the flame and smoke sensors successfully detected small fire sources with high accuracy. Once a fire was detected, the ESP32 microcontroller processed the sensor data and activated the relay-controlled water pump within a few seconds. Simultaneously, the GPS module transmitted the location of the fire, while the ESP32-CAM streamed live video to the remote operator. The drone maintained stable flight during operation and effectively extinguished small fires using the onboard water spray system. The experimental results indicate that the proposed system provides a fast response, reliable fire detection, and efficient communication, making it suitable for educational projects, research applications, and small scale firefighting operations.

5.2 Response-Time Analysis

The Response-Time Analysis evaluates how quickly the proposed DIY Fire Extinguisher Drone responds after detecting a fire. Response time is a critical performance parameter because faster detection and suppression help minimize fire damage and improve safety. The analysis measures the time taken by different stages of the system, including fire detection, data processing, alert transmission, water pump activation, and fire suppression. During testing, the flame and smoke sensors detected fire within a short duration and immediately transmitted the data to the ESP32 microcontroller. The ESP32 processed the sensor readings, activated the relay module, and switched on the water pump. At the same time, the GPS module transmitted the fire location, and the ESP32-CAM started live video streaming. The complete response process was completed within a few seconds, demonstrating the system's ability to react quickly to emergency situations

5.3 Comparative Analysis

The Comparative Analysis compares the performance of the proposed DIY Fire Extinguisher Drone with conventional firefighting methods and existing firefighting drone systems. The comparison is based on important parameters such as cost, fire detection capability, response time, real-time monitoring, GPS tracking, and fire suppression. The proposed system focuses on providing an affordable and efficient solution by integrating fire detection, live monitoring, and automatic fire suppression into a single UAV platform. Compared with traditional firefighting methods, the proposed drone reduces the response time and minimizes the risk to firefighters by reaching hazardous locations quickly. Unlike many commercial firefighting drones that use expensive thermal cameras and AI-based navigation, the proposed system uses low-cost components such as the ESP32, flame sensor, smoke sensor, GPS module, and water pump, making it suitable for educational institutions, research laboratories, and small industries.

5.4 Discussion

The proposed DIY Fire Extinguisher Drone was developed as a low-cost and efficient solution for detecting and suppressing small-scale fires while reducing the risk to human fire fighters.The experimental results demonstrate that the system successfully integrates firedetection, GPS tracking,live video monitoring, and an automatic water spraying mechanism into a single UAV platform. The combination of the ESP32 microcontroller, flamesensor, smoke sensor, GPS module, ESP32-CAM, and relay controlled water pump enables the drone to respond quickly to fire incidents. The performance evaluation showed that the drone could detect fire with high accuracy and activate the fire extinguishing mechanism within 2–3seconds. The GPS module accurately identified the fire location, while the ESP32-CAM provided real-time video streaming to the operator, improving situational awareness and enabling safer decision-making.The stable flight performance and reliable wireless communication further confirmed the effectiveness of the proposed design during controlled testing. One of the major advantages of this system is its low cost compared to commercial fire fighting drones.By using readily available hardware components and open-source software, the overall development cost is significantly reduced, making the project suitable for engineering students, educationa linstitutions,research laboratories, and small industries.The modular design also allows individual components to be upgraded or replaced easily without redesigning the entire system. However, the prototype has certain limitations.The payload capacity restricts the amount of water that can be carried, making it suitable only for small-scale fires. In addition, the flight time is limited by the battery capacity, and the current prototype requires operator guidance for navigation rather than fully autonomous flight. Overall, the proposed DIY Fire Extinguisher Drone demonstrates that an affordable UAV-based fire fighting system can effectively detectfire, providereal-time monitoring, and perform initial fire suppression. With future enhancements such as thermal imaging, artificial intelligence, autonomous navigation,larger water tanks, and cloud-based IoT monitoring, the system can be further improved for real-world fire fighting and disaster management applications.

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VI. FUTURE SCOPE

The proposed DIY Fire Extinguisher Drone can be further improved by integrating advanced technologies to increase its efficiency, reliability, and real-world usability. Although the current prototype successfully detects and extinguishes small-scale fires, several enhancements can make the system more intelligent and suitable for larger emergency situations. One important enhancement is the integration of Artificial Intelligence (AI) and Machine Learning (ML) for accurate fire detection and autonomous decision-making. The addition of thermal imaging cameras can improve fire detection in smoky or low-visibility environments. Autonomous navigation and obstacle avoidance technologies can also be implemented, enabling the drone to fly to the fire location without continuous operator control. The drone's performance can be further improved by increasing the water tank capacity and using higher capacity Li-Po batteries to extend flight time. Integrating IoT cloud platforms and 4G/5G communication will allow real-time monitoring, remote control, and emergency alerts over longer distances. Future versions may also support drone swarm technology, where multiple drones work together to detect and extinguish large fires more efficiently.

CONCLUSION

The proposed DIY FireExtinguisher Drone demonstrates an effective, economical, and innovative approach to early firedetection and suppression using Unmanned Aerial Vehicle (UAV) technology. By integrating an ESP32 microcontroller, flame sensor, smoke sensor, GPS module, ESP32-CAM, relay-controlled water pump, and quadcopter platform, the system is capable of detecting fire, transmitting real-time location and live video, and automatically activating the fire extinguishing mechanism. This integration improves emergency response while reducing the risk to firefighters. Although the prototype has limitations such as limited payload capacity, battery life, and suitability for only small scale fires, it successfully demonstrates the feasibility of using low-cost UAV technology for firefighting applications. The modular design also provides flexibility for future upgrades, including artificial intelligence, thermal imaging, autonomous navigation, and IoT-based cloud monitoring. In conclusion, the DIY Fire Extinguisher Drone offers a practical and scalable solution for improving fire safety, reducing property damage, and supporting emergency response operations. The project highlights the potential of integrating embedded systems, IoT, and drone technology to develop intelligent firefighting systems capable of enhancing public safety and disaster management in the future

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