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AETHERRESQ: AI DRIVEN FIREFIGHTING RESCUE DRONE WITH SMART SURVEILLANCE AND AUTONOMOUS FIRE EXTINGUISHER

Arthi. S[*1], Vedha. D[*2], Vishalakshi. N[*3], Varsha. KG[*4], George Armstrong[*5]

[*1,2,3,4,5]Department Of ECE, Sambhram Institute Of Technology, Bengaluru, India.

ABSTRACT

Fire incidents in residential, industrial, and forest environments often require rapid intervention under conditions that pose serious risks to human responders. To enhance safety and response efficiency, this paper presents **AetherResQ**, an autonomous unmanned aerial system designed to support firefighting and rescue operations through intelligent sensing, aerial surveillance, and onboard fire suppression. The proposed drone platform utilizes a Pixhawk flight controller to achieve stable autonomous navigation and waypoint-based mission execution. Flame sensors and passive infrared (PIR) sensors are integrated to detect active fire sources and human presence in real time. Continuous telemetry and command exchange with the Ground Control Station are achieved using the MAVLink communication protocol. Upon confirmation of fire detection, the system automatically activates an onboard fire extinguishing unit while maintaining flight stability. Experimental evaluations demonstrate reliable flight performance, accurate fire detection, and effective suppression in controlled environments. The proposed system highlights the potential of autonomous UAV-based solutions to reduce firefighter exposure, improve response time, and enhance operational effectiveness in emergency and disaster management scenarios.

Keywords: UAV, Firefighting Drone, Autonomous Systems, Artificial Intelligence, Disaster Management.

I. INTRODUCTION

Fire-related emergencies continue to pose a critical challenge to public safety, infrastructure protection, and environmental preservation. In densely populated urban regions, industrial zones, and forested areas, fire outbreaks can escalate rapidly due to unpredictable flame propagation, limited accessibility, and delayed situational awareness. Conventional firefighting practices depend heavily on human intervention, often requiring personnel to operate in environments characterized by extreme heat, dense smoke, toxic gases, and structural instability. These conditions significantly increase the likelihood of injury and operational failure during emergency response.

Recent advancements in unmanned aerial vehicles (UAVs), embedded electronics, and intelligent sensing technologies have opened new opportunities for improving emergency response systems. UAV platforms are capable of rapid deployment, aerial monitoring, and real-time data transmission, making them suitable for operations in hazardous or inaccessible locations. By integrating sensors, communication modules, and autonomous control algorithms, drones can assist responders by providing early fire detection, continuous surveillance, and critical information for decision-making without direct human exposure to danger.

In this context, the **AetherResQ** project focuses on the development of an AI-assisted autonomous firefighting and rescue drone that combines aerial mobility with intelligent sensing and automated suppression capabilities. The system is designed to navigate autonomously toward fire-affected regions using GPS-based waypoint control while continuously monitoring environmental conditions through onboard flame and PIR sensors. A Pixhawk flight controller ensures stable flight dynamics, whereas MAVLink-based telemetry facilitates real-time communication with a Ground Control Station for mission supervision and data analysis.

In addition to fire detection, the system supports rescue-oriented functionality by identifying human presence and transmitting location data to ground operators. An integrated fire extinguishing mechanism allows the drone to respond immediately upon detecting a fire source, thereby minimizing response delay. Through the combination of autonomous navigation, real-time sensing, and onboard actuation, the proposed system aims to enhance firefighting efficiency, reduce risks to emergency personnel, and demonstrate the applicability of intelligent UAV platforms in modern disaster management operations.

II. LITERATURE SURVEY

Recent research efforts have explored the application of unmanned aerial vehicles, Internet of Things (IoT) frameworks, and intelligent sensing techniques to improve fire detection, monitoring, and emergency response. Several studies emphasize early fire identification using distributed sensor networks, where temperature and gas sensors are integrated with wireless communication modules to provide remote alerts through cloud platforms. While such IoT-centric approaches enable wide-area surveillance at low cost, their functionality is largely limited to detection and notification, lacking autonomous navigation and active fire suppression capabilities.

UAV-based fire detection systems have gained attention due to their mobility and ability to operate in hazardous environments. Some quadcopter designs utilize infrared and PIR sensors to distinguish fire sources from human movement, improving detection reliability in indoor and cluttered settings. Although these systems demonstrate effective sensing performance, they generally rely on manual control and do not incorporate automated firefighting or rescue mechanisms, restricting their use in large-scale emergency scenarios.

Autonomous firefighting drones capable of deploying suppression agents have been investigated to address response delays in conventional firefighting. These systems typically combine thermal or optical sensors with waypoint-based navigation to approach fire zones and release extinguishing materials. Experimental results confirm the feasibility of aerial fire suppression; however, limitations such as restricted payload capacity, limited extinguishing agent volume, and reduced endurance affect long-duration operations and rescue-oriented missions.

Thermal imaging–based fire detection using UAV platforms has also been widely studied. Advanced image processing techniques applied to thermal infrared data enable accurate identification of fire hotspots, even in smoke-filled or low-visibility environments. Despite high detection accuracy, these approaches require significant onboard computational resources and increased power consumption, which can be challenging for lightweight UAV platforms intended for extended missions.

The Pixhawk flight control system has emerged as a widely adopted open-source solution for autonomous UAV operation. It supports GPS-based navigation, inertial stabilization, and modular sensor integration, making it suitable for research and real-world applications. While Pixhawk provides reliable flight control and mission execution, additional external controllers and actuators are required to support application-specific tasks such as firefighting payload control and intelligent sensing.

Communication protocols play a critical role in UAV coordination and monitoring. MAVLink has been extensively studied for its lightweight design, real-time telemetry support, and compatibility with popular ground control stations. Although communication reliability may be affected in harsh or signal-degraded environments, MAVLink remains a practical choice for real-time UAV operations in emergency response scenarios.

More recent studies have focused on multi-sensor fusion techniques combining visible cameras, infrared imaging, and environmental sensors to enhance fire detection accuracy and reduce false alarms. While such systems improve robustness, they often involve complex calibration, higher costs, and increased payload weight. Additionally, many existing solutions prioritize detection accuracy rather than integrating suppression and rescue functionalities into a unified platform.

Overall, existing research demonstrates significant progress in UAV-assisted fire detection and monitoring. However, gaps remain in developing compact, autonomous systems that combine intelligent sensing, real-time communication, fire suppression, and human detection within a single platform. The proposed AetherResQ system addresses these limitations by integrating autonomous navigation, multi-sensor fire and human detection, and onboard extinguishing capabilities to support comprehensive firefighting and rescue operations

III. HARDWARE DESCRIPTION

The AetherResQ firefighting and rescue drone is an integrated system that uses a comprehensive set of hardware components to detect fire, identify human presence, perform autonomous navigation, and carry out fire suppression operations. The system is designed to reduce human risk and improve emergency response efficiency by leveraging unmanned aerial technology, sensors, and intelligent control units.

A. Block Diagram

The block diagram illustrates the overall hardware architecture and functional flow of the AetherResQ system. It shows how sensor data from flame, PIR, and gas sensors is processed by the Arduino controller and transmitted to the Pixhawk flight controller through MAVLink telemetry. The Pixhawk manages autonomous flight, navigation, and stability, while communication with the Ground Control Station enables real-time monitoring and control. Based on detection logic, the fire extinguishing mechanism is activated using relay and solenoid valve control.

B. Components

1. **PIXHAWK FLIGHT CONTROLLER:**

Acts as the main control unit of the UAV.

Handles flight stabilization, altitude control, and autonomous navigation.

Supports waypoint missions and failsafe operations.

2. **GPS MODULE:**

Provides real-time latitude, longitude, and altitude data.

Enables autonomous navigation and return-to-launch functionality.

3. **FLYSKY TRANSMITTER AND RECEIVER:**

Allows manual control during testing and emergency situations.

Acts as a safety override for autonomous operation.

4. **SAFETY SWITCH:**

Prevents accidental arming of the drone.

Ensures safe handling and transportation.

5. **BUZZER:**

Provides audible alerts for system status and warnings.

Useful in noisy and emergency environments.

6. **PIR SENSOR:**

Detects human presence based on infrared radiation.

Assists in identifying trapped individuals during rescue operations.

7. **FLAME SENSOR:**

Detects infrared radiation emitted by fire sources.

Enables early fire detection in low-visibility environments.

8. **GAS SENSOR:**

Detects harmful gases generated during combustion.

Enhances safety and environmental monitoring.

9. **ARDUINO UNO BOARD:**

Processes sensor data from flame, PIR, and gas sensors.

Controls relay and solenoid valve for fire suppression.

10. **I2C COMMUNICATION PORT:**

Enables communication between sensors and controllers.

Reduces wiring complexity.

11. **BRUSHLESS DC MOTORS:**

Provide required thrust for lift and maneuverability.

Offer high efficiency and reliability.

12. **ELECTRONIC SPEED CONTROLLERS (ESCS):**

Regulate motor speed based on flight controller commands.

Ensure smooth and precise motor operation.

13. **PROPELLERS:**

Convert motor rotation into lift and thrust.

Designed for balanced and stable flight.

14. **DRONE FRAME:**

Provides mechanical support for all components.

Designed to withstand vibration and payload weight.

15. **LIPO BATTERY:**

Supplies power to all onboard components.

High energy density suitable for UAV applications.

16. **POWER DISTRIBUTION BOARD:**

Distributes power evenly to motors, controllers, and sensors.

Ensures stable voltage levels.

17. **RELAY MODULE:**

Enables low-power control of high-power devices.

Used to activate the fire extinguisher.

18. **ELECTRONIC SOLENOID VALVE**:

Controls the release of the extinguishing agent.

Ensures controlled fire suppression.

19. **FIRE EXTINGUISHER:**

Suppresses detected fire automatically.

Mounted onboard the UAV.

20. **SPRAY NOZZLE:**

Directs the extinguishing agent accurately toward the fire source.

Improves suppression effectiveness.

C. Working Process

The working process of the proposed system, AetherResQ, begins with system initialization, where the Pixhawk flight controller, Arduino Uno, sensors, and communication modules are powered on and checked for proper operation. A communication link between the drone and the Ground Control Station is established using MAVLink for real-time monitoring and control.After initialization, the drone performs autonomous takeoff and navigates to the target area using GPS-based waypoint navigation. During flight, the flame sensor continuously monitors for fire sources, while the PIR sensor detects human presence by sensing body heat. The sensor data is processed by the Arduino controller and shared with the Pixhawk flight controller for decision-making.When fire is detected beyond a predefined threshold, the system automatically triggers the fire extinguishing mechanism through a relay and solenoid valve. The spray nozzle directs the extinguishing agent accurately toward the fire source while the Pixhawk maintains flight stability. If human presence is detected, the location information is transmitted to the ground station to assist rescue operations. Throughout the mission, telemetry data such as position, altitude, battery status, and sensor readings are sent to the ground control interface for real-time supervision. After completing the firefighting or surveillance task, the drone autonomously returns to the launch point and performs a safe landing, completing the mission successfully.

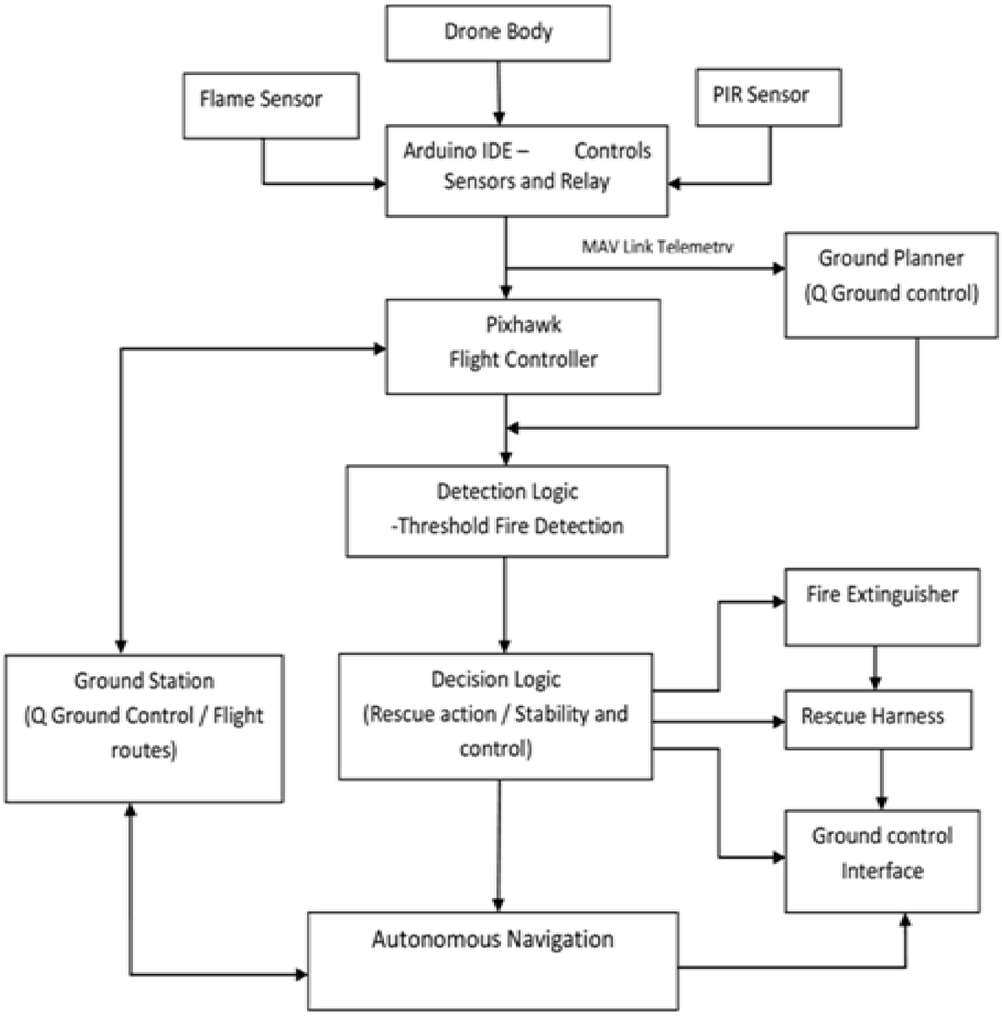

Fig 3: Block Diagram for AtherResQ

IV. EXPERIMENTAL RESULT

The AetherResQ firefighting and rescue drone was fabricated and evaluated through a series of controlled indoor and outdoor experiments to assess its flight stability, sensing accuracy, communication reliability, and fire suppression performance. All system components, including the Pixhawk flight controller, Arduino-based sensor module, and onboard extinguishing unit, were integrated and tested prior to mission execution.

During initial trials, stable communication between the drone and the Ground Control Station was successfully established using the MAVLink protocol. The system consistently achieved GPS lock, enabling reliable execution of waypoint-based autonomous navigation. Both manual and autonomous flight tests demonstrated smooth takeoff, stable hovering, responsive maneuvering, and safe landing under varying operating conditions.

Fire detection experiments confirmed that the flame sensor was able to identify active fire sources within its effective detection range. In parallel, the PIR sensor reliably detected human movement during simulated rescue scenarios, indicating its suitability for identifying trapped individuals. Sensor data processing and decision-making were performed without noticeable delay, ensuring timely system response.

Upon confirmation of fire detection, the relay-controlled fire extinguishing mechanism was automatically activated. The solenoid valve and spray nozzle operated as intended, allowing accurate deployment of the extinguishing agent toward the fire source while maintaining flight stability. Telemetry parameters such as altitude, position, battery status, and sensor readings were continuously monitored using Mission Planner, providing real-time feedback throughout the mission.

The experimental results validate the operational reliability of the proposed system in terms of autonomous navigation, fire detection, human presence identification, and suppression functionality. These observations demonstrate that the AetherResQ platform can effectively support firefighting and rescue tasks in controlled environments, highlighting its potential for deployment in real-world emergency response scenarios.

Fig 4: Model picture of flying AtherResQ

Fig 5: Model picture of complete setup of AtherResQ

V. CONCLUSION

This work presented AetherResQ, an AI-assisted autonomous firefighting and rescue drone developed to support emergency response operations in hazardous environments. The proposed system integrates autonomous flight control, intelligent fire detection, human presence identification, real-time telemetry, and an onboard fire suppression mechanism into a single unmanned aerial platform. By employing a Pixhawk-based flight controller in combination with Arduino-driven sensor processing and MAVLink communication, the system demonstrated stable flight performance and reliable coordination between sensing, navigation, and actuation modules.

Experimental evaluations conducted under controlled conditions confirmed the drone's ability to detect fire sources accurately, identify human movement using PIR sensing, and activate the extinguishing mechanism with minimal response delay. The use of real-time telemetry and ground station monitoring enhanced situational awareness and allowed effective supervision of autonomous missions. The results indicate that UAV-assisted firefighting systems such as AetherResQ can significantly reduce direct human involvement in high-risk scenarios while improving operational efficiency and response speed. Overall, the project validates the feasibility of integrating autonomous aerial platforms into modern firefighting and rescue frameworks and highlights their potential role in next-generation disaster management systems.

VI. FUTURE SCOPE

The operational capabilities of the AetherResQ system can be further enhanced through several future improvements. Advanced computer vision techniques using thermal cameras and deep learning–based fire and victim detection models can be incorporated to improve detection accuracy in complex and low-visibility environments. The addition of onboard companion computers such as Raspberry Pi or NVIDIA Jetson modules would enable higher-level autonomous decision-making without continuous dependence on ground control communication.Fire suppression performance may be improved by integrating higher-capacity extinguishing systems, pump-assisted spray mechanisms, or fire-retardant agents suitable for medium-scale fire scenarios. Multi-sensor fusion involving thermal, gas, and temperature sensors can further increase system reliability under dynamic environmental conditions. Additionally, coordinated multi-UAV swarm operation using mesh-based communication protocols could enable large-area coverage for forest fire monitoring and disaster response missions. Improvements in energy storage technology, including high-density lithium-ion batteries or hybrid solar-assisted charging systems, may extend flight endurance and mission duration. Structural enhancements using lightweight, heat-resistant materials and the inclusion of modular rescue payload mechanisms would further improve durability, scalability, and adaptability. These future developments can transform AetherResQ into a more robust, intelligent, and field-deployable platform for advanced firefighting and search-and-rescue applications.

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