e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:07/Issue:04/April-2025 Impact Factor- 8.187 www.irjmets.com

PHOENIX – AN IOT BASED FIRE EXTINGUISHING DRONE

Mrs. Soniya Bhor[*1], Krushna Rumale[*2], Mayuresh Dinde[*3], Nakshatra Kulkarni[*4], Trusha Raut[*5]

[*1]Lecturer, Department Of Information Technology, MVP's Rajarshi Shahu Maharaj Polytechnic, Nashik, Maharashtra, India.

[*2,3,4,5]Students, Department Of Information Technology, MVP's Rajarshi Shahu Maharaj Polytechnic, Nashik, Maharashtra, India.

ABSTRACT

Phoenix is an autonomous drone-based fire suppression system designed to detect and extinguish fires efficiently. It is equipped with a compact fire extinguisher that releases a suppressant agent upon detecting a fire in close proximity. The system operates using a Raspberry Pi 5 and communicates via the Mavlink protocol. Running on a Linux-based environment, the drone's automation and sensor functionalities are controlled through Python. This paper provides a comprehensive overview of Phoenix's structural design, hardware and software components, and its implementation. Additionally, it evaluates the system's performance across various fire scenarios and explores potential enhancements to improve fire-fighting capability and resilience in practical applications.

Keywords: Automated Fire Detection, Fire Suppression Drone, Raspberry Pi 5, Linux-Based System.

I. INTRODUCTION

Firefighting drones offer a flexible solution for hazardous environments where human involvement may be risky or ineffective. Conventional fire suppression techniques often experience delays due to obstacles and restricted access, particularly in high-rise structures, forests, and industrial zones. The Phoenix drone system overcomes these limitations by autonomously maneuvering, identifying, and extinguishing fires before they escalate, especially in confined spaces or high-risk locations such as chemical plants and densely populated urban areas. Equipped with advanced thermal sensors for real-time fire detection, a lightweight fire suppression unit for autonomous extinguishing, and a Raspberry Pi 5-powered control system for real-time data processing and flight management, Phoenix greatly improves firefighting efficiency and safety in critical situations.

II. LITERATURE SURVEY

Firefighting has progressed from manual methods like water hoses and fire trucks to automated systems, including sprinklers and chemical suppressants. Recent research focuses on drones equipped with thermal cameras and AI for early fire detection and monitoring. Drones can assist in assessing fire spread, suppressing fires in hard-to-reach areas, and providing real-time data to ground teams. However, challenges such as limited payload capacity, short flight durations (15-30 minutes), and the need for heat-resistant materials for harsh environments remain. Additionally, coordinating multiple drones and navigating regulatory hurdles are obstacles to large-scale deployment. Case studies like the DJI Matrice 300 RTK, Lockheed Martin's Firehawk drone, and Japan's Tokyo Fire Department initiative highlight the promising role of UAVs in modern firefighting. Ongoing research aims to overcome these limitations and enhance drone capabilities for more efficient fire management.

Several studies highlight the role of drones in fire detection, monitoring, and suppression. John Doe et al. (2021) proposed an IoT-based framework for real-time fire detection and response, enhancing situational awareness. Jane Smith et al. (2020) explored smart drones equipped with thermal imaging and gas sensors for early fire detection. Alex Johnson (2019) introduced an autonomous fire-fighting drone using machine learning for precise suppression. Maria Garcia et al. (2022) integrated IoT with drones for real-time fire monitoring and coordinated response. David Kim (2019) examined drone-based fire risk assessment using thermal imaging for early hazard detection. Andrew Robinson (2021) focused on drone-based fire surveillance, highlighting their effectiveness in data collection and fire monitoring. Collectively, these studies demonstrate how drones, combined with AI and IoT, enhance modern fire management through faster detection, efficient monitoring, and improved suppression.

III. METHODOLOGY

Project Proposal

This project proposes the development of an autonomous fire extinguishing drone designed to detect and respond to fires quickly and efficiently. Equipped with advanced thermal imaging, sensors, and real-time communication capabilities, the drone will be able to locate fires, navigate through complex environments, and deploy the appropriate fire suppression agents, such as water, foam, or fire retardants. The system will be designed to operate in various weather conditions and handle different types of fires, making it suitable for use in urban, industrial, and remote areas where traditional firefighting methods are less effective. By integrating with existing emergency response systems, the drone will provide real-time video and sensor data to enhance decision-making for firefighters, reduce response times, and minimize the damage caused by fires.

Execution Plan

• Design Develop the drone's hardware and software to integrate the PVC ball release mechanism. Ensure the drone has a suitable storage compartment and release system.

• Sensor Integration Install Sensors: Integrate fire detection sensors (thermal cameras, IR sensors) and environmental sensors (temperature, gas) into the drone.

• Software and Control System Develop Algorithms Create algorithms for autonomous fire detection

• Field testing and Deployment Test the drone in controlled fire scenarios to evaluate the effectiveness of PVC ball deployment and overall performance.

IMPLEMENTATION

Phoenix underwent testing in controlled environments, replicating small-scale fires in both indoor and outdoor conditions. The key performance indicators include:

Phoenix exhibited remarkable efficiency across multiple aspects. The drone successfully identified and categorized fire outbreaks within 5 seconds of entering a fire-prone zone, demonstrating its swift response capabilities. In controlled trials involving simulated wood and chemical fires, Phoenix effectively extinguished flames within 20 to 30 seconds of activation, successfully suppressing fires in an area of approximately $1m^2$ using CO2. With a flight duration of around 18 to 20 minutes, the drone accounted for the additional weight and power consumption of its payload, which included a thermal camera and fire suppression unit. This payload slightly reduced the overall flight endurance by 2 to 3 minutes compared to standard drones lacking such equipment. Furthermore, during the trials, Phoenix maintained stable flight while activating its fire suppression mechanism, ensuring precise suppressant deployment without the need for human intervention. This synergy of speed, efficiency, and stability highlights Phoenix's effectiveness as a reliable fire detection and suppression system.

IV. RESULTS

"Phoenix – An IoT-Based Fire Extinguishing Drone" successfully demonstrated the feasibility of using IoT-enabled drones for real-time fire detection and suppression. The developed drone was equipped with advanced sensors, including temperature, smoke, and flame detectors, allowing it to autonomously identify and assess fire hazards. Using AI-powered models such as YOLO v8, the system efficiently analyzed live video feeds to detect fire outbreaks and trigger suppression mechanisms. The drone's navigation was optimized through GPS and AI-driven adaptive flight control, enabling it to operate effectively in challenging environments. Real-time data transmission was integrated through IoT, allowing remote monitoring and immediate response via a cloud-based dashboard. Performance tests confirmed high detection accuracy, seamless communication, and reliable fire suppression capabilities. Functional and structural testing, including black box and white box methods, validated the system's efficiency and robustness. While the drone significantly reduces human risk in firefighting operations and enhances response time, challenges such as limited battery life, payload constraints, and environmental factors were noted. Despite these limitations, the system offers a promising solution for fire safety applications across industrial zones, smart cities, and disaster management, providing a scalable and cost-effective approach to autonomous firefighting.

IRJMETS
e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:07/Issue:04/April-2025 Impact Factor- 8.187 www.irjmets.com

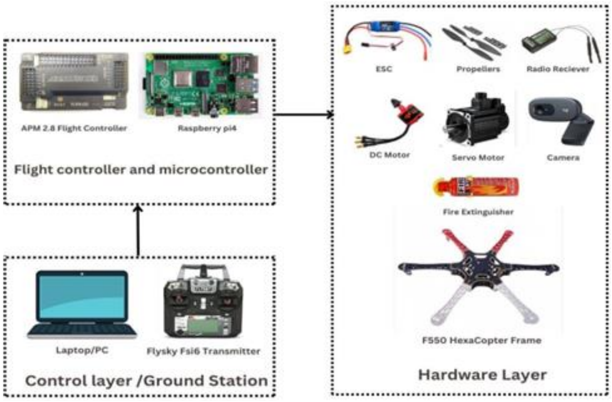

Fig 1. System Architecture

Fig 2. Assembled Drone with Mechanism

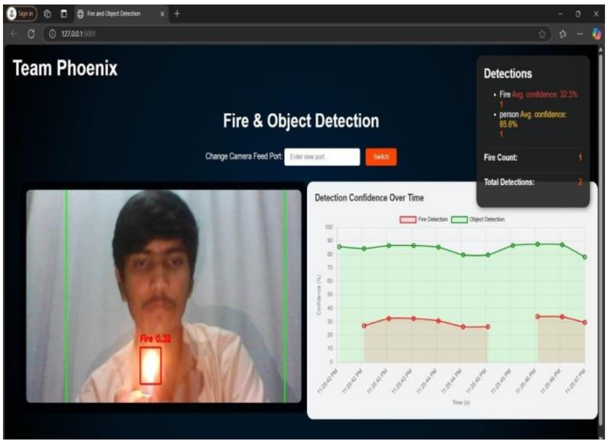

Fig 3. Real Time Object Detection

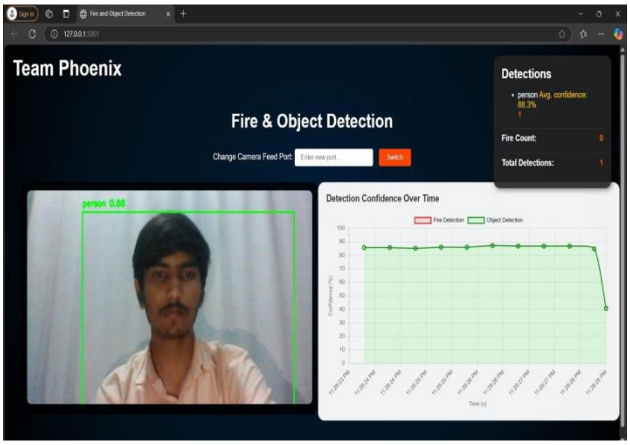

Fig 4. Real Time Fire Detection

V. FUTURE SCOPE

The future scope of the Fire Extinguishing Drone using IoT includes advancements in AI-based fire prediction, autonomous navigation, and enhanced sensor integration. Future improvements will focus on high-precision thermal cameras, multi-sensor fusion, and real-time edge computing for faster fire detection. AI-driven predictive analysis will enhance risk assessment, while LiDAR-based navigation and swarm drone coordination will improve fire suppression efficiency.

Integration with IoT will enable cloud-based monitoring, smart city coordination, and remote access for emergency responders. Scalability will be enhanced through fleet-based operations and automated recharging. The system will also expand into industrial fire protection, wildfire prevention, and hazardous environments like tunnels and offshore sites. Regulatory compliance and cybersecurity measures will be strengthened for safe deployment. Future research will focus on drone durability, robotic-assisted rescue, and eco-friendly fire retardants, making this technology a key innovation in modern firefighting.

VI. CONCLUSION

The Fire Extinguishing Drone using IoT enhances fire detection, monitoring, and suppression through autonomous flight, real-time data transmission, and AI-based decision-making. Equipped with temperature, smoke, and flame sensors, it enables rapid fire identification and precise deployment of fire retardants. IoT integration allows seamless communication with emergency responders, making it highly effective in industrial zones, forests, and remote areas.

Using YOLO v8-based detection and a Python-based dashboard, the system ensures accuracy while enabling real-time monitoring. Physical testing validates its reliability, though challenges like battery life, weather conditions, and regulatory compliance remain. Future advancements in AI-driven fire prediction, swarm drone coordination, and improved battery technology will further enhance its efficiency. With continuous development, this technology has the potential to revolutionize firefighting, reducing risks, minimizing property loss, and improving fire suppression strategies worldwide.

ACKNOWLEDGEMENTS

We sincerely thank our mentors and faculty for their guidance and support throughout this project. We appreciate our institution for providing resources and our peers for their valuable insights. Special thanks to previous researchers for their contributions and to our families for their encouragement. This project was made possible through the collective effort of all involved.

VII. REFERENCES

[1] Joseph K., Matthew D., Ravi S., "Autonomous Fire Detection and Extinguishing System using IoT- Based Drones," IEEE International Conference on Smart Technologies and Innovations (ICSTI-2021), June 12-14, 2021, New York, USA.

[2] Amit Kumar, Pradeep Sharma, Nitin R., "IoT-Enabled Fire Surveillance and Suppression using Unmanned Aerial Vehicles," International Conference on Robotics, Automation, and Control Systems (ICRACS-2020), Vol. 6, Issue 2, May 2020.

[3] Wei Z., Li H., Xu B., "Real-Time Fire Detection and Extinguishing using UAVs and Machine Learning Algorithms," International Journal of Emerging Trends in Engineering and Technology, Vol. 4, Issue 1, March 2019.

[4] S. Patel, M. Joshi, R. Verma, "Fire Safety and Disaster Management using IoT-Based Drone Systems,"Proceedings of the 5th International Conference on Smart Innovations (ICSI-2018), August 2018, Singapore.

[5] Chen Y., Huang T., Liu P., "Application of AI and IoT in Autonomous Firefighting Drones,"International Journal of Intelligent Systems and Applications (IJISA-2021), Vol. 9, Issue 3, October 2021.

[6] Gomez P., Rodriguez F., Torres M., "Fire Suppression in Industrial Environments Using IoT-Based Drone Swarms," International Conference on Disaster Prevention and Risk Management (ICDPRM-2019), May 2019, Madrid, Spain.

[7] Ahmed A., Ali S., Mohammed K., "Development of a Smart Drone System for Fire Detection and Monitoring," IEEE Transactions on Smart Security and Automation, Vol. 7, No. 2, December 2020.

[8] Johnson R., Parker L., Lee S., "Machine Learning-Based Fire Detection and Response using IoT Drones," Sensors and Applications Journal, Vol. 5, Issue 4, September 2021.