INTEGRATED DRONE FOR EFFECTIVE DISASTER MANAGEMENT

Abstract: This study presents the Dual Mobility Drone-Rover (Drover) System, an advanced solution for real-time disaster monitoring, detection, and alerting by integrating unmanned aerial vehicles (UAVs) and ground rovers. The system is designed to detect and track natural disasters such as fires, landslides, and earthquakes using a combination of aerial and ground-based sensors. An RC FPV drone equipped with an ESP32 camera captures and streams live video to a laptop, where the YOLO (You Only Look Once) algorithm processes the feed to identify fires and landslides. For seismic activity detection, a NodeMCU with an accelerometer senses earthquakes and transmits data to a laptop via the ThingSpeak cloud. To ensure rapid response, the system provides real-time alerts through beep sounds and visual notifications, enhancing situational awareness and enabling timely action. By leveraging real-time data processing and cloud-based communication, the Drover System offers an efficient and reliable approach to disaster management, minimizing damage and improving emergency response capabilities.

***Index Terms* -** Dual Mobility Drone-rover system, UAV integration, AI-Based detection models.

I. INTRODUCTION

Natural disasters such as wildfires, landslides, and earthquakes pose significant threats to human life, infrastructure, and the environment (Smith, 2013). Traditional disaster monitoring systems often suffer from inefficiencies, including delayed detection, limited coverage, and inadequate real-time alerting capabilities (Basha & Rus, 2007). These shortcomings highlight the urgent need for innovative solutions that leverage emerging technologies to enhance disaster response and mitigation. Unmanned Aerial Vehicles (UAVs), commonly known as drones, have emerged as a powerful tool for real-time monitoring, detection, and alerting in disaster management scenarios (Erdelj et al., 2017). This study introduces a Drone-Based Natural Disaster Monitoring, Detection, and Alerting System, integrating advanced drone technology with Internet of Things (IoT) and machine learning to enhance real-time disaster monitoring. The core of the system is an RC FPV drone equipped with an ESP32 camera, which streams live video footage to a laptop for immediate processing. The YOLO (You Only Look Once) algorithm, a state-of-the-art deep learning-based object detection technique, is employed to detect fires and landslides in real time, ensuring rapid identification of potential hazards (Redmon et al., 2016).

In addition to aerial surveillance, the system incorporates a NodeMCU with an accelerometer to detect seismic activity. Earthquakes often occur with minimal warning, making real-time detection crucial for timely response (Gao et al., 2018). The accelerometer continuously monitors ground vibrations, and upon detecting seismic disturbances, the NodeMCU transmits alerts to the laptop via the ThingSpeak cloud platform. This ensures remote monitoring capabilities and facilitates a rapid emergency response. The integration of drone-based video surveillance, real-time object detection, and IoT-enabled seismic sensing allows for multi-disaster detection and response. Upon detecting a disaster, the system triggers audio and visual alerts on the laptop, ensuring that emergency responders receive instant notifications. By leveraging these technologies, the system enhances situational awareness, reduces response time, and mitigates disaster impact. This research contributes to the field of disaster management by demonstrating the potential of drones in real-time data collection, automated hazard detection, and rapid communication. Unlike traditional monitoring methods, which may be hindered by geographical constraints or delayed data processing, drone-based systems offer cost-effective, scalable, and efficient disaster response solutions (Restas, 2015). The proposed system bridges the gap between disaster detection and emergency response, ensuring a proactive approach to disaster mitigation and preparedness.

Also the system incorporates an IoT-based seismic monitoring unit using a NodeMCU microcontroller and an accelerometer to detect seismic activity. Earthquakes often occur with minimal warning, making real-time detection crucial for timely response (Gao et al., 2018). The accelerometer continuously monitors ground vibrations, and upon detecting seismic disturbances, the NodeMCU transmits alerts to the laptop via the ThingSpeak cloud platform. This cloud-based communication ensures remote monitoring capabilities, enabling disaster response teams to receive instant alerts regardless The integration of drone-based video surveillance, real-time object detection, and IoT-enabled seismic sensing allows for a comprehensive multi-disaster detection and response system. Upon detecting a disaster, the system triggers audio and visual **alerts** on the laptop, ensuring that emergency responders receive immediate notifications. This proactive approach significantly reduces response time, enhancing disaster preparedness and mitigation efforts. The system is also adaptable, allowing for future integration of additional sensors, such as gas detectors for chemical leaks or temperature sensors for heatwave monitoring.

This research contributes to the field of disaster management and emergency response by demonstrating the potential of drones and IoT in real-time data collection, automated hazard detection, and rapid communication. Unlike traditional monitoring methods, which may be hindered by geographical constraints, human limitations, or delayed data processing, drone-based systems offer **cost-**effective, scalable, and efficient disaster response solutions (Restas, 2015). By combining aerial surveillance, IoT cloud connectivity, and deep learning-based hazard detection, the proposed system bridges the gap between disaster detection and emergency response, ensuring a proactive and technology-driven approach to disaster mitigation and preparedness. The development of such integrated solutions is crucial for modern disaster management, particularly in regions prone to frequent natural disasters. As technology continues to advance, leveraging UAVs, IoT, and AI-driven analytics will be instrumental in minimizing loss of life, protecting infrastructure, and enhancing overall community resilience in the face of natural disasters.

II. LITERATURE REVIEW

Several studies have explored the use of drone technology for disaster monitoring and response. Smith et al. (2020) highlighted the limitations of traditional disaster response systems, emphasizing the need for real-time monitoring to enhance early detection. Similarly, Jones and Lee (2019) discussed the inefficiencies of manual monitoring and ground-based sensors, which are often restricted to specific locations and lack wide-area coverage.

Drones equipped with computer vision algorithms have shown significant promise in detecting natural disasters. Redmon and Farhadi (2016) developed the YOLO object detection algorithm, which has been widely used for real-time image processing applications, including fire and landslide detection. Patel et al. (2021) demonstrated how YOLO-based object detection enhances the accuracy and speed of hazard identification in disaster-prone areas.

In terms of seismic activity detection, Kumar et al. (2017) proposed the integration of accelerometer-based earthquake sensing with IoT platforms, allowing for real-time data collection and remote alerts. Hassan and Gupta (2020) expanded on this concept by integrating cloud-based platforms like ThingSpeak to facilitate continuous seismic monitoring.

Further research has explored the combination of IoT and UAVs for enhanced disaster management. Chen et al. (2018) presented a drone-assisted monitoring system that leverages IoT connectivity for data transmission. Wang et al. (2022) improved upon this approach by incorporating AI-based predictive analytics to optimize disaster response strategies.

Recent advancements in machine learning and AI have further strengthened the capabilities of disaster monitoring systems. Zhang et al. (2022) explored the role of deep learning in improving the accuracy of early disaster detection, highlighting the potential of integrating AI-driven models into UAV-based surveillance.

Additionally, several studies emphasize the role of UAVs in disaster management. Erdelj et al. (2017) discussed how UAVs provide rapid deployment, damage assessment, and communication restoration in disaster scenarios. Yuan et al. (2015) explored UAV-based remote sensing for wildfire detection and monitoring, while Bekmezci et al. (2013) introduced the concept of Flying Ad-Hoc Networks (FANETs) for UAV coordination in disaster management. Adams and Friedland (2011) examined UAV imagery collection for disaster assessment, and Allison et al. (2016) analyzed airborne optical and thermal remote sensing for wildfire detection. The use of drones in disaster detection and management has been increasingly researched and implemented. According to five literature surveys, drones can rapidly deploy and assess damage in disaster scenarios, providing real-time data and enhancing response efforts.

They can also detect and monitor forest fires, collect high-resolution images for damage assessment, and form flying ad-hoc networks (FANETs) for communication and coordination. Additionally, drones equipped with optical and thermal sensors can detect and monitor wildfires, providing critical data for firefighting strategies. Overall, drones offer enhanced situational awareness, improved communication, and increased efficiency in disaster detection and response. Future research directions include integrating drone data with existing systems, developing autonomous flight and decision-making capabilities, and integrating sensors for detecting and monitoring various disasters. Overall, the literature underscores the importance of integrating drones, IoT, and machine learning for real-time disaster monitoring. While existing studies provide valuable insights, this research aims to enhance current methodologies by developing a more comprehensive and efficient system that offers real-time detection, automated alerts, and improved response mechanisms.

III. PROPOSED WORK

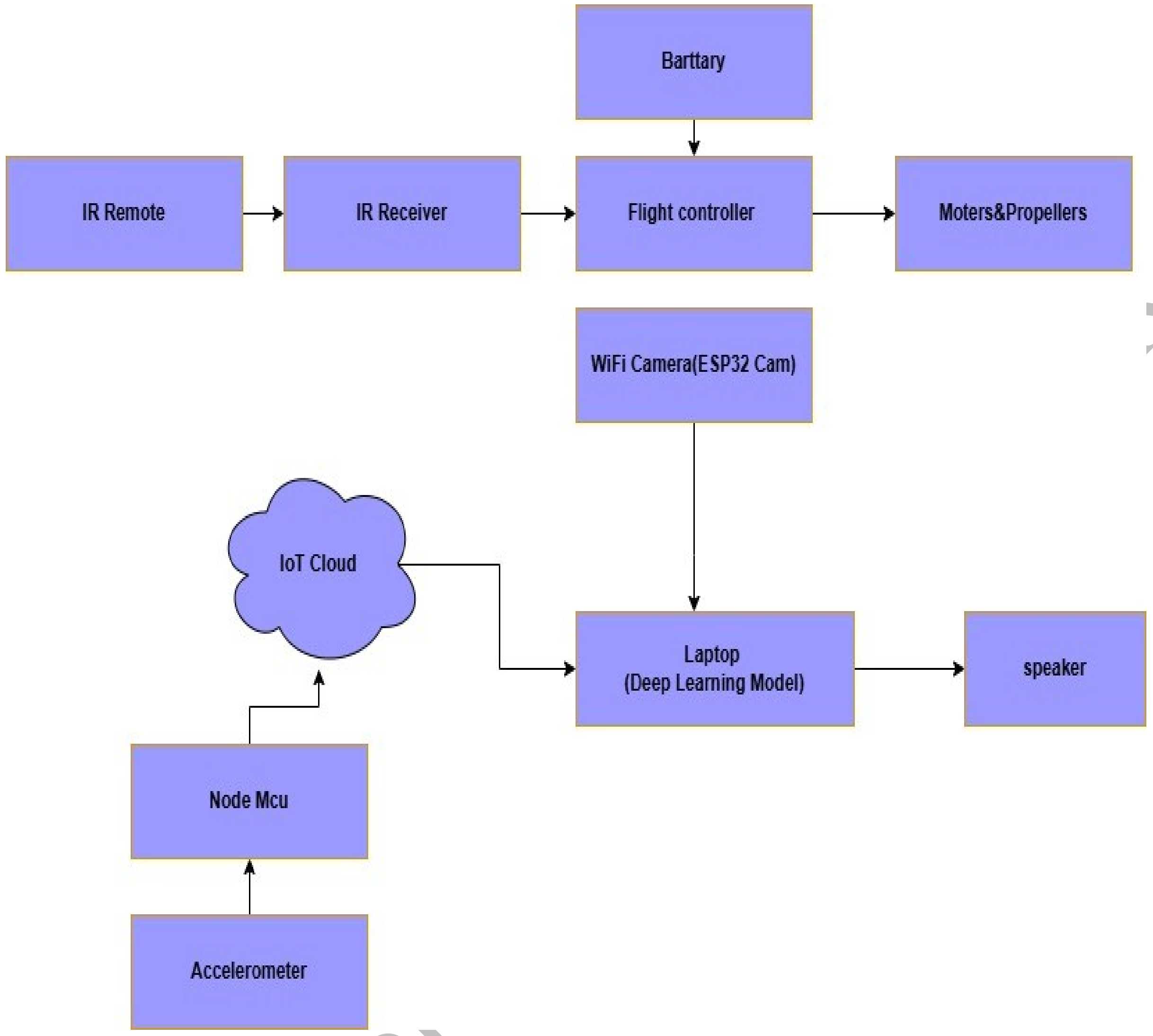

Fig: Block diagram of Proposed system

The proposed system integrates advanced drone technology, deep learning, and IoT-enabled seismic monitoring to create an efficient real-time disaster detection and alert system. The system consists of four key components that work in conjunction to ensure rapid hazard detection and response:

a. **Drone-Based Surveillance:** An RC FPV drone is equipped with an ESP32 camera that captures real-time video footage. The drone provides a wide aerial view of disaster-prone areas, enabling early detection of hazards such as fires and landslides. The video feed is streamed to a laptop for further analysis.

b. **YOLO-Based Object Detection:** The YOLO deep learning model processes the video feed in real-time to detect and classify disasters. YOLO's fast and accurate detection capabilities allow for instant recognition of fire outbreaks, landslides, or other hazardous events, ensuring timely alerts and interventions. IoT-Enabled Seismic Monitoring: A NodeMCU microcontroller, equipped with an accelerometer, continuously measures ground vibrations to detect potential earthquakes. The data is transmitted via the ThingSpeak cloud platform to enable real-time seismic monitoring. If abnormal seismic activity is detected, alerts are instantly generated.

c. **Automated Alert System:** When a disaster is detected, the system triggers real-time notifications through multiple channels. Alerts are displayed on a laptop interface, accompanied by audible beep sounds to ensure immediate response by authorities and first responders.

This integrated system enhances situational awareness and improves disaster response efficiency. By combining the real-time monitoring capabilities of drones with AI-driven object detection and IoT-enabled seismic sensing, the proposed solution provides a robust, scalable, and cost-effective approach to disaster risk mitigation. The project's key advantages include real-time hazard detection, automated alerts, and enhanced coordination of emergency response teams, ensuring rapid intervention and minimal damage during disaster events.

IV. Methodology

The methodology for the Dual Mobility Drone-Rover (Drover) System integrates CNN, YOLO, and sensor-based disaster detection to ensure efficient real-time monitoring and alerting. The process begins with **data collection**, where the drone captures images and videos using an ESP32 camera, while an accelerometer sensor detects seismic activity. The acquired data undergoes preprocessing and feature extraction, involving resizing, normalization, and augmentation to enhance detection accuracy. For object detection and disaster recognition, CNN is employed to extract essential image features that help in disaster classification. YOLO is then applied for real-time object detection, where the input image is divided into a grid, and bounding boxes with confidence scores are predicted to identify disasters such as fires and landslides. Simultaneously, the **earthquake** detection module utilizes a NodeMCU with an accelerometer, continuously monitoring ground vibrations. The sensor data is transmitted to ThingSpeak for real-time cloud analysis, and if seismic activity exceeds the predefined threshold, an alert is triggered.

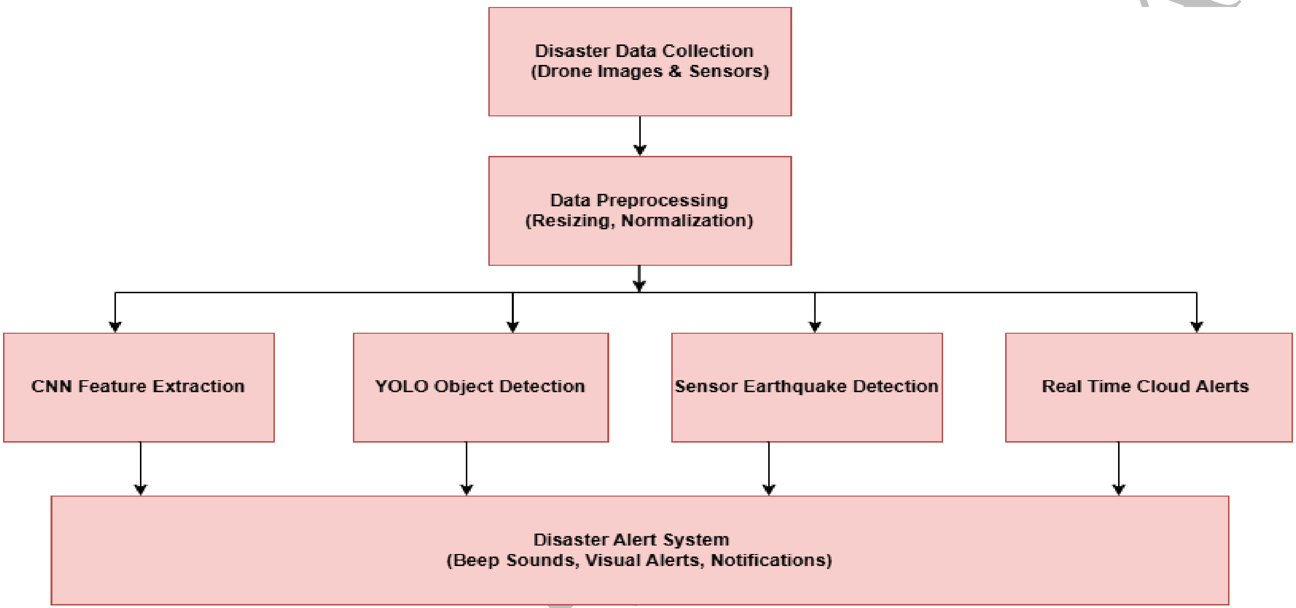

Fig 2: Flowchart of proposed work

The final stage of the system is the disaster alert mechanism, which ensures that when a disaster is detected, emergency notifications are promptly generated. These alerts include beep sounds, visual notifications, and cloud-based updates, enhancing situational awareness for timely response. The integration of CNN for feature extraction, YOLO for object detection, and sensor-based earthquake detection creates a robust and reliable disaster management system that facilitates rapid identification and mitigation efforts.

V. RESULTS

a. **Drone Operation:** The drone, operated via remote control, integrates a **CNN model** to analyze real-time visual input from its onboard camera. This allows the drone to generate autonomous steering commands, reducing the need for human intervention in certain scenarios. The CNN model processes images frame-by-frame, enabling obstacle detection and navigation optimization. This autonomous capability enhances the drone's efficiency in disaster monitoring. **Figure 3.1** shows the drone in its **"On Mode"**, while **Figure 3.2** captures its **"Flying Mode"**, actively surveying the environment for disaster conditions.

Fig 3.1: Drone on mode

Fig 3. 2: Flying mode of drone

b. **Earthquake Output:** An earthquake detection and alarm system was developed using **Arduino**, an **accelerometer**, and components such as an **LCD display, buzzer, and LED**. The accelerometer continuously monitors ground vibrations, and when the magnitude exceeds a predefined threshold, the system **activates an alarm**.As illustrated in **Figure 3.3**, the system detected an **earthquake with a magnitude of 5.0 on March 11, 2025, at 09:44:53**, with data transmitted through **ThingSpeak channel 2867128**. Users are provided options to **manually stop detection** or allow continuous monitoring. The system effectively captures real-time seismic activity, making it a reliable tool for earthquake alerts.

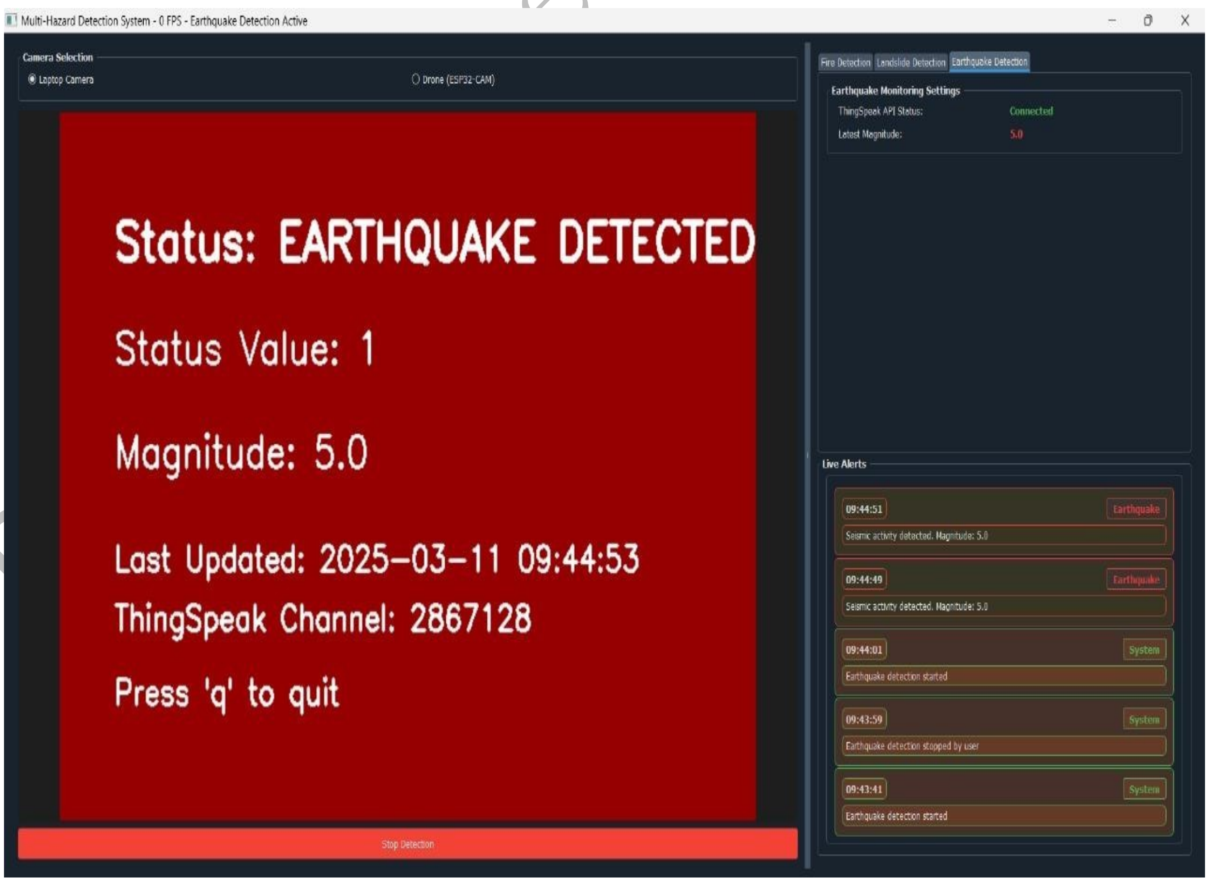

Fig 3.3 Earthquake detected

c. Fire Detection Output: The fire detection module **employs a** Convolutional Neural Network (CNN) to process video footage and identify fire occurrences in real time. CNN-based computer vision algorithms classify image regions containing flames, enabling early warning systems. **Figure 3.4** demonstrates the system successfully detecting a fire, proving its efficiency in identifying hazardous situations. This capability ensures rapid response to fire outbreaks, minimizing potential damage.

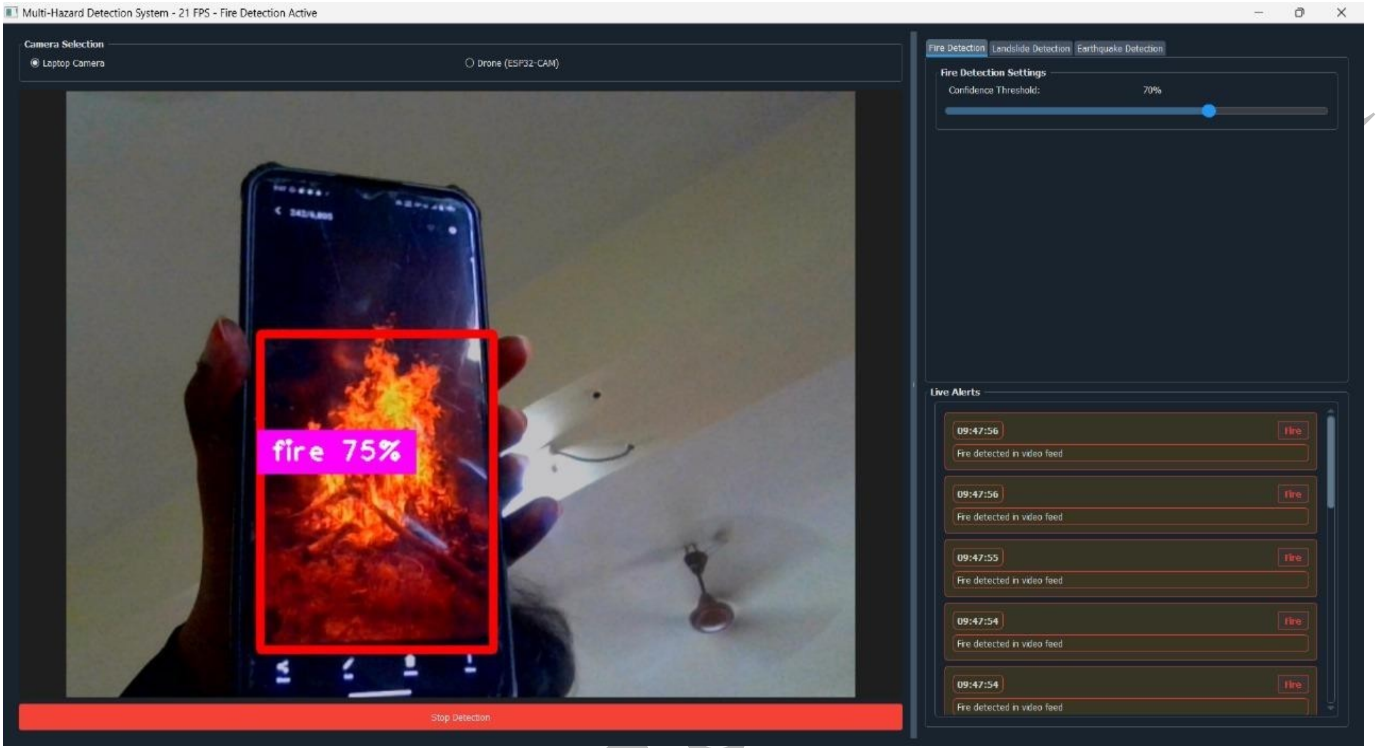

Fig 3. 4: Fire detected Landslide output

d. Landslide Detection Output: For landslide detection, the system leverages CNN-based remote sensing image analysis. The CNN model automatically extracts critical features from geological terrain images, enhancing prediction accuracy over traditional methods. As shown in **Figure 3.5**, the system detects a landslide occurrence, validating its ability to process and classify terrain changes effectively**.** This approach contributes to proactive disaster

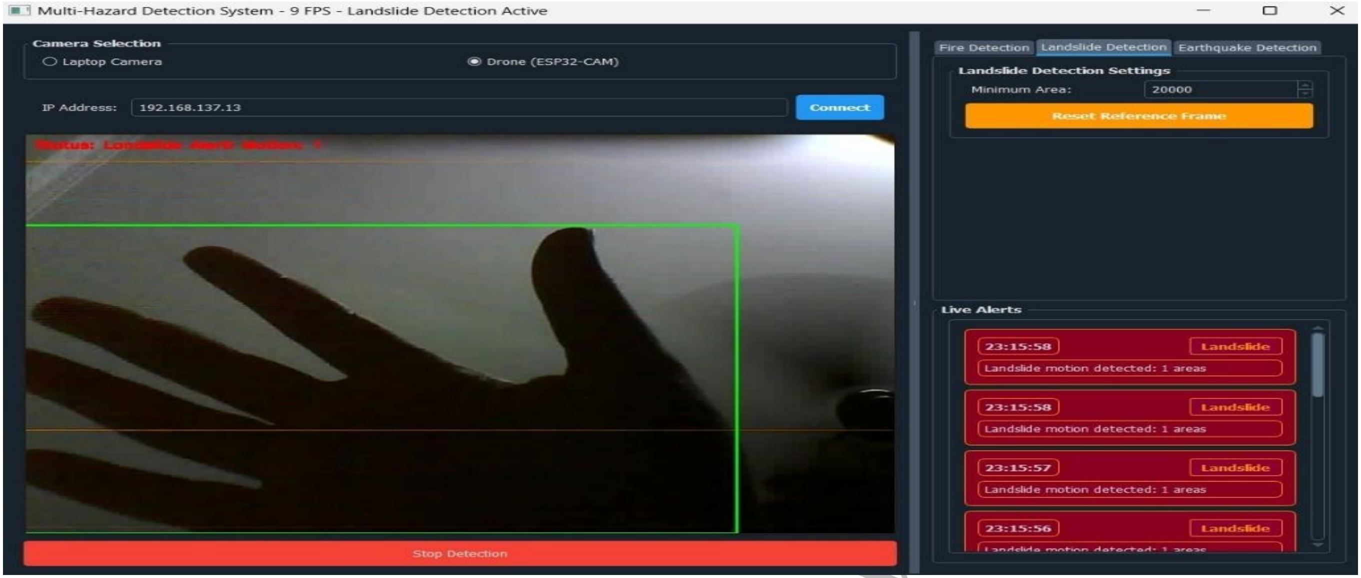

Fig 3.5: Landslide detected mitigation efforts.

IV CONCLUSION AND FUTURE DIRECTIONS

The "Integrated Drone for Effective Disaster Management" represents a transformative approach to disaster detection and response, leveraging drone mobility, advanced sensors, machine learning algorithms (YOLO), and cloud-based communication (ThingSpeak). By combining these technologies, the system enables real-time monitoring of disasters such as earthquakes, fires, and landslides, significantly improving response efficiency and coverage compared to traditional stationary sensor-based methods. A key advantage of this system lies in its ability to operate in remote and hazardous environments, where conventional monitoring techniques face limitations. The use of an RC FPV drone with an ESP32 camera ensures continuous live video streaming, which is processed using YOLO-based algorithms for rapid hazard identification. Real-time alerts are immediately transmitted to emergency responders, reducing response times and enhancing disaster mitigation efforts. Additionally, the cost-effectiveness of this system—built with affordable, off-the-shelf components—makes it a viable solution for both developed and resource-constrained regions.

Future advancements in the Integrated Drone for Effective Disaster Management can enhance its accuracy, scalability, and autonomy. Implementing Reinforcement Learning (RL) and SLAM (Simultaneous Localization and Mapping) will enable autonomous navigation and obstacle avoidance, reducing reliance on manual control. Deploying multi-drone systems with swarm intelligence can improve coverage and coordination in large-scale disaster scenarios. Expanding detection capabilities by integrating thermal imaging for fire and human detection, as well as sensors for floods, gas leaks, and radiation, will enhance disaster response. Additionally, real-time data-sharing frameworks with emergency networks and leveraging 5G or satellite communication can ensure faster response times.

REFERENCES

[1] M. Erdelj, E. Natalizio, K. R. Chowdhury, and I. F. Akyildiz, “Help from the Sky: Leveraging UAVs for Disaster Management,” *IEEE Pervasive Computing*, vol. 16, no. 1, pp. 24–32, Jan. 2017. DOI: 10.1109/MPRV.2017.11

[2] C. Yuan, Y. Zhang, and Z. Liu, “A Survey on Technologies for Automatic Forest Fire Monitoring, Detection, and Fighting Using Unmanned Aerial Vehicles and Remote Sensing Techniques,” *Canadian Journal of Forest Research*, vol. 45, no. 7, pp. 783–792, July 2015. DOI: 10.1139/cjfr-2014-0347

[3] İ. Bekmezci, O. K. Sahingoz, and Ş. Temel, “Flying Ad-Hoc Networks (FANETs): A Survey,” *Ad Hoc Networks*, vol. 11, no. 3, pp. 1254–1270, May 2013. DOI: 10.1016/j.adhoc.2012.12.004

[4] S. Adams and C. Friedland, “A Survey of Unmanned Aerial Vehicle Usage for Imagery Collection in Disaster Research and Management,” Jan. 2011. DOI: 10.13140/RG.2.1.4687.6563

[5] R. Allison, J. Johnston, G. Craig, and S. Jennings, “Airborne Optical and Thermal Remote Sensing for Wildfire Detection and Monitoring,” *Sensors*, vol. 16, no. 8, pp. 1226, Aug. 2016. DOI: 10.3390/s16081226

[6] E. Matthes, *Python Crash Course*, No Starch Press, 2019. Available: https://automatetheboringstuff.com/

[7] I. Goodfellow, Y. Bengio, and A. Courville, *Deep Learning*, MIT Press, 2016. Available: https://www.deeplearningbook.org/