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Smart drones for human detection in disaster response

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ABSTRACT

Natural disasters require swift, coordinated responses to minimise human casualties and infrastructure damage. This paper presents a novel AI-assisted drone system designed to enhance disaster relief efforts through advanced human detection and a distributed emergency Wi-Fi network. This drone system, equipped with state-of-the-art machine learning algorithms and thermal imaging, excels at locating and identifying individuals even in challenging conditions, such as smoke, debris, or low visibility. The drone fleet operates autonomously, dynamically forming an ad-hoc network that adapts to the evolving needs of the disaster zone. By integrating real-time data processing with efficient network management, our system provides a critical lifeline for communication and a powerful tool for rescuers to navigate and respond effectively. The detection and communication times are observed to be within the range of 5 to 8 seconds for this proposed system, which is widely used in disaster response.

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1. INTRODUCTION

A network of drones equipped with edge computing capabilities can collaboratively operate to enhance real-time data processing and coverage in disaster scenarios. With edge computing technology, drones can process data within local area networks, reducing latency and improving system responsiveness [1]. The drones can be utilised for various functions, including aerial surveillance, real-time monitoring, and data sampling. High-resolution images and the capture of vital information are essential in rescue operations. This work highlights the integration of drones with other technologies, such as geographic information systems (GIS) and machine learning. It has several advantages in improving efficiency [2].

The autonomous response drone for critical-situation management in future wireless networks. The proposed system utilises a cutting-edge wireless network for reliable communication and operates independently, utilising sensors and algorithms to navigate and respond to emergencies [3]. The proposed method used drones and social media platforms to analyse real-time data during emergencies. This integrated approach utilises the architecture of a social drone system to prioritise information through algorithms. The system enhances the effectiveness of disaster response systems [4] by using advanced algorithms to enable unmanned aerial vehicles (UAVs) to detect survivors and process real-time data to locate individuals in distress. The system's robustness in various environmental conditions is achieved through automation and intelligent decision-making [5].

Survival detection in emergencies depends on different types of sensors, communication technologies, and data processing techniques. This review utilises real-time data acquisition and automated system deployment to enhance response time and accuracy. The effectiveness of different approaches and innovations in intelligent systems for disaster response [6]. Furthermore, this system utilises advanced networking techniques to enable seamless communication among drones, enabling obstacle detection and reliable energy-efficient strategies, thereby extending the drone's operational time. This improvement enhances system performance and increases operational efficiency in real-world disaster scenarios [7].

The integration of GIS and data analytics to improve decision-making processes, the effectiveness of drones in reducing disaster risks and increasing response time, and the authors address the challenges associated with deploying drones in disaster situations, including technical limitations and regulatory issues, as well as support for crisis response activities [8]. The authors introduce a system that optimises the deployment and operation of drones in disaster scenarios by integrating environmentally aware algorithms with energy-efficient strategies. This approach utilises real-time monitoring data to identify obstacles and adjust flight paths accordingly, thereby enhancing the safety and effectiveness of drone operations in complex and unpredictable conditions [9].

The UAV system [10] integrates with smart city infrastructure, utilising real-time data collection, aerial surveillance, and situational awareness to address urban challenges during crises. The UAVs [11] are designed to work seamlessly with existing innovative city systems, enabling efficient communication and coordination among various emergency services [12]. This proposed system is designed to coordinate multiple drones for area surveillance, supply delivery, and condition monitoring. The architecture supports continuous data transmission between the drones and control stations [13]. Integrating these advanced technologies aims to enhance the efficiency of disaster response efforts, offering a practical and robust solution for real-time data collection and expedited decision-making in emergencies [14].

Remote engineering applications play a significant role in disaster management [15]. Drones are used in search-and-rescue missions during disasters to capture aerial images [16] and identify structural damage [17]. The AI-based drone [18] is used for real-time data collection and payload delivery [14], thereby improving telemonitoring and remote diagnosis [19]. The embedded control software is used in AI-based drones [20] that support Android phones and also enable virtual reality worlds. The AI wings provide a cloud server for communication methods [21]. The nanometer-based UAV was designed to assist humans in complex scenarios, such as monitoring terrorists' activities [22]. This work utilises a deep neural network [23] model for nano UAV analysis, and performance metrics are measured, showing that 87 mW is the consumed power at peak throughput [24]. AI-based tools play a crucial role in enhancing the effectiveness of the design process, particularly through the AI—assisted model using the HyForm design method [25].

During natural disasters, timely and effective communication, as well as rescue operations, are crucial for saving lives and coordinating relief efforts. Traditional methods of locating survivors and maintaining communication in disaster-stricken areas face significant challenges due to environmental conditions such as smoke, debris, and disrupted infrastructure. Existing communication systems struggle with maintaining reliable links in disrupted areas, whereas our mesh network provides distributed, resilient communication among rescue teams and survivors, even in areas with destroyed infrastructure. Many disaster response technologies fail to integrate real-time sensor data. Current search-and-rescue operations often rely on manual methods, which are ineffective in low-visibility environments (e.g., smoke, debris). The proposed drones, equipped with thermal imaging and machine learning algorithms, enhance human detection in challenging conditions. Our system fuses data from multiple sensors and provides real-time situational awareness through an intuitive user interface, enabling rapid decision-making.

2. RESEARCH METHOD

2.1. System overview

The proposed block diagram for an innovative drone system dedicated to disaster response systems integrates advanced technologies to facilitate effective human detection and communication. The drone platform is engineered from a lightweight, durable device that ensures optimal flight performance in challenging environments. The power supply system features a lithium polymer battery equipped with an energy management system to optimise time duration and usage. The following section is the sensor unit, which includes high-resolution cameras for capturing visual data, thermal imaging sensors that detect heat signatures, and light detection and ranging (LiDAR) for precise environmental mapping. Data collected from these sensors is processed by the processing unit, which utilises NVIDIA Jetson, and the image processing unit, which helps gather information from various sources and enhances the accuracy of human detection. The communication system block enables drones to dynamically interconnect and establish a resilient network that mitigates the risk of data loss from individual node failures. Adaptive routing protocols ensure reliable connectivity even in rapidly changing environments, a critical requirement during disaster response operations. The data handling subsystem manages the processed data, secures sensor data storage and oversees real-time transmission to the ground control station, as shown in Figure 1.

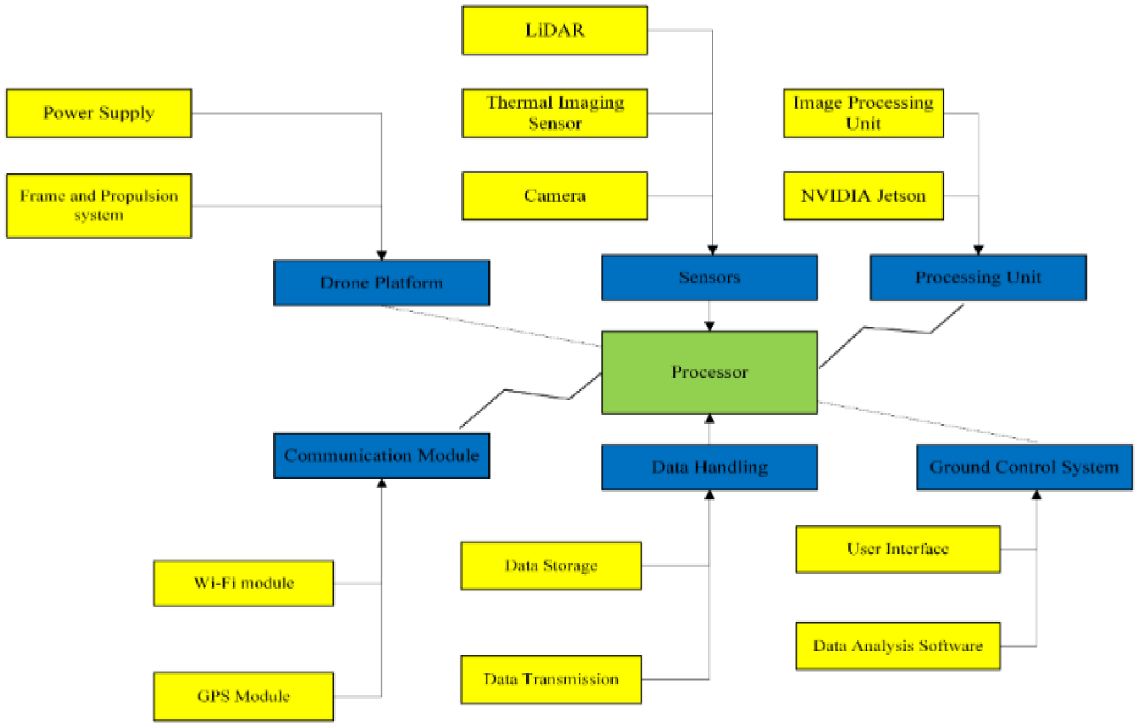


Figure 1. Block diagram of the proposed system

2.2. Drone hardware and sensors

Drone technology involves designing and operating autonomous or remotely piloted aircraft. Drones can vary in size and capability, often equipped with cameras and sensors for various applications, including surveillance and photography, as well as establishing Wi-Fi networks for disaster communication, as proposed in the project. The ESP8266 web server is a lightweight server framework for the ESP8266 microcontroller. It allows ESP8266 to host a website, handle HTTP requests, and serve web pages. This enables the ESP8266 to act as a standalone device with a user interface accessible through a web browser. A captive portal featuring redirection is a web page that users encounter upon accessing a network. Common in public Wi-Fi setups, it prompts users to interact or agree to terms before redirecting to a designated webpage. Using a Raspberry Pi camera and OpenCV, the drone captures a live video feed and processes it in real time. It identifies humans within the video frames and provides directional assistance by drawing arrows from the centre of the image to the detected individuals. The system streams the processed video to a web interface, making it accessible for remote monitoring and control. Figure 2 presents the hardware setup of the proposed drone system, where Figure 2(a) shows the front view of the drone and Figure 2(b) illustrates the remote control used for system operation.

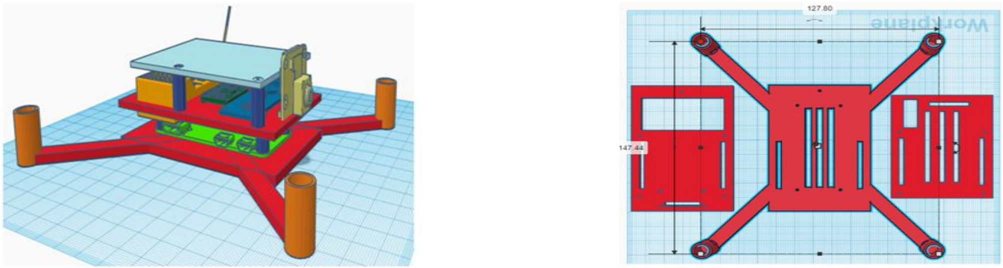
2.3. Drone design

The Quad-X drone design for the AI-enabled Disaster Relief Drone with Human Detection and Emergency Wi-Fi Network Distribution features a stable four-rotor configuration optimised for precise manoeuvrability. Tailored for carrying payloads, especially Wi-Fi and camera modules, it enables rapid deployment of a resilient network in disaster areas where traditional infrastructure is compromised.

The flight controller is the drone's central brain, interpreting data from onboard sensors to stabilise and control the aircraft's movement. It calculates real-time adjustments to motor speeds, ensuring optimal stability and responsiveness during flight. This component facilitates navigation and execution of user commands, allowing the drone to maintain a stable position, follow specific flight paths, and respond dynamically to external factors. The flight controller is crucial for safe and effective drone operations, as it significantly influences overall performance, responsiveness, and the ability to carry out specific tasks accurately. Figure 3 presents the design configuration of the proposed drone system, where Figure 3(a) shows the 3D view of the drone structure and Figure 3(b) illustrates the internal design layout of the drone components.

(a) (b)

Figure 2. Drone system hardware setup (a) drone front view and (b) remote control



(a) (b)

Figure 3. Drone design (a) 3D view and (b) internal design

2.4. ESP8266 Wi-Fi access point and built-in emergency portal

The ESP8266 is a Wi-Fi access point and server that simultaneously functions as a versatile IoT hub. It establishes its Wi-Fi network, allowing devices to connect and host a web server. This dual capability enables the ESP8266 to serve web pages to connected clients, facilitating data exchange. As a standalone access point, it creates a local network for communication devices. Its integration of access-point and server functionality makes it an efficient solution for IoT applications, enabling devices to connect to the ESP8266, exchange data, and access hosted web pages for configuration or monitoring. The in-built emergency portal on the drone, implemented using the ESP8266 microcontroller, enables individuals in disaster-stricken areas to request help quickly and efficiently. The ESP8266 serves as a Wi-Fi access point with a captive portal. When users connect to the network, they are automatically redirected to a simple web form where they can submit their names and emergency requests. These requests are stored and displayed on an admin page for rescue teams to access and respond promptly. This portal ensures reliable emergency communication, especially when regular communication infrastructure is unavailable.

2.5. Human detection and video streaming

Human detection in this drone is achieved using OpenCV and a pre-trained Haar Cascade classifier. The Raspberry Pi camera captures live video, which is processed frame by frame. Each frame is converted to grayscale to simplify detection. The Haar Cascade classifier scans the frame to identify human figures based on predefined patterns of human features. When a human is detected, the system draws a rectangle around the figure and an arrow pointing from the image centre to the detected person. This processed video stream is served via a Flask web server for real-time remote viewing and navigation assistance. Video transmission in this drone is handled by capturing live video from the Raspberry Pi camera and streaming it over a network using a Flask web server. The camera continuously captures frames, which OpenCV processes to detect humans. Each processed frame is encoded as a JPEG and sent as a series of HTTP responses. The rescue team can access the live video feed through a web browser by navigating to the specified server address, enabling real-time remote monitoring and control of the drone's video feed.

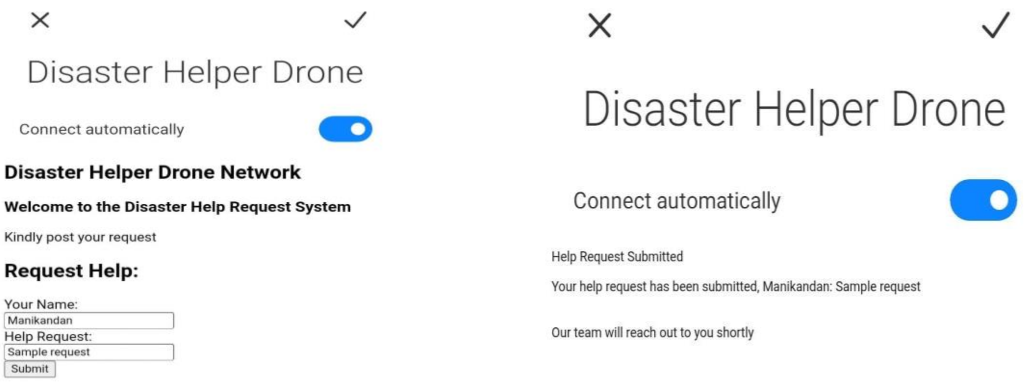
3. RESULTS AND DISCUSSION

The project implementation involves deploying Quad-X drones equipped with ESP8266-based Wi-Fi modules to create a dynamic aerial network. The drones, controlled by Arduino Pro Mini and utilising MultiWii firmware, stabilise flight with MPU6050 sensors. The ESP8266 serves as an access point and server, hosting an emergency portal.

3.1. Web interface and help request page

The web interface in this project serves as a user-friendly platform accessible via the drones' Wi-Fi networks. Users can submit help requests by filling out a form that includes fields for their name and the nature of their request. The interface provides an intuitive design for easy navigation. Once a help request is submitted, the web server processes the data, and users receive a confirmation message. Additionally, an admin page displays all submitted requests, aiding coordination. The interface ensures simplicity and efficiency, empowering users to seek assistance seamlessly in disaster scenarios via a responsive, accessible online portal hosted on the drone network.

Users can input essential information, including their name and a brief description of the assistance needed. This form simplifies communicating urgent needs to relief coordinators. A submit button accompanies the help request form, enabling users to send their requests with a single click. The simplicity of this button encourages quick submission, catering to the urgency often associated with disaster situations. Figure 4 presents the web-based help request interface of the proposed system, where Figure 4(a) shows the help request page used by users to submit assistance requests, and Figure 4(b) illustrates the request submission response page confirming successful data submission.



(a) (b)

Figure 4. Web-based help request interface (a) help request page and (b) request submission response page

3.2. Admin page

The admin page in the proposed disaster relief system serves as a centralised dashboard for managing and monitoring incoming help requests submitted through the user interface hosted on the drones. The admin page displays a list of help requests received from individuals in disaster-stricken areas. Each request includes relevant information, such as the user's name and their specific help request. This real-time display provides relief coordinators with an up-to-date overview of the assistance needed, as shown in Figure 5.

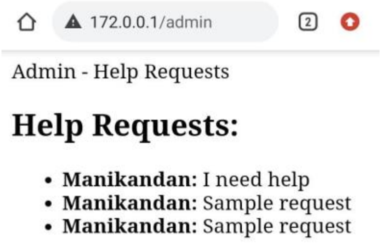


Figure 5. Creation of the administration page

3.3. Human detection, OpenCV live server and streaming

Human detection is a computer vision technique that identifies people within images or video streams. Using algorithms such as Haar cascades or deep learning models, it analyses visual data to locate human figures based on predefined feature patterns, including body shape and contours. Once detected, bounding boxes or other indicators are drawn around the identified humans to highlight their presence. This feature has applications in various fields, including surveillance, crowd monitoring, and human-computer interaction.

OpenCV streaming involves capturing camera frames, processing them with OpenCV for tasks such as object detection, and then encoding them into formats like JPEG or H.264. By utilising frameworks such as Flask, a web server is set up to serve the video feed. Encoded frames are transmitted over a network as a continuous stream of HTTP responses to connected clients. Users can view the live video feed in a web browser or compatible application. OpenCV's real-time output, including processed video frames such as human detection results, is streamed over a network using a web server. The server serves the processed frames as a live video feed, allowing remote users to view the dynamic output in their web browsers or compatible applications, as shown in Figure 6.

The software implementations in this project are integral to the successful operation of the disaster relief system using ESP8266-based drones. The primary software components include the ESP8266 Wi-Fi library, the domain name system (DNS) Server library, the ESP8266 WebServer library, and the electrically erasable programmable read-only memory (EEPROM) library for non-volatile data storage. The ESP8266 Wi-Fi library enables drones to act as Wi-Fi access points, establishing a wireless network for user connectivity, as shown in Figure 7.

This library is crucial for configuring Wi-Fi modes, network names (SSIDs), and IP addresses, ensuring seamless communication between drones and connected devices. The DNS Server library enables DNS spoofing, redirecting all DNS queries to a specified IP address. This project ensures that all HTTP requests are directed to the ESP8266-based web server, allowing users to access the web interface by simply typing a domain name into their browsers. The ESP8266WebServer library manages the HTTP communication between the drones and connected users. It handles incoming HTTP requests, processes form submissions, and sends appropriate responses. The web server is responsible for serving the HTML pages for the user interface, accepting help requests, and displaying them on the admin page. The EEPROM library is utilised to store critical data persistently.

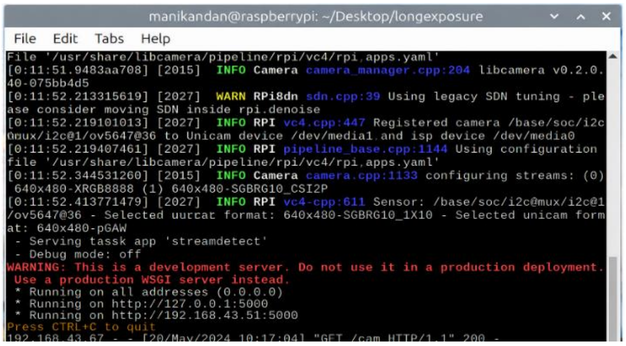


Figure 6. OpenCV live server

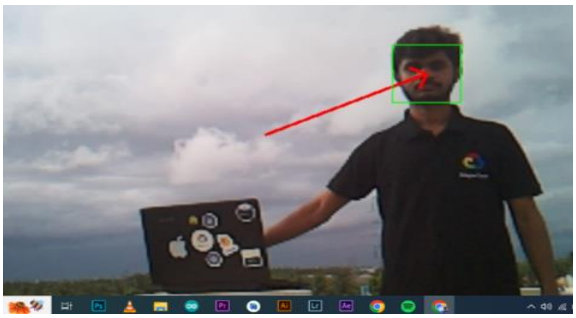


Figure 7. Live streaming over transmission control protocol/internet protocol (TCP/IP)

4. CONCLUSION

This proposed design lays a strong foundation for the future development of AI-powered drone systems in disaster response, benefiting society. Integrating advanced sensors on drones enables the real-time collection of environmental data, greatly enhancing situational awareness for relief teams in the field. The machine learning algorithms help categorise incoming help requests, optimising response efforts and resource allocation. Furthermore, the system's scalability could be significantly improved through the collaborative deployment of drone fleets covering large areas. Additionally, implementing more robust security measures will be imperative to safeguard sensitive user data and ensure the system's integrity during deployment in real-world disaster scenarios. The detection and communication times are observed to be within the range of 5 to 8 seconds for this proposed system.

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V. R. Seshagiri Rao	✓		✓	✓			✓			✓	✓		✓	✓
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Manikandan S.	✓	✓	✓	✓	✓	✓		✓	✓	✓				✓

C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

The authors state there is no conflict of interest.

DATA AVAILABILITY

Data availability does not apply to this paper as no new data were created or analysed in this study.

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