AI Powered Post Disaster Surveillance Drone System

Madhav Manoj
Dept. of Information Technology
Toc H Institute of Science & Technology
Ernakulam, India

Mitul K.
Dept. of Information Technology
Toc H Institute of Science & Technology
Ernakulam, India

Nathaneal Vinod
Dept. of Information Technology
Toc H Institute of Science & Technology
Ernakulam, India

Rachel P. Jose
Dept. of Information Technology
Toc H Institute of Science & Technology
Ernakulam, India

Kurien Thampy
Dept. of Information Technology
Toc H Institute of Science & Technology
Ernakulam, India

ABSTRACT
A self-managing drone that is equipped with computer facilities has been developed, which can process artificial intelligence algorithms independently [7] without any external computer facilities. Such a drone can be equipped with an onboard computer, the Raspberry Pi 5, and other facilities that can improve the speed of the processing system [5]. The drone is equipped with the facilities to identify people in real time by detecting the positions of the joints of the human body and tracing people even when there is limited internet connectivity [11]. The efficiency of the drone in tracing people has been improved by incorporating information from various sources, such as standard cameras, information from thermal cameras, information from lasers, and location information. The technology is equipped with the facilities to trace the people in real time even when the people go out of sight, which is important in tracing people in emergency situations [13]. Such technology can trace disaster-prone areas at low costs, trace assets in difficult situations, and trace the environment in adverse situations.[1][4]

General Terms
Artificial Intelligence, Computer Vision, Embedded Systems, Robotics

Keywords
Edge AI, autonomous drone, YOLOv8, pose estimation, search and rescue, multisensor fusion, real-time object detection.

1. INTRODUCTION
The use of drones with on-device artificial intelligence has been found to be highly effective in disaster situations where communication networks are not readily available or are not functioning properly [6][7]. The conventional artificial intelligence system is based on cloud servers. However, this may result in limitations for the proper functioning of the system when the communication network is not functioning properly [3]. Such limitations may be critical for disaster situations such as search and rescue operations [12].

The main aim of the study is to investigate the use of on-device artificial intelligence based on the Raspberry Pi 5 platform with the integration of the Hailo AI HAT+ accelerator for improved performance up to 26 trillion operations per second [5][15]. The conventional artificial intelligence system is based on the execution of complex artificial intelligence operations on embedded devices with limited computational capabilities. The system is based on the implementation of the conventional artificial intelligence system for the detection of objects and human movements by applying the YOLOv8 algorithm. The system can identify human anatomical features with the help of pose estimation. The conventional sensing mechanism is based on the integration of multiple sensors such as RGB camera sensors, thermal sensors.

The system also checks the pattern of movement in the images from one frame to another. The fact that the system processes the images on the drone means that it can work even without an internet connection. This makes the system applicable in disaster response in disaster zones where there is no network connectivity. The proposed system, therefore, makes the system reliable and effective in disaster response, border surveillance, and environmental monitoring [8].

2. SYSTEM DESIGN
The system runs on a Raspberry Pi 5. The system also runs on a Hailo AI accelerator. This ensures that there is a balance between the power consumption and the abilities of the system. The system runs on devices that consume a certain level of power. The object recognition is done by using a YOLOv8 framework. This allows for the recognition of humans and other important objects. The recognition of humans is done by using pose estimation, whereby the keypoints of a human are examined.

To ensure that there is reliability in perception, the system will use:

- RGB camera: used to capture visual images

- Thermal camera: used to capture thermal signatures in low light.

- LiDAR sensor: used to measure distance and map the surroundings

- GPS: used to track the location

A sensor fusion module is used to combine the information from the above-mentioned data sources to obtain more accurate detection results.[1][4].

3. PROPOSED SYSTEM
The drone system is autonomous and can operate in low-connectivity environments. It is valuable in complex

environments for providing assistance during disaster response, monitoring borders, and observing natural conditions. The system allows drones to observe, analyze, and act independently using an onboard subsystem. It does not require the aeromodel to transmit information to a remote server, allowing almost instantaneous self-flying operational capability.

3.1 Hardware Architecture

The Raspberry Pi 5 functions as the main processor for the system, and it also utilizes a Hailo AI HAT+ to significantly enhance the speed at which complex artificial intelligence tasks are performed. These components work together to manage processing power, conserve energy, and provide up to 26 TOPS of AI performance with limited power requirements, enabling drones to use this processing unit while still in flight. The sensor suite consists of:

- A camera that produces clear color images of observed subjects
- A heat-detecting camera to enhance vision during night or low-visibility conditions
- A LiDAR sensor that provides spatial awareness to help avoid obstacles
- A GPS device that provides accurate location information for navigation

3.2 Software and AI Models

The system utilizes a fast object detection model known as YOLOv8. This model can be utilized by a device with limited computational power. The system allows for the fast detection of people and other critical objects during the course of a monitoring process to identify people who need assistance. The system includes a method for determining the location of a human within an image. The system detects body landmarks to provide information on the posture or movement of a person even when the whole body is not visible. The accuracy of the detection process is improved by incorporating the results obtained from various types of sensors, such as a camera that detects color, thermal, distance, and location. This minimizes errors and improves the reliability of the detection process.

3.3 Temporal Modeling and Tracking

Recognition of objects is based on the recognition of the sequence of images as the camera mounted on the drone scans the moving objects. The process is effective since the objects can change positions or may be partly hidden from view. An object may be identified and tracked even if only the limbs or part of the body is visible. Tracking objects over time allows the drone to move with the objects. This enhances situational awareness and the understanding of the events happening, leading to the successful accomplishment of the mission.

3.4 Edge AI Benefits

The drone is able to analyze the data directly. Analyzing the data directly allows the drone to act faster. In addition, the drone is able to operate without the need to be connected to the network. Analyzing the data directly allows the information to be secure, which enables the drone to operate over a longer period.

3.5 System Integration

The drone would also be in an advantageous position to process the data internally, hence facilitating an early response without relying on the network. This would also be helpful in reducing communication costs, hence increasing the lifespan of the system.
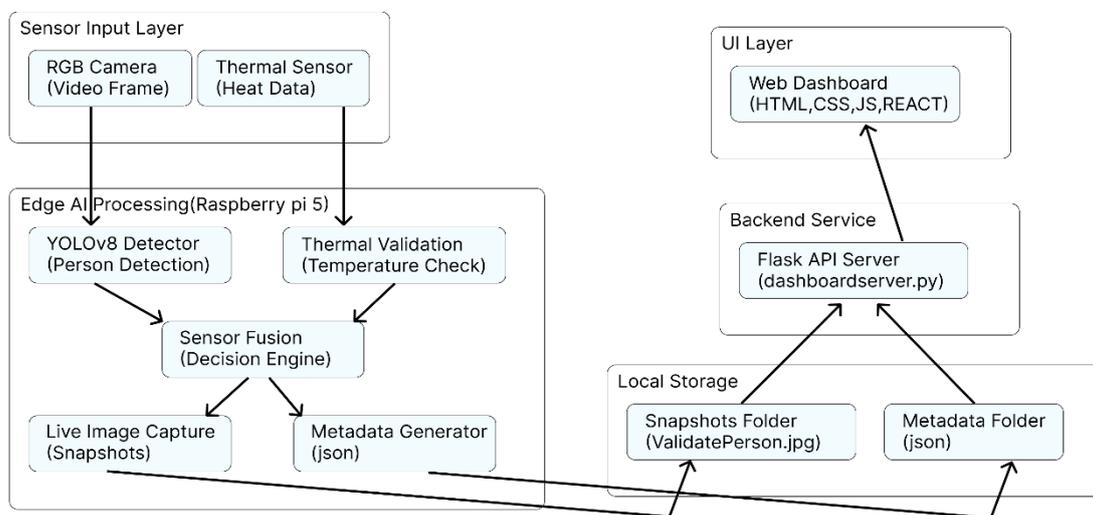

Fig 1: System Architecture Design

4. METHODOLOGY

The methodology will be based upon the assessment of the quantitative performance of the proposed drone surveillance system. It will include the assessment of the capability of the proposed system to identify the human subjects and objects, process the information, and then finally track the objects with varying environmental constraints. The performance of the proposed drone surveillance system will be assessed based upon the following key parameters:

- **Detection Accuracy:** It will include the proportion of the identified human subjects and objects to the total number of instances present in the dataset.

- **Inference Speed:** It will include the average value of the processed frames per second in order to evaluate the real-time processing capability of the proposed system, using the Raspberry Pi 5 platform and the Hailo AI HAT+ accelerator.

- **Robustness:** It will include the capability of the proposed

system to maintain a consistent level of reliability with respect to the results obtained with varying environmental constraints.

For the evaluation of these parameters, a controlled test environment was developed that could mimic realistic disaster scenarios. The idea was to develop an environment that could mimic realistic scenarios that are often faced during emergency response operation situations. Some test environments were designed to include structures that resembled disaster scenarios, such as buildings destroyed in disasters, vegetation, and scattered objects that resembled disaster scenarios. These environments were designed to test how the system could be effective in scenarios where visibility is limited and objects are partially occluded.

Performance evaluation of the system was carried out in different operating conditions, such as indoor and outdoor environments, varying lighting conditions, and different weather conditions. A data collection system was designed to collect data from different combinations of sensor technologies, such as RGB camera, thermal camera, LiDAR, and GPS-based location tracking modules. The system is designed to work efficiently on hardware due to an optimized hardware configuration. The software components are also optimized to reduce overhead and ensure detection accuracy. The system is designed to work on the Raspberry Pi hardware and utilize the Hailo accelerator for high-speed neural network execution.

For the purpose of object detection and tracking, the system performs a sequence of analysis of the captured images by the camera of the drone. The pattern of movement of the objects is analyzed based on the movement of the objects. The movement pattern of the objects is analyzed based on the movement of the objects between two images. This enables the tracking of individuals even when the human body is partially hidden. For instance, when the human body is partially hidden by other objects, such as rubbles, debris, and vegetation, the system identifies the location of the person by the visibility of the limbs of the human body, for example, the hands and legs. The object tracking system uses various computational techniques, for instance:

- **Association Algorithms:** A class of sequential data association algorithms that associate object detections across two consecutive frames to maintain consistency.

- **Motion Forecast Models:** A class of models that predict the path of detected objects based on the patterns of motion.

- **Spatial-Temporal Feature Integration:** Spatial-Temporal Feature Integration: A class of features that integrates the spatial features from the object detection with the motion features to ensure stability.

These techniques enable the development of an intelligent perception system for the purpose of object detection, tracking, and decision-making for the drone system. The use of edge-based artificial intelligence and multi-sensor perception enables the development of a successful object detection and tracking system for the purpose of surveillance and search and rescue operations during a disaster [7][8].

5. EXPERIMENTAL EVALUATION

5.1 Construct Test Environment

To evaluate the efficacy of our drone's detection system independently, we developed a sophisticated computer simulation of disaster scenarios. We captured photographs that represented scenes in which objects obscured areas of the image, e.g. fallen buildings, trees, debris. We put the detection system through its paces indoors, outdoors, in differing weather conditions, and at varying levels of light intensity. We clearly used mixed sensor types for testing, e.g. thermal cameras, standard cameras, LiDAR, GPS, etc., for collecting multimedia inputs to test.

5.2 Metrics For Evaluation

The performance of the system was evaluated in three assessed quantitative ways:

- Correct detection: The number of objects and human figures accurately recognized (counted as the detection by the model) over the total number of occurrences from ground truth.

- Inference Speed: The inference speed of the model (in real time frames per second (FPS)) on the Raspberry Pi 5 with the Hailo AI HAT+.

- Robustness: detection and tracking ability in response to differing meteorological sensor inputs and conditions in the environment.

5.3 Results Overview

Based on the test results, the ability of the system to correctly identify an object increases with the use of information from multiple sensors. The results show that the system was able to correctly identify objects with an accuracy of more than 90%. The system was able to process the images with an average of 15 frames per second.

The experimental results show that the integration of multiple sensors improves the reliability of the human detection in complex environments. The performance of the human detection was affected when the system only used the RGB image from the camera. However, the performance was improved with the integration of the thermal image and LiDAR sensors, which enhanced the perception capability of the system. Thermal sensors aided in the detection of humans based on their thermal signature, even in poor lighting conditions. LiDAR technology helped in identifying objects, and their distances were calculated.

The YOLOv8 detection model enabled fast object detection with relatively low computational overhead, making it suitable for embedded platforms such as Raspberry Pi 5. The combination of sensor fusion and temporal tracking allowed the system to maintain object identity even when individuals were partially occluded. This capability is particularly useful in disaster environments where visibility conditions frequently change.

5.4 Qualitative Analysis

The system is effective in locating people when using normal cameras, as well as when using thermal cameras. The system highlights boxes around people and also recognizes significant body parts, including when people are obstructed from view. The system correctly identifies people in each image when looking at the images. The images show that the system is efficient in real-world use for search purposes, including when people are obstructed from view.

Table 1. Hardware and sensor specifications

Device	Specification	Power Consumption
Raspberry Pi 5	Quad-core ARM Cortex-A76, 8GB RAM	~7W
Hailo AI HAT+ Accelerator	AI Edge Accelerator, 26 TOPS	~5W
RGB Camera	1920x1080 resolution, 30 FPS	~1W
Thermal Camera	640x480 resolution, low-light imaging	~1.2W
LiDAR Sensor	Range up to 40 meters	~3W
GPS Module	10 Hz update rate	~0.5W

Table 2. AI model performance metrics

Model	Detection Accuracy	Inference Speed	Model	Power Consumption
YOLOv8 Object Detection	91%	15 FPS	25 MB	5 W
Pose Estimation Network	89%	12 FPS	20 MB	5.5 W

4. CONCLUSION

The project entails the description of a modern drone, which flies independently. This is achieved through the use of intelligent software, which operates the drone. This software operates independently, thanks to the team-up of a Raspberry Pi 5 computer and a Hailo AI accelerator. Therefore, the drone can process information quickly. This system processes neural networks even in adverse conditions, thanks to the new small Deep Learning Model, used for the identification of objects, and people, to establish their relative pose and bodies. This system receives information from various sources, such as the optics camera, thermal camera, LiDAR, GPS, and many more. This system can "see" a thing or a person and maintain the ability to recognize the object or person for a longer period, thanks to the different types of information, using technologies that are temporal in nature. This way, the drone becomes better at identifying people, as well as objects, and performs the same functions even in adverse conditions, such as when the object to be identified is partly occluded or obstructed or even in conditions of darkness. This system operates independently, without the worry of accessing the data from a remote source, as well as being very well for devices with constrained power, while performance outcomes remain very good while remaining accurate and dependable. We will continue to grow the latest iterations of these systems further.

5. FUTURE WORK

Our goal is to improve AI models for less power use and longer flight times, while keeping accuracy, adding audio and gas sensors, and increasing situational understanding. As we enhance the system to control multiple drones as a team, they will go faster while covering more area, working together as a coordinated operation knowing what their teammates are sensing and acting intelligently with it as a group. Improved algorithms to plan missions and determine decisions will allow the drones to make timely modifications to their actions in a dynamic environment, identifying best routes, prioritizing targets, and making decisions on the fly. Improved communications will allow for data transfers while all this is occurring in a wide range of situations, even when communications networks are not reliable. This can create teamwork with people on the ground as well. We will build drones to operate with as little human intervention as possible and handle operations in extreme and inclement environments while expanding the overall mission task package. This unmanned capability can help support challenging roles such as disaster response, law enforcement security missions, and environmental monitoring.

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