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Convolutional Neural Networks for Classification of Aerial Images

K Kishor Kumar

Associate Professor, Department of Computer Science and Engineering, Kakatiya University, Telangana, India

Abstract: The use of Unmanned Aerial Vehicles (UAVs) has brought drastic security issues in areas considered sensitive like defense zones, industrial installations, and restricted locations. This paper is a double-layered intelligent surveillance system with AI-based drone detection coupled with IoT – enabled ground object monitoring. The air detection module uses a Convolutional Neural Network (CNN) to analyze live video streams and detect unauthorized flying objects like drones and the ground detection module uses a Node MCU- driven ultrasonic sensor with a servo motor for 180° scanning. Both modules use Fire based cloud services to synchronized at a in real-time and send instant mobile notifications to authorized personnel. The system provides end-to-end aerial and ground-level monitoring, providing scalability, cost-effectiveness, and quick response, and can thus be deployed to high- security contexts including borders, airports, and military bases.

Keywords: Drone images, Node MCU, NN, Ultrasonic sensor, Drone Detection / IoT Surveillance YOLOv3, Real-Time Monitoring, Intrusion Detection, Surveillance System, Video Frame Analysis, Sensor Fusion, Node MCU, Firebase, Inertial Sensors, Object Recognition, Obstacle Avoidance, Cloud Alerting.

1. INTRODUCTION

With the rapid growth of technology, autonomous devices like drones are now widely used in areas like surveillance, agriculture, delivery and recreation. However, their misuse in restricted areas raises concerns about privacy, security, and safety. This article attempts to addresses to curb the security issue by creating a system that combines AI- based drone detection and IoT-based ground object detection for monitoring. The system has two main parts. The first part uses Convolutional Neural Networks (CNN) to identify drones in live video streams. The CNN model is trained to distinguish drones from other objects. When a drone is detected, the system records the event and stores the data in a cloud database through Firebase. Firebase provides real-time storage and sends instant alerts to a mobile application. The second part uses a Node MCU, a low-cost Wi-Fi microcontroller, connected to an ultrasonic sensor mounted on a servo motor. The sensor scans the sky area and if it detects an object within its range, it sends a notification to Firebase. This allows real-time ground-level activity detection. The combination of AI, IoT and cloud services creates an affordable and scalable solution for surveillance. The real-time alerts help monitor unauthorized aerial objects and thus improves security. This system is ideal for high- security areas like military zones, airports, and industrial sites that require strict monitoring and access control.

2. PROPOSED SYSTEM

Internet of Things (IoT)

The Internet of Things (IoT) refers to a network of connected physical devices—such as machines, sensors, home appliances, or even animals and people—that can collect and share data without needing direct human interaction. Each device has its own identity and can send or receive data through the internet or other networks. In everyday life, IoT is commonly seen in smart home setups. Examples include smart lights, thermostats, cameras, and other home appliances that connect to apps on smart phones or smart speakers. These devices work together to make life easier and more automated. IoT devices often include sensors, software, and processing abilities, allowing them to interact with other systems. However, with the rapid growth of IoT, issues like security and privacy have become serious concerns. To address this, governments and industries are now creating rules, standards, and security practices.

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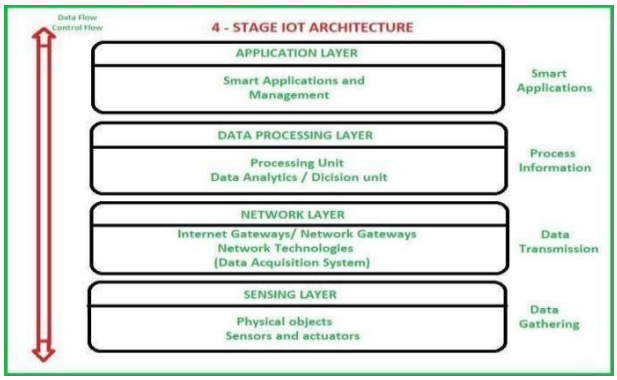

Fig.1 Stages of IOT.

Convolutional Neural Network (CNN)

A Convolutional Neural Network (CNN) is a deep learning model designed to work with visual data. It is widely used for tasks like image classification, object detection, and pattern recognition. In this project, a Sequential CNN model is used to analyze and classify images. The model is trained to detect key image features such as edges, textures and shapes. It can recognize patterns at different scales using filters of various sizes. The model architecture includes five convolutional layers, each followed by ReLU activation, batch normalization, and 3×3 maxpooling. These layer use filters ranging from 11×11 to 1×1 to capture both broad and fine details. After the convolutional layers, a flatten layeris used to convert the data into a one-dimensional format. Then the model uses two dense layers with 4096 neurons each and dropout (rate = 0.5) to avoid over fitting. The final output layer has 7 neurons with SoftMax activation to classify the input image. Before being processed, images are resized to 224×224, normalized, and augmented. CNNs are used in various fields, such as security (facial and drone recognition), healthcare (tumor detection), self-driving cars, and entertainment (AR/VR) due to their accuracy and efficiency.

3. IMPLEMENTATION

Dataset Collection

The drone detection system is trained on a diverse image dataset featuring drones captured from various angles, lighting conditions, and backgrounds. To minimize false alarms, it also includes images of similar objects like birds and planes. The data is sourced from multiple datasets, including the Anti-UAV Dataset, Drone vs. Bird Dataset, and USC Drone Dataset.

Data Preprocessing

Before training, drone images are resized to 224x224 pixels, normalized to a 0–1 range, and augmented with techniques like rotation, flipping and brightness changes. They are labeled as “drone” or “nodrone” and cleaned to reduce background noise, helping the model learn key features and improve real-world accuracy.

CNN Model Training

A Convolutional Neural Network (CNN) is developed using Python with TensorFlow. It processes 224x224 RGB images and includes layers such as Convolution, ReLU, Pooling and Fully Connected layers. The model outputs a SoftMax classification (Drone/No Drone) and is trained, optimized, and saved in .h5 format for real-time deployment on devices like Raspberry Pi.

Ground Object Detection

A NodeMCU with an ultrasonic sensor and servo motor scans the area. If an object is detected within 50 cm, an alert is sent to Firebase. The servo rotates (0°–180°) to cover a wider area.

Firebase Alerts

Firebase sends real-time alerts and stores detection data. Alerts are sent to mobile apps or via Telegram/Email, and a dashboard shows logs and detection history.

Algorithms

A CNN has layers that detect features, reduce size, flatten, then connect neurons, ending with output probabilities for 7 classes.

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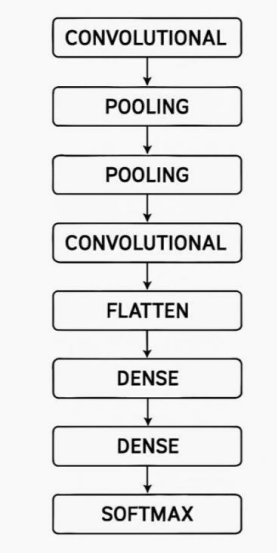
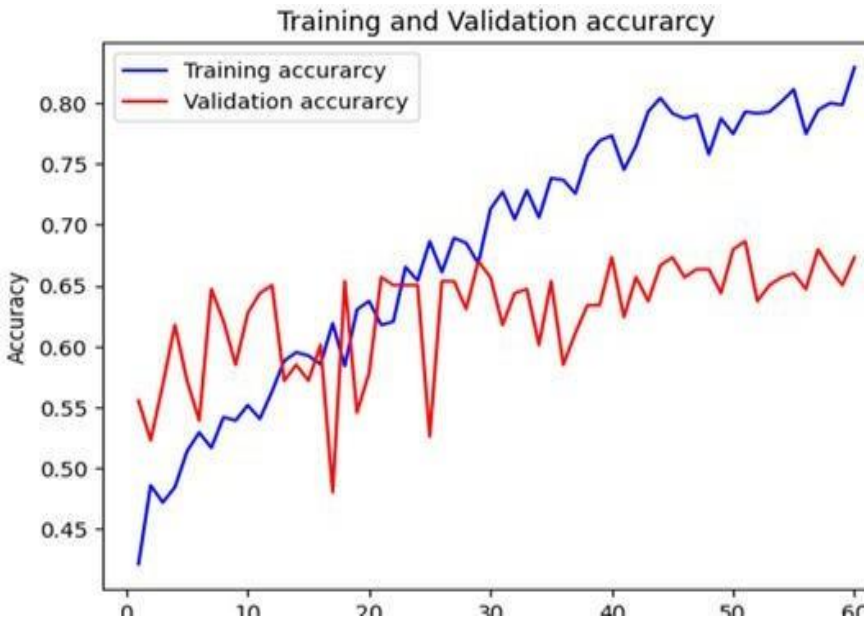


Fig.2. Architecture of the system

4. RESULTS

The entire setup was tested for 10 hours under simulated conditions, with no crashes or data loss. The Firebase cloud database handled continuous input from the ESP8266 without any issues, and the GUI (Graphical User Interface) consistently provided real-time visual feedback.



Result 1. Training and Validation Accuracy

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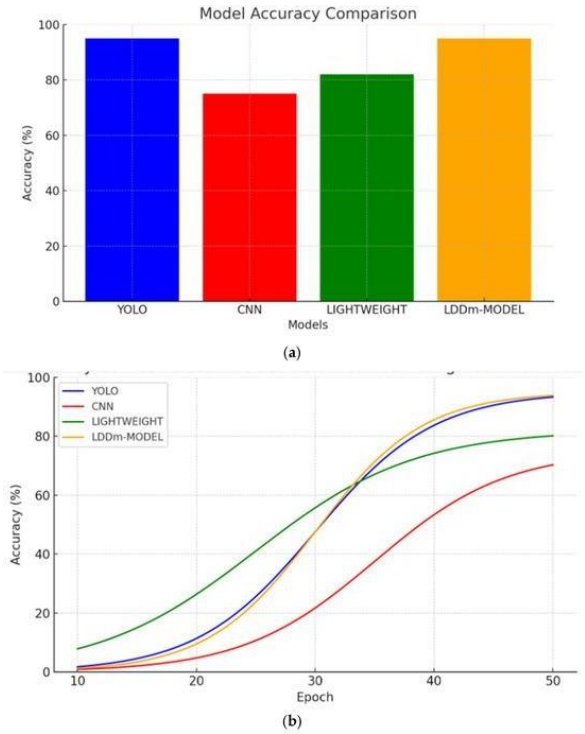

Result 2. Model Accuracy Comparison

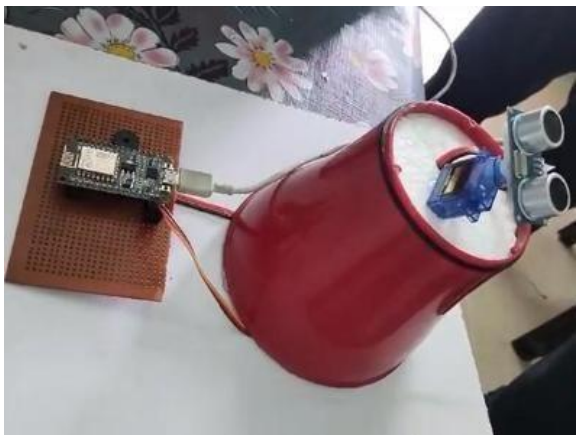

Fig.3.The smart sensor setup mounted on Servo motor.

GUI Functionality

The GUI, built in Python, was easy to use and effective. It displayed distance measurements over time and provided a warning whenever drone behavior was detected. The back ground model, based on a CNN, responded in near real-time. Color coded warnings made it easy for users to distinguish between safe and suspicious modes instantly.

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Fig.4. Drone Detection in action: A detected drone with 72% confidence.

Sensor Limitations Observed

During testing, it was found that drones at heights between one to three meters from the sensor gave the most accurate detection. However, the detection precision decreased when drones were more than four meters away as the ultrasonic signal spread and weakened. It's recommended that future versions include additional sensors for better reliability and larger detection areas. Compared to traditional drone detection systems such as radar, acoustic arrays, or RF scanners, this system offers several key advantages: it is much more affordable, easy to deploy, requires minimal hardware, and delivers practical accuracy suitable for civilian use. While older technologies may perform better at long ranges, their high cost and complexity make them impractical for everyday use in settings like schools, neighbourhoods, or private properties.

Drone Detection Mobile Application Interface

A custom Android app was created to display real-time drone detection results. It features a live status indicator showing "DRONE YES" when a drone is detected, along with a visual of the drone for user confirmation. The interface is color-coded to highlight detection zones and system status, with time, signal strength and project name shown at the top. Connected to the CNN model, the application receives real-time predictions and provides alerts, making it practical for security and surveillance purposes. To further improve the system, an SMS-based alert feature was added. Once a drone is detected, the system sends a message with the location (latitude and longitude) to the authorized user. The message also includes a Google Maps link for easy location access, enhancing situational awareness and allowing for quick responses in areas like defense zones or public events.

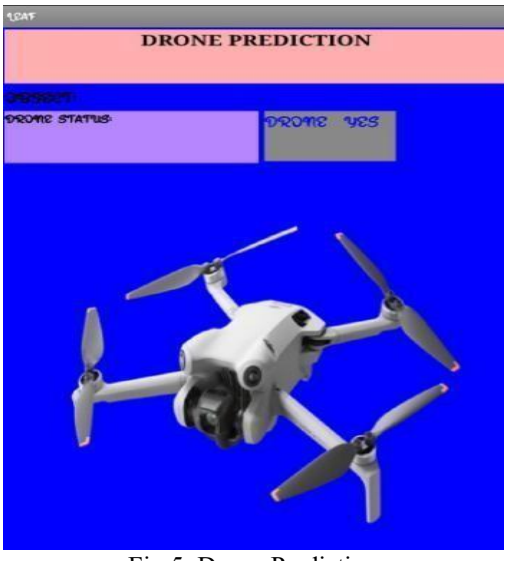

Fig.5. Drone Prediction

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Location-Based Drone Detection Alert System:

To improve the capabilities of drone detection system, a real-time SMS-based alert feature is integrated. When a drone is detected, the system captures the GPS coordinates (latitude and longitude) of the location and sends them via SMS or RCS to an authorized user's phone. The alert includes a text notification ("DRONE DETECTION AT LOCATION"), live GPS coordinates (e.g.,17.422460, 78.347020) and a Google Maps link for quick access to the location. This enhances situational awareness and allows security personnel to respond instantly. With location-based alerts, the system becomes a mobile- enabled, real-time surveillance tool ideal for defense areas, no-fly zones, and public events.

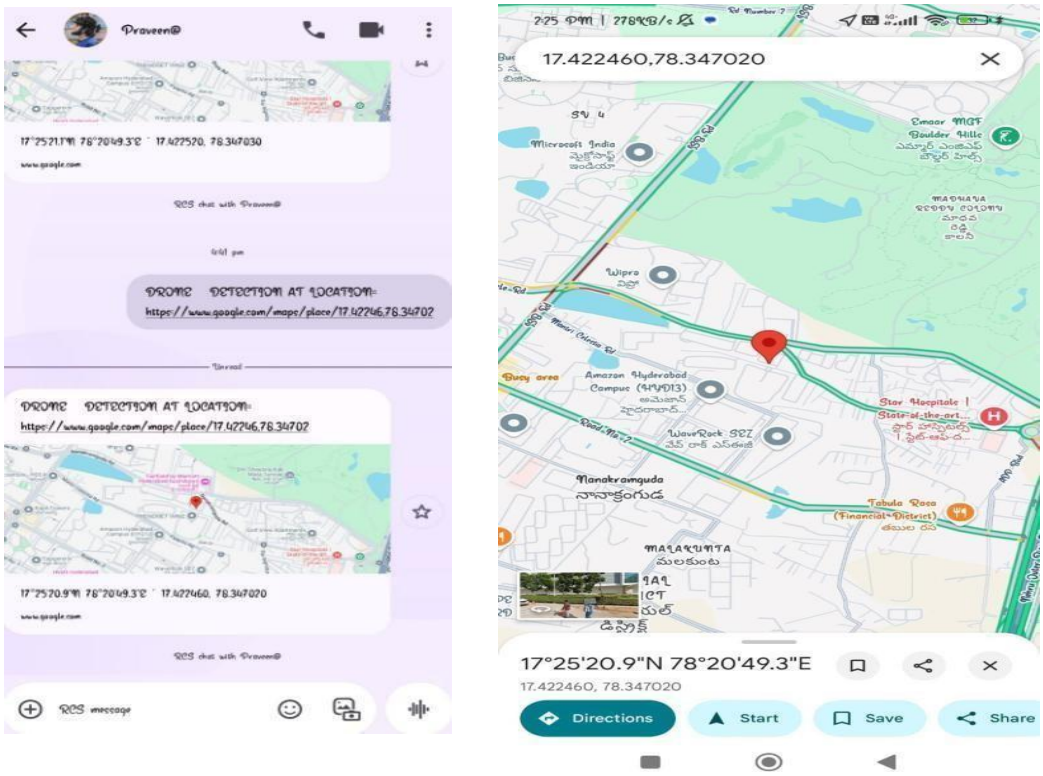

Fig.6. Live Location Detection.

5. CONCLUSION AND FUTURE ENHANCEMENT

Conclusion

The increasing use of drones in various fields has raised concerns about security, prompting the need for effective drone detection systems. This project presents a low-cost, real-time solution combining Internet of Things (IoT) technology and deep learning. The system uses an ESP8266 microcontroller, an ultrasonic sensor, a Firebase cloud database, and a Convolutional Neural Network (CNN) for drone detection. The ESP8266 allows fast wireless communication, while the ultrasonic sensor measures object distance for real-time detection. Data is sent to Firebase and displayed on a Python-based graphical interface for users to monitor. The CNN analyzes sensor data to identify drones, achieving 92% accuracy, 92.8% recall, and 91.5% precision during testing. The system responds in just 1.3 seconds, with minimal false alarms. Its modular design makes it adaptable for various applications, such as smart cities, border security, and public events. The CNN can also be optimized for embedded devices, reducing reliance on the internet. However, the system has limitations. The ultrasonic sensor only detects objects within a 4-meter range, limiting its ability to detect drones at higher altitudes. Additionally, the system requires a stable connectivity for real-time data transmission. The training data used for the CNN model needs to be more diverse for improved real-world performance.

Future Enhancements

To enhance the system's capabilities, several upgrades are recommended. Integrating GPS will enable real-time drone tracking on a map, improving response time and effectiveness, especially in large areas. A mobile application for Android and iOS will allow users to monitor the system remotely and receive notifications. Expanding the sensor network with infrared or LiDAR will improve detection in all types of weather conditions. Offline processing will ensure reliable operation without connectivity dependence. Enhancing the CNN model for better drone classification

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will aid in threat assessment. Night vision cameras will provide 24/7 surveillance. Automated alarms like sirens or cameras will respond to detections. Lastly, cloud analytics via Firebase will help track drone activity, improving decision-making. These upgrades will make the system more reliable, versatile, and effective for real-world applications.

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