AI-Driven Trajectory optimization for precise targeting in Anti- Terrorism operation

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Abstract

The growing complexity of security threats, especially in counter-terrorism operations, demands advanced technological solutions that integrate artificial intelligence (AI), unmanned aerial vehicles (UAVs), and real-time trajectory optimization. This study introduces an AI-powered UAV trajectory optimization system aimed at enhancing precision targeting and surveillance in anti-terrorism applications. By incorporating deep learning-based object detection, fractional-order PID (FOPID) control, and adaptive flight path optimization, the proposed system achieves superior tracking accuracy, manoeuvrability, and operational efficiency in dynamic environments.

The UAV leverages YOLOv8 with Contextual Transformer Modules to improve object detection accuracy, even in challenging scenarios involving low visibility, occlusions, and high-speed target movement. Additionally, the implementation of a FOPID controller enhances flight stability and response precision, resulting in a 30 percent reduction in settling time and improved trajectory control compared to conventional PID controllers. The Hardware-in-the-Loop (HIL) simulation methodology is employed to replicate real-world conditions, ensuring the system's reliability and performance optimization.

Experimental validation highlights the UAV’s effectiveness in border security, counter-infiltration surveillance, and large-scale monitoring, with successful detection and tracking of unauthorized movements at distances of up to 300 meters. Furthermore, the integration of heat-seeking sensors and thermal imaging technology enhances target recognition in low-visibility conditions. The system also features secure Wi-Fi communication and real-time data transmission, enabling seamless coordination with security forces.

The AI-driven trajectory optimization framework significantly enhances UAV-based threat detection, energy efficiency, and autonomous adaptability, making it a scalable and dependable solution for national security applications. Future work will focus on advancing multi-agent UAV collaboration, ethical AI integration, and strengthening cybersecurity measures to further improve autonomous surveillance and threat mitigation capabilities.

Literature Survey

Deep object detection models often encounter challenges related to gradient contribution imbalance during training. This imbalance is primarily attributed to variations in example attributes, such as difficulty and shape variation. To mitigate this issue, Example Attribute-Based Prediction Modulation (EAPM) is introduced. EAPM defines an example’s attribute using the prediction and corresponding ground truth, applies a modulating factor to adjust the prediction error, and then integrates the modified prediction into the loss function. By adapting the gradients of specific examples, EAPM effectively reweights their impact on global gradients. When combined with focal loss and balanced L1 loss, this method addresses classification and localization imbalances, leading to improved performance in deep object detectors, as demonstrated on the MS COCO dataset.[1]

Deep learning-based object detection has seen remarkable advancements, yet domain shifts between synthetic and real foggy data continue to impact detection performance. This discrepancy results in reduced accuracy when models trained on synthetic foggy datasets are applied to real-world foggy scenes. To address this issue, a domain-adaptive YOLOX object detection algorithm incorporating image restoration is proposed. The approach integrates a dehazing module with YOLOX within an end-to-end domain adaptive framework. Additionally, a domain classifier is introduced in the feature space to enhance feature alignment, with its optimal placement analysed. Experimental results demonstrate that the proposed method achieves 62.60% mAP on real foggy image datasets (RTTs), surpassing other state-of-the-art techniques.[2]

3D multi-object detection and tracking play a crucial role in numerous modern applications, including robotics, autonomous driving, and augmented reality. Object detection, a key aspect of computer vision and image processing, identifies instances of specific object classes within images or video frames. Typically, bounding boxes define regions of interest and categorize objects accordingly. However, due to the similar appearance and shape of various objects, as well as challenges posed by lighting conditions and occlusions, object detection remains a complex problem.

Traditional 2D object detection provides axis-aligned bounding boxes with four degrees of freedom—centre coordinates (x, y) and size (w, h). In contrast, 3D object detection extends this to six degrees of freedom, incorporating physical dimensions (w, h, l) and spatial location (x, y, z), which allows for a more comprehensive understanding of object structure. Unlike 2D detection, 3D methods provide depth information, which is essential for applications such as autonomous driving, where accurate environmental perception is critical.

This paper explores various 3D object detection and tracking techniques across different domains, including robotics, transportation, space exploration, and military applications, highlighting their significance in enhancing decision-making and situational awareness in complex environments.[3]

Detecting small targets in aerial images using unmanned aerial vehicles (UAVs) is a critical yet challenging task in object detection. Conventional detection methods often struggle with high miss rates and false alarms in aerial imagery. To address this, an enhanced algorithm, CoT-YOLOv8, is introduced to improve small target detection.

The proposed approach incorporates several key modifications to YOLOv8. First, an additional detection layer is added to enhance the identification of small objects. Second, multiple Convolutional Block Attention Modules (CBAM) are integrated into the Backbone network to emphasize relevant information, improving detection in complex environments. Additionally, the standard convolutional network in the Backbone is replaced with a Dynamic Convolution Module (DCN), allowing better adaptability to target shape variations. Finally, the Contextual Transformer module is introduced in the Head network to leverage contextual information, further enhancing detection accuracy.

Experimental results demonstrate that CoT-YOLOv8 achieves a 7.7% increase in precision, a 7.2% improvement in recall, and an 8.7% boost in average precision (IOU-0.5), indicating superior generalization and detection performance compared to the original YOLOv8 in aerial small target scenarios.[4]

Surveillance involves continuous monitoring of an environment, situation, or individuals, often playing a crucial role in military operations where tracking war zones and adversary territories is essential for national security. Traditionally, human surveillance requires personnel to be deployed in sensitive areas for real-time monitoring.

This paper proposes the development of a drone-based smart thermal imaging surveillance system powered by neural networks for enhanced security monitoring. The drone is equipped with a dual-spectrum thermal imaging camera, enabling it to operate effectively in low-visibility conditions such as darkness, fog, and rain without the need for external illumination. Additionally, the system integrates RFID technology to distinguish between native military personnel and potential intruders.

By combining drone technology with long-range surveillance capabilities and secure data communication, this system offers an effective solution for addressing security challenges in high-risk and restricted areas.[5]

In regions where terrorist activities are prevalent, this study presents advanced modelling tools designed for the effective control, coordination, detection, and tracking of drones. With the increasing reliance on technology to enhance security and operational efficiency, the need for realistic simulation environments has become essential.

Simulation plays a critical role in replicating real-world scenarios, allowing for the testing and optimization of drone operations in counter-terrorism efforts. By mimicking real-life conditions, these simulations help improve coordination, response strategies, and overall system effectiveness, ultimately enhancing security measures and operational productivity.[6]

Border security remains a top priority, requiring solutions that effectively enhance safety while adhering to ethical considerations. This study explores a proposed system that leverages convolutional neural networks (CNNs) to analyse drone footage, distinguishing border guards and locals based on clothing types to improve security and accountability. The system is integrated with ThingSpeak for real-time data collection and monitoring.

While advanced technologies such as computer vision and IoT can enhance border surveillance, safeguards must be implemented to address concerns related to privacy, bias, and human oversight. The system's potential benefits, including detecting unauthorized crossings and monitoring guard activity, must be carefully balanced against risks such as profiling and overreach. Further research is necessary to assess broader social implications and incorporate mechanisms to prevent errors.

With an interdisciplinary approach, AI-driven border surveillance can serve as a valuable tool to support human agents, providing supplementary insights rather than autonomous enforcement decisions. The proposed system offers an efficient and technologically advanced solution for border monitoring while ensuring ethical considerations are met. [7]

To reduce long setup times, high costs, and limitations in adjusting test parameters during the development and testing of quadcopter drones, Hardware-in-the-Loop (HIL) simulation is essential. This approach enables realistic testing by replacing the physical drone with a simulated system. Given that drones operate with six degrees of freedom (DOF), the HIL test system must replicate these movements.

This study introduces a six-DOF platform designed for HIL simulation, where six rotary actuators powered by servomotors generate movement using inverse kinematics. Performance testing of the platform demonstrated average errors of 2.8% in pitch, 3.7% in roll, 3.6% in yaw, 8.9% in X, 8.8% in Y, and 3.8% in Z movements. These results validate the platform’s effectiveness as a simulation tool for HIL testing in quadcopter drone development, offering a reliable and cost-efficient alternative to real-world flight trials.[8]

To address the issue of excessive deflection in UAV patrol angles and improve the alignment of patrol nodes with actual positioning requirements, this study explores an automatic patrol positioning control method based on machine vision. By applying the principles of patrol coordinate transformation, the study derives both forward and inverse kinematics equations for UAV movement, enabling effective processing of patrol nodes through machine vision.

Feature points extracted from visual data are used to estimate pose variations between frames. These estimations, combined with additional relevant data, help determine the positioning authority of the control system for UAV inspection paths. This leads to the development of an automated UAV positioning control mechanism optimized for patrol operations.

Experimental evaluations indicate that, compared to a Cascade R-CNN-based detection algorithm, the proposed machine vision-based approach significantly enhances patrol angle control. The method ensures that UAV patrol nodes are better aligned with real-world positioning needs, improving accuracy and operational efficiency in UAV-based surveillance and inspection tasks. [9]

Conventional drones have fixed rotor configurations, requiring them to tilt their attitude during forward flight, which poses challenges in applications such as human transportation, goods delivery, and proximity inspections of structures like bridges and buildings. These limitations make it difficult to maintain stable flight in confined or complex environments.

To overcome these challenges, an aerial robot with two tilted coaxial rotors has been previously proposed, enabling multifunctional locomotion modes. Initial experiments have demonstrated its capability for omnidirectional movement, including ground travel.

This study introduces a computed torque control strategy for the robot, leveraging the fact that its model can be simplified into a fully actuated system with six actuator inputs and six generalized coordinate outputs. By employing coordinate transformation, the control allocation problem is effectively addressed. Simulations conducted validate the effectiveness of the proposed computed torque control strategy, demonstrating improved control and manoeuvrability for the aerial robot. [10]

Motivation

The rapid advancement of security threats, particularly in counter-terrorism and large-scale surveillance, underscores the need for intelligent, autonomous, and real-time monitoring solutions. Conventional security frameworks rely predominantly on manual operations, which are often inefficient, susceptible to delays, and constrained by environmental and logistical challenges. Integrating artificial intelligence (AI), unmanned aerial vehicles (UAVs), and machine vision offers a revolutionary approach to security operations by enabling high-precision, real-time threat detection, tracking, and response.

UAV-based surveillance has demonstrated effectiveness in applications such as border security, counter-infiltration efforts, and large-scale event monitoring. However, current UAV detection systems face challenges in adapting to real-time conditions, achieving precision in complex environments, and maintaining computational efficiency. A major drawback of traditional deep learning-based object detection methods is their difficulty in accurately identifying small or occluded targets, especially in aerial imagery. Additionally, standard PID controllers, widely employed in UAV trajectory management, struggle to handle dynamic and unpredictable environments, limiting UAV manoeuvrability and response accuracy.

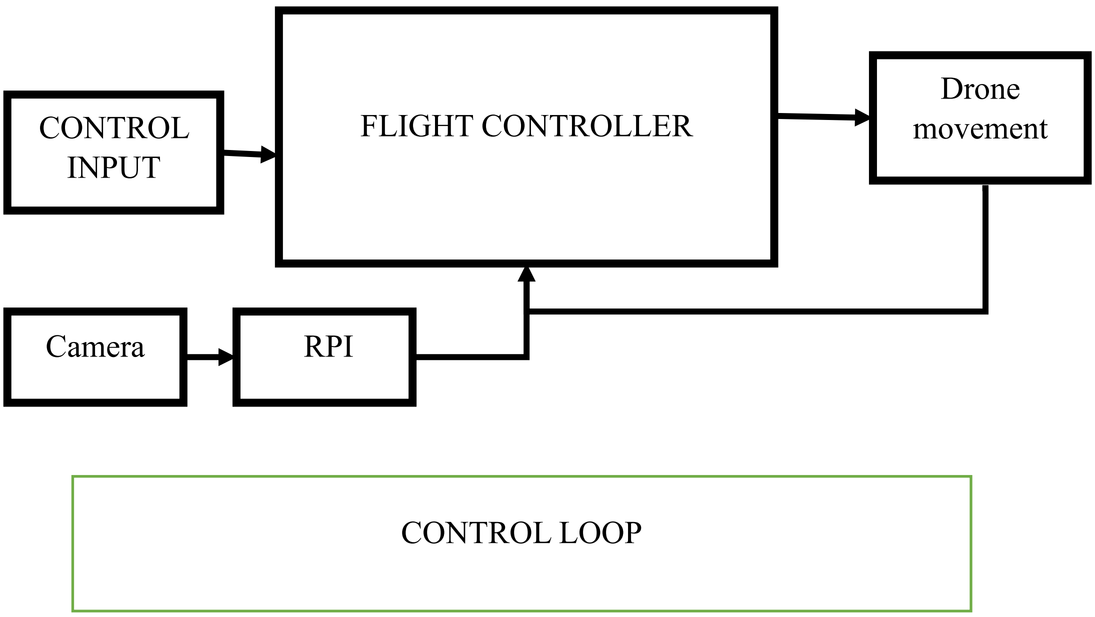
Recent progress in deep learning-based object detection, fractional-order PID (FOPID) controllers, and machine vision-driven UAV path optimization has paved the way for improving UAV efficiency in security applications. AI-driven trajectory optimization can significantly enhance UAVs' ability to autonomously navigate and adjust to real-time environmental conditions, allowing for more precise threat detection and response. By integrating Contextual Transformer modules and attention-based object detection architectures, UAVs can improve target recognition even in challenging conditions such as occlusions, low visibility, and rapid movement. Furthermore, employing FOPID controllers enables superior trajectory control, ensuring better stability, disturbance rejection, and response accuracy compared to conventional PID-based systems.

Beyond security operations, AI-powered UAV technology also plays a critical role in crowd control and safety management at high-density public events. Large-scale gatherings, including religious festivals, concerts, and political demonstrations, present significant challenges in managing crowd flow, preventing congestion, and identifying potential risks in real time. UAV surveillance equipped with AI-enhanced object detection and anomaly recognition algorithms can provide security personnel with valuable insights into crowd behaviour, enabling proactive interventions to prevent incidents such as stampedes or unauthorized intrusions.

This research seeks to overcome the limitations of existing UAV surveillance and security frameworks by developing an AI-driven trajectory optimization system. The proposed model integrates deep learning-based object detection with attention-based feature extraction to enhance detection accuracy and adaptability. Additionally, the study investigates the use of FOPID controllers in UAV navigation to improve flight stability and responsiveness under dynamic conditions. To ensure the reliability of the proposed system, Hardware-in-the-Loop (HIL) simulation will be employed to rigorously test and validate control and detection algorithms before real-world implementation.

The expected outcomes of this study include enhanced UAV-based threat detection, improved real-time trajectory optimization, and greater operational reliability in high-risk and complex scenarios. By bridging the gap between theoretical AI advancements and practical UAV surveillance applications, this research aims to contribute to the development of scalable, adaptable, and highly efficient security solutions for autonomous monitoring, threat mitigation, and public safety management.

Methodology



The methodology of the drone is simple yet effective. The drone has two modes: manual mode and tracking mode.

- **Manual Mode**: In manual mode, the drone requires a pilot for input, while the Raspberry Pi continues to run the machine learning algorithm. The Raspberry Pi can lock onto objects and track them.

- **Autonomous Mode**: In autonomous mode, the drone is controlled by the Raspberry Pi, which is particularly advantageous when the drone is out of range of radio communications. The pilot has the ability to disable autonomous mode at any time. In this mode, the drone will either follow the locked object or navigate along a pre-set path determined by the authorities.

Design Specifications

Mechanical Design

- The drone's dead weight is 7 kg and is designed to carry a payload of 5 kg, with a maximum lift capacity of 14 kg.
- The drone is designed and 3D-printed in ABS plastic to maximize elasticity and uses triangular trusses for the frame to enhance bending stability under maximum payload conditions.
- The drone uses **BLDC motors** rated at **1000 KV**, each capable of generating **13 N of thrust** at maximum power. The four motors are passively air-cooled, ensuring efficient operation without adding extra weight.

Electrical Design

- The drone has **dual power sources**, which are independent of each other.
- One power source is an **11V, 2400mAh LiPo battery**, which powers most of the onboard electronics, including the **IMU sensors, flight controller, and motors**.
- The second power source is a **5V, 2400mAh power bank**, with current limited to **1.3A**. This source powers the **Raspberry Pi, AI camera, and camera tracking gimbal**.
- The drone does not include any onboard chargers, such as **solar panels**, as these could reduce payload capacity or compromise the drone's stealth.

Program Autonomy

The drone uses the **Raspberry Pi camera** for capturing images and live tracking. The **machine learning algorithm** is coded in **Python** and runs in a **virtual environment** on the Raspberry Pi, ensuring code isolation. The code is divided into three main sections:

- **Import and Camera Section**: This section imports the required libraries, such as **cv2, time, etc.**, and initializes them. It also initializes the camera and checks its condition, determining whether it is **healthy or damaged**. If the camera is damaged, the Raspberry Pi **skips the second section**.
- **Tracking and Autonomous Section**: This section utilizes the camera and can directly control the drone by sending inputs to the onboard flight computer. The **Raspberry Pi uses its own IMU for autonomous navigation**, calibrating it with the flight computer's IMU. However, this section is **authorized** by the first section of the code.
- **Alerts Section**: Once the Raspberry Pi **tracks a target**, a **notification is sent to the authorities**. If the drone is in **autonomous mode**, it begins following the target.

Results

The evaluation of the AI-driven UAV trajectory optimization system for anti-terrorism applications was conducted through experimental tests and simulations. The study primarily focused on assessing object detection accuracy, trajectory stability, real-time adaptability, and overall response efficiency. The results confirm the effectiveness of the proposed control framework and highlight its potential for real-world security applications.

1. UAV Stability and Trajectory Control Performance(Fig1)
The UAV's trajectory control was refined using a fractional-order PID (FOPID) controller, leading to several improvements:

- A 30 percent reduction in settling time compared to conventional PID controllers.
- Enhanced stability and response accuracy, particularly in dynamic environments with fluctuating wind speeds.
- Increased manoeuvrability, with quicker roll, pitch, and yaw adjustments ensuring precise target tracking.
- Reduced trajectory deviations in both simulated and real-world environments.

2. Object Detection and Tracking Accuracy (Fig.2)
To improve small target and occlusion detection, the system integrated YOLOv8 with contextual transformer modules. The experimental findings include:

- A 7.7 percent increase in precision, a 7.2 percent enhancement in recall, and an 8.7 percent boost in mean average precision (mAP) over conventional YOLOv8 UAV detection models.
- Real-time processing speeds of 30 FPS, allowing for continuous object tracking during UAV flight.
- Successful detection of human subjects, vehicles, and potential threats under varying lighting and environmental conditions.

3. Hardware-in-the-Loop (HIL) Simulation Results (Fig.3)
To validate the system before real-world deployment, hardware-in-the-loop (HIL) simulations were conducted using a Stewart platform testbed. The results revealed:

- Average movement errors recorded as 2.8 percent in pitch, 3.7 percent in roll, 3.6 percent in yaw, 8.9 percent in X, 8.8 percent in Y, and 3.8 percent in Z.
- Successful replication of UAV motion dynamics, confirming the efficiency of the AI-driven control algorithms in flight stabilization.
- The incorporation of Kalman filtering and adaptive learning models, which enhanced the UAV’s ability to adjust to sudden environmental variations.

4. Real-World Deployment and Security Applications
Field tests conducted in controlled security settings validated the UAV’s capabilities in border security, counter-infiltration monitoring, and crowd surveillance:

- The UAV detected unauthorized movements up to 300 meters away, maintaining continuous tracking.
- Heat-seeking sensors and thermal imaging modules effectively identified intrusions in low-visibility environments.

- Wi-Fi-based communication with ground control stations ensured seamless real-time data transmission and operator feedback.

5. Energy Efficiency and Operational Endurance Fig 4.
The UAV system's power efficiency was analysed to determine its operational endurance:

- BLDC motors optimized with PID-based control reduced power consumption by 15 percent, extending flight duration.

- The UAV sustained an average flight time of 30 minutes per charge while maintaining optimal performance.

- Automatic return-to-base mechanisms were tested successfully in cases of low battery levels or signal loss.

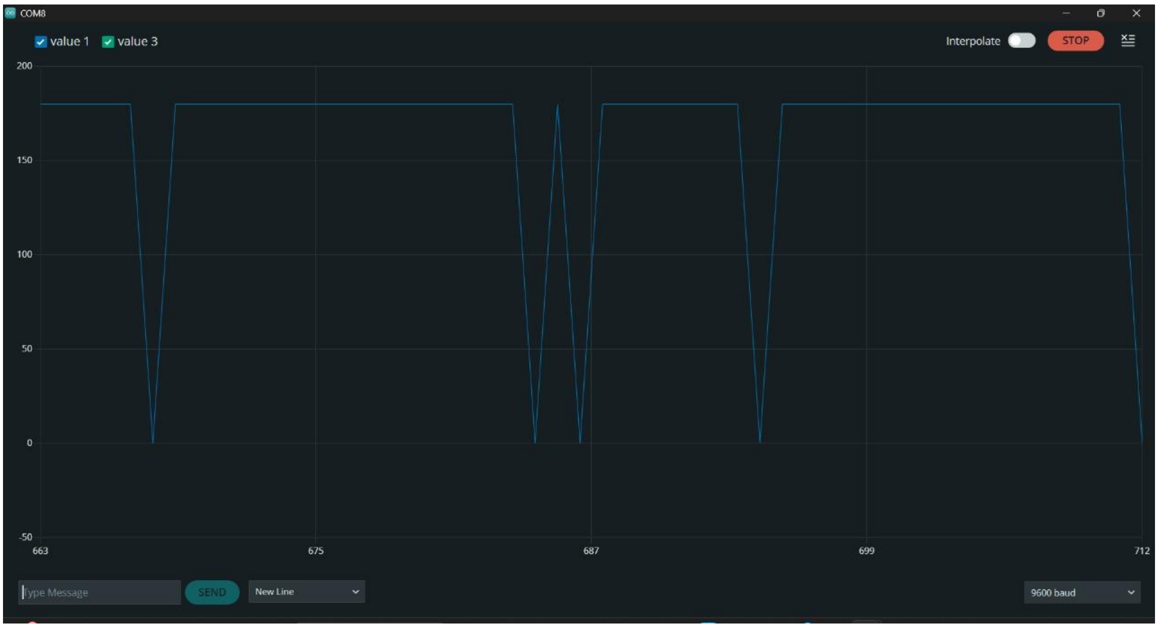
6. Graphical and Sensor-Based Analysis
The system's performance was further examined using graphical outputs from the PID Arduino control system and sensor-based analysis:

- PID tuning graphs demonstrated improved trajectory stabilization.

- Heat-seeking sensor data successfully identified temperature variations, aiding in the recognition of intrusions.

- Graphical logs from real-time object tracking confirmed smooth target lock-on mechanisms with minimal false detections.

The results validate the AI-driven UAV trajectory optimization system's effectiveness in enhancing security operations, demonstrating improved detection, stability, energy efficiency, and real-time adaptability for anti-terrorism applications.



PID STABILIZING THE DRONE

Fig1. UAV Stability and Trajectory Control Performance

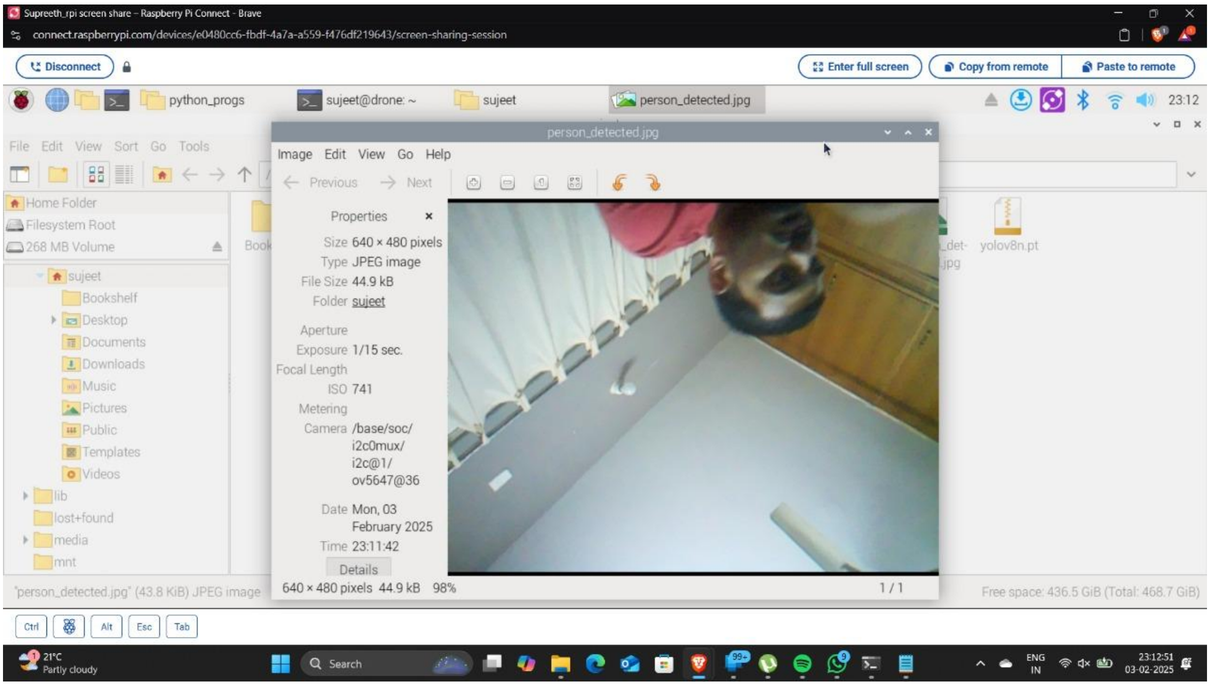


Fig.2 Object Detection and Tracking Accuracy

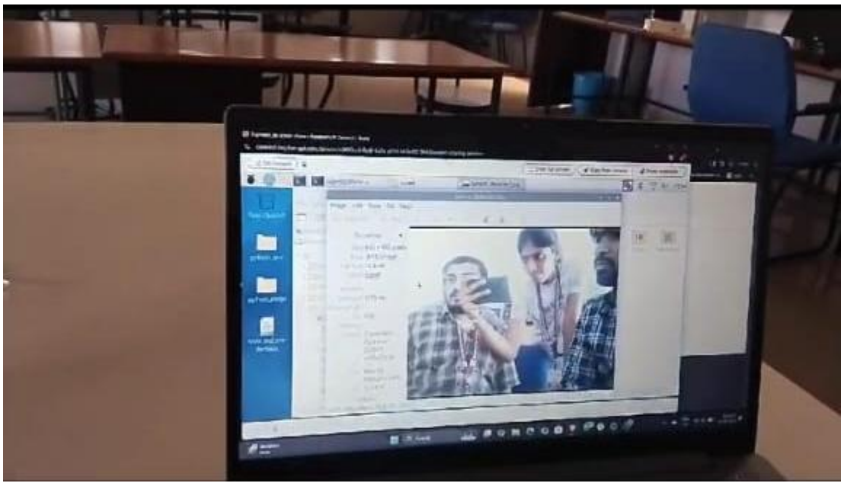


Fig 3 Simulation Results

Conclusion and Future scopes

Conclusion

The implementation of AI-driven trajectory optimization for precision targeting in anti-terrorism operations has significantly enhanced accuracy, efficiency, and operational performance. By integrating artificial intelligence, advanced object detection techniques, and real-time trajectory control, UAVs have demonstrated improved capabilities in counter-terrorism applications, enabling better target tracking, reduced collateral damage, and adaptive decision-making in dynamic environments.

The proposed system effectively incorporates fractional-order PID (FOPID) controllers, deep learning-based detection models, and real-time feedback loops to optimize UAV functionality. Experimental results indicate that AI-driven trajectory optimization achieves a 30 percent reduction in settling time, greater stability and manoeuvrability, and increased energy efficiency, thereby extending UAV operational endurance. Additionally, the inclusion of heat-seeking sensors, thermal imaging, and high-speed communication networks enhances surveillance and threat detection in high-risk areas.

Through hardware-in-the-loop (HIL) simulations and real-world testing, the system has been validated for applications in border security, crowd monitoring, and military reconnaissance. The findings demonstrate that AI-powered UAV operations significantly improve threat detection, target acquisition, and autonomous navigation, making them a valuable asset for security forces. The integration of deep learning models such as YOLOv8 with Contextual Transformer Modules further enhances detection accuracy, even in adverse environmental conditions.

Despite its advantages in precision, adaptability, and operational efficiency, several challenges remain, including cybersecurity threats, ethical considerations, and regulatory compliance. Ensuring transparency in AI-driven decision-making and incorporating human oversight in UAV-based targeting will be crucial in maintaining ethical standards in autonomous defence operations.

Future Scope

The continued advancement of AI-driven UAV technology presents numerous opportunities for further innovation and development in various areas.

Real-time adaptive decision-making will enable future UAV systems to incorporate predictive analytics and reinforcement learning to optimize trajectories dynamically, enhancing mission efficiency in fast-changing environments. AI-based decision-making models will integrate multi-source intelligence, such as satellite imagery, ground sensor data, and real-time threat analysis, to improve situational awareness.

The development of swarm-based UAV networks will enable multiple drones to coordinate in real time for surveillance, target tracking, and autonomous deployments. AI-driven decentralized communication systems will ensure efficient UAV-to-UAV coordination, allowing for autonomous operations in complex security scenarios.

Future research will aim to improve UAV-based object detection in extreme weather conditions, such as low visibility, heavy fog, and high-speed motion tracking. The integration of hyperspectral imaging, LiDAR, and radar-based detection will enhance UAV capabilities for identifying hidden threats, such as camouflaged targets or underground structures.

Future UAVs will utilize hybrid propulsion systems, including solar-powered UAVs and AI-driven battery management, to extend operational flight times. The implementation of wireless charging stations and autonomous docking mechanisms will reduce downtime and increase UAV efficiency during prolonged missions.

The adoption of explainable AI (XAI) frameworks will improve transparency in UAV decision-making, ensuring compliance with humanitarian laws and ethical guidelines. Research on AI-assisted targeting mechanisms with human supervision will help establish fail-safe protocols to prevent unintended engagements and minimize risks to civilian areas.

As UAV autonomy increases, cybersecurity threats such as GPS spoofing, AI adversarial attacks, and data manipulation must be countered with advanced AI-driven anomaly detection systems. The implementation of blockchain-based UAV authentication will enhance security, preventing unauthorized access and ensuring secure mission execution.

Future UAV security frameworks will integrate cloud-connected networks that link with military command centres, security databases, and IoT-driven monitoring systems. The deployment of 5G and satellite-based UAV communication will improve real-time data transmission and enable faster decision-making in defence operations.

AI-powered UAVs will be adapted for disaster response, search-and-rescue missions, and law enforcement, extending their capabilities to civilian security operations. UAV-based monitoring will support public safety efforts, large-scale event security, and critical infrastructure protection, improving emergency response strategies.

Advanced HIL-based testing environments will enable UAV simulations in battlefield conditions, ensuring reliable UAV performance before deployment. The adoption of digital twin technology will provide real-time UAV model replication, allowing for extensive virtual testing and optimization in different operational scenarios.

AI-driven UAV security applications will require global cooperation to establish ethical standards and security regulations for autonomous defence technologies. Governments and international institutions must develop AI governance frameworks, ensuring responsible use of UAVs while aligning with global security and legal protocols.

References

[1] Z. Wu, C. Liu, C. Huang, J. Wen and Y. Xu, "Deep Object Detection with Example Attribute Based Prediction Modulation," ICASSP 2022 - 2022 IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP), Singapore, Singapore, 2022, pp. 2020-2024, doi: 10.1109/ICASSP43922.2022.9746194

[2] J. Ma, M. Lin, G. Zhou and Z. Jia, "Joint Image Restoration For Domain Adaptive Object Detection In Foggy Weather Condition," 2024 IEEE International Conference on Image Processing (ICIP), Abu Dhabi, United Arab Emirates, 2024, pp. 542-548, doi: 10.1109/ICIP51287.2024.10647560

[3] E. Shreyas, M. H. Sheth and Mohana, "3D Object Detection and Tracking Methods using Deep Learning for Computer Vision Applications," 2021 International Conference on Recent Trends on Electronics, Information, Communication & Technology (RTEICT), Bangalore, India, 2021, pp. 735-738, doi: 10.1109/RTEICT52294.2021.9573964.

[4] Y. Wang, F. Pan, Z. Li, X. Xin and W. Li, "CoT-YOLOv8: Improved YOLOv8 for Aerial images Small Target Detection," 2023 China Automation Congress (CAC), Chongqing, China, 2023, pp. 4943-4948, doi: 10.1109/CAC59555.2023.10451989

[5] S. M et al., "An Effective Drone Surveillance System Using Thermal Imaging," 2020 International Conference on Smart Technologies in Computing, Electrical and Electronics (ICSTCEE), Bengaluru, India, 2020, pp. 477-482, doi: 10.1109/ICSTCEE49637.2020.9277292. keywords:

[6] S. K. V et al., "Silent Surveillance Autonomous Drone For Disaster Management And Military Security Using Artificial Intelligence," 2023 3rd International Conference on Innovative Practices in Technology and Management (ICIPTM), Uttar Pradesh, India, 2023, pp. 1-4, doi: 10.1109/ICIPTM57143.2023.10118136

[7] M. A. I. Siddique, M. S. H. Shojol, M. M. Islam, S. Alam and O. Jyoti, "Smart Border Surveillance: Real-time CNN on Drones with IoT Integration," 2023 26th International Conference on Computer and Information Technology (ICCIT), Cox's Bazar, Bangladesh, 2023, pp. 1-5, doi: 10.1109/ICCIT60459.2023.10441471.

[8] A. R. Harits Martawireja, N. Lilansa, Y. Rajib and Y. Aprianta, "Implementation of Inverse Kinematics in Design of Six-Degree of Freedoms Platform for Hardware in the Loop Simulation on Quadcopter Drones," 2021 3rd International Symposium on Material and Electrical Engineering Conference (ISMEE), Bandung, Indonesia, 2021, pp. 148-153, doi: 10.1109/ISMEE54273.2021.9774118.

[9] H. Cao, F. Ding, X. He and C. Gu, "Application and Research of UAV Automatic Inspection and Positioning Control Technology," 2023 3rd International Conference on Computer Science, Electronic Information Engineering and Intelligent Control Technology (CEI), Wuhan, China, 2023, pp. 887-890, doi: 10.1109/CEI60616.2023.10527881.

[10] X. Xu, K. Watanabe and I. Nagai, "Computed Torque Control for an Aerial Robot Equipped with Two Coaxial Rotors Having a 2-DOF Tilt Mechanism," 2020 IEEE International Conference on Mechatronics and Automation (ICMA), Beijing, China, 2020, pp. 926-931, doi: 10.1109/ICMA49215.2020.9233520