AI-Driven Surveillance Drones: An Overview of Capabilities and Applications

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***Abstract*:**
Unmanned Aerial Vehicles (UAVs), commonly known as drones, are being used commonly as their applications continue to expand across various fields. The introduction of Artificial Intelligence (AI) has evolved these drones into powerful surveillance tools. Central to their effectiveness is using sensors like advanced CMOS (Complementary Metal-Oxide-Semiconductor) sensors, which provide high-resolution imaging, low power consumption, and adaptability in various lighting conditions, other sensors like thermal sensors. This paper explores innovative approaches to the development and deployment of AI-powered drone systems for surveillance. By reviewing the latest advancements and future trends, this paper aims to showcase the immense potential highlighting key areas and challenges.

***Keywords*: drones, surveillance, sensor, object detection**
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I. INTRODUCTION

Surveillance drones have become popular modern monitoring system due to their ability to provide high-quality imaging with low power consumption. They can be deployed in high security areas that require monitoring in real time. Aerial drone surveillance can offer law enforcers a vantage point cheaply and efficiently. For instance, railway and land transportation security now leverage advanced technologies, including drones, for aerial surveillance.[1] Another important aspect is that drones can reach places where humans can't reach or is difficult to do so. Surveillance drones for landmine extraction [2] provide accurate locations of the mines. Surveillance drones can also be useful for traffic surveillance according to a survey conducted in Unmanned Aerial Vehicle (UAV) [4] . Further development in this field will possibly pave way for better analysis such as traffic congestion analysis, detection of incidents and anomalies promptly and enhance overall safety and management.

Utilization of drones by border security forces in countries where the problem of illegal immigration and border crossing can also be monitored using drones. [5]. This will particularly be useful for keeping a check and manning a large portion of the border fence in an efficient manner. In the context of India, border issue and problem of illegal is not uncommon or unheard of. According to reports, crimes and incidents along India-Bangladesh border is becoming alarmingly high. Number of incidents crossed over 50 in the year 2019 alone. [6]. This is where role of drones come in, to keep a check on such activities.

The objective of this paper is to explore the current capabilities of UAV technology in surveillance and pave way for potential areas for future advancements

II. LITERATURE REVIEW

A. *Basic understanding of the movement of drones and controlling involves the following –*

- **Pitch:** up and down movement of the nose.
- **Yaw:** nose movement left or right along the axis.
- **Roll:** rotation movement along an axis.
  In manual surveillance mode, a trained pilot is required to fly and maneuver the aerial vehicle and monitor the real time footage from the camera installed on the drone. However, this setup often involves chances of human error and the need for specialized control expertise.

Fig 1 : Quadcopter with Neo3 GPS and Pixhawk flight controller

This led to the need for an autonomous surveillance approach. Many studies have been conducted to reduce the manual effort involved in controlling quadcopter navigation.

AI in drones has made it possible for drones to carry out complex tasks such as image recognition, object detection, etc. Drones now have the capability to adapt to changing environment in real time, enhancing their overall effectiveness, disaster response and other critical operations. Fig 2 shows the various drone parameters that are influenced by Artificial Intelligence

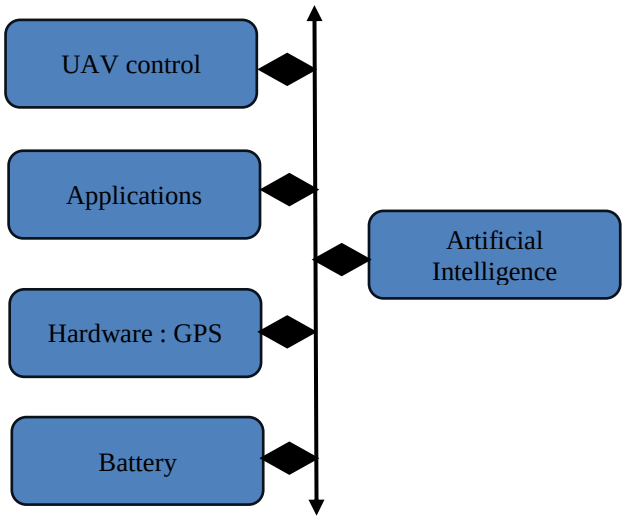


Fig 2: AI in Drones

B. Image recognition and processing

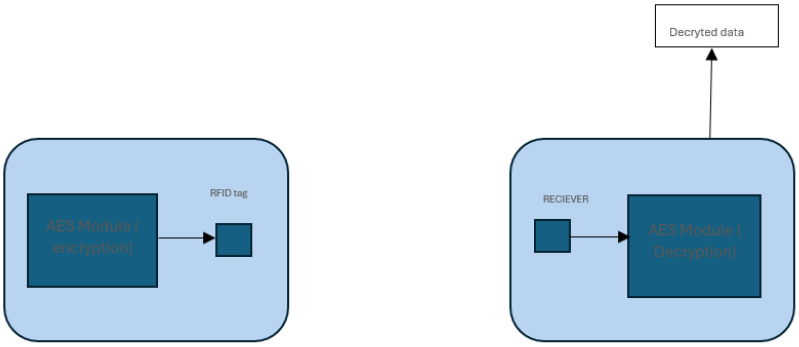
Aerial object detection is an important technology when it comes to surveillance drones. This is a result in advancements in the field of Computer vision. Drones with advanced technology such as the YOLO (you only look once) is a significant progress in this field. They utilize Convolutional Neural Networks (CNNs) to extract features, classify objects and localize them within image frames. [7]

Image processing from sensors like CMOS sensor has also been conducted using power efficient AI based accelerator. The accelerator executes object and recognition of human using ML (machine learning algorithms). [8]

However, conventional cameras often struggle to detect and identify humans in varying light conditions. Infrared cameras address these challenges by enabling vision in total darkness, resisting light variations, and preserving privacy. To improve efficiency and portability, thermal cameras are integrated into drones (UAVs), which can monitor large areas and detect humans with minimal effort. These drones use fast detection algorithms to send real-time data to control rooms, making them highly effective for surveillance, including military applications, to enhance security. [9]

Thermal Imaging: Thermal imaging uses the principle infrared radiation. It can be used to detect objects without having to rely on the visible spectrum of light. The resulting images, known as thermograms, can be taken in complete darkness since all objects emit heat above absolute zero. These images are displayed in varying shades of gray to represent the differences in temperature between objects.

A study has also explored the use of drones alongside soldiers tracked by RFID reader technology to distinguish between friends and foes.[10] The test subjects i.e. soldier in our case are equipped with an RFID tag containing their encrypted identity, along with a transceiver to receive updates from a distant base station. The base station, located far from the UAV and soldiers, houses a server that tracks and logs data from the UAV. It then sends the whereabout of the enemy in the form og coordinates and that of the enemy targets to the soldiers. A user controls the UAV's flight and analyzes the data it collects.



It has been observed that thermal imaging method is better suited and reliable for surveillance purposes as it can operate in complete darkness i.e. without the visible spectrum of light.

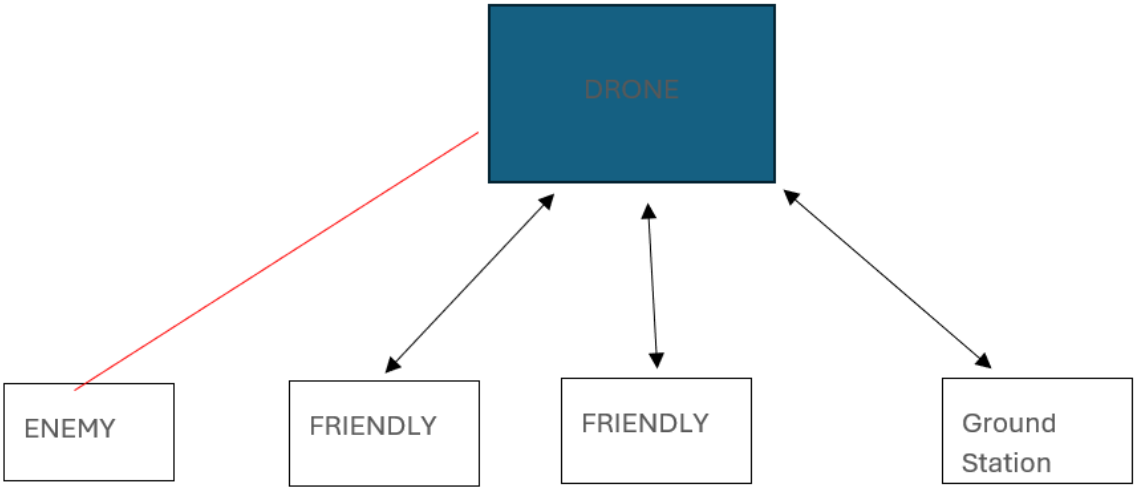


Fig 4 : UML diagram

C. Autonomous Drones:

Autonomous drones are equipped with advanced technologies that allow them to perform tasks without direct human control. These drones rely on sensors, GPS, and AI algorithms to navigate, avoid obstacles, and complete missions independently. A mission planner is a crucial tool in this system, enabling operators to pre-program the drone's flight path, mission objectives, and specific tasks to be executed [11]. It also explores how machine learning and artificial intelligence enhance drone autonomy, highlighting the importance of real-time operations, obstacle detection and avoidance systems, and GPS and optical-based navigation. Since 2013, there has been a surge in interest and funding for this technology, such as precision agriculture and search-and-rescue missions

GPS enabled autonomous drones can also be used in agriculture for survey purposes. Another example is the use of drones in small scale delivery services although they're mostly in trial and testing phase currently.

Object tracking by implementing CNN in real time

In 2020, another project explored the use of CNN with the UAV [18]. In another study, the current scenario of AI technology like deep learning is examined for surveillance of border areas using drones . A study has also been conducted on border area surveillance using drones integrated with CNN models, focusing on classifying individuals based on their attire. [19]

D. The CNN model

The convolutional neural network (CNN) utilized in the study comprises two convolutional layers, each followed by a ReLU activation function. After each ReLU layer, a (2,2) max-pooling operation is applied to reduce spatial dimensions. To mitigate overfitting, the output of the second convolutional layer is flattened and processed through a dropout layer with a 50% dropout rate.. Following this, the model incorporates a fully connected layer consisting of 50 neurons, also activated by the ReLU function. Finally, the network concludes with an output layer containing two neurons, activated by the softmax function, which calculates the probabilities for classifying images into one of two categories: border guards or local residents.

The model is trained using the categorical cross-entropy loss function and the Adam optimizer, with accuracy serving as the evaluation metric. Designed to make classification of images based on the basis of features extracted by the convolutional layers, the model has demonstrated excellent accuracy on our dataset.

Result Analysis

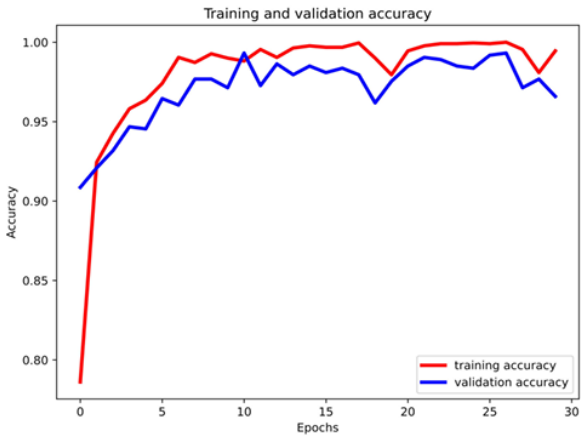


Fig 5 : Training and validation accuracy

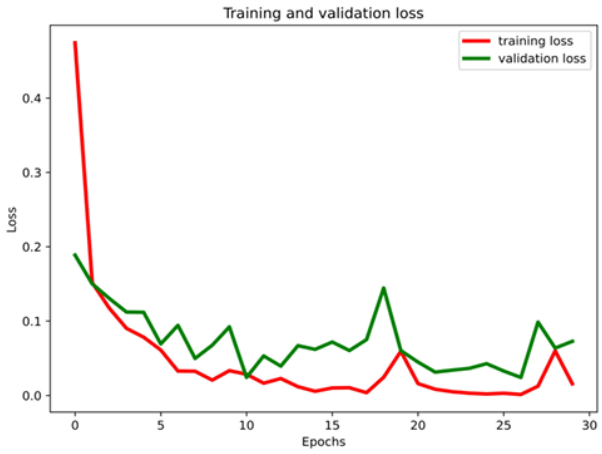


Fig 6 : Training and validation loss

This approach guarantees exceptional model performance on unseen inputs, improving the reliability of our proposed border security system.

E. Challenges and limitations in current drone surveillance technology

Drones have become incredibly popular and are a hot topic, but one of the major challenges today is their limited endurance. One of the primary limitations of using drones for surveillance is their limited flight duration coupled with the extended time needed to recharge their batteries.[12].

The primary goal is to tackle the challenge of drone operational downtime caused by battery recharging and improve the efficiency of this process. The solution to this problem as mentioned in the above study are

- Cableway and pantograph solutions and
- Mobile electric platform (MEP) solution.

The core idea involves integrating an electromechanical coupling with a drone, enabling the motors and battery to receive power through the connection.

The second approach entails developing a Mobile Electric Platform (MEP) capable of carrying two drones while charging their batteries simultaneously. This platform would feature remote-controlled electric motors, a backup battery to handle power outages, thermal imaging cameras, and GSM connectivity for extended-range patrols. To ensure the drones' safety during transport, a retractable, remote-controlled windshield would provide protection. [13]

Although long-range wireless power transmission technologies, such as microwaves and lasers, are still under development, the suggested supply of charging methods for surveillance drones is currently a practical approach and one that is feasible. [14]

III. ETHICAL CONCERNS

The usage of drones with modern cameras with high resolution to capture images for analysis of data is growing exponentially [15]. European Convention on Human Rights states that "everyone has the right to respect for their private and family life, their home, and their correspondence." It's clear that such drones can pose a threat to privacy, and its consequences may negatively impact civil liberty [16][17]

It is the need of the hour to address the use of such technology to prevent invasion of privacy and uphold constitutional principles. Taking record of one's activities and disclosing them poses a serious breach of privacy. Without consent, it can lead to negative consequences, as it would violate fundamental principles of individuals and democracy

IV. SURVEY STRUCTURE

A combination of qualitative and quantitative analysis was used to synthesize the information.
Case studies were analyzed to understand real world applications of surveillance drones, highlighting strengths and weaknesses and operational challenges

V. SHORTCOMINGS OF THIS SURVEY

This survey is limited to available literature and publicly available case studies. While extensive, the survey may not capture every emerging technology. Additionally, due to the ra[idly evolving drone technology, some of the information may not reflect the most current advancements

VI. CONCLUSION

This survey methodology aims to provide a detailed and balanced view of the state of surveillance drones, based on careful examination of existing research and reports. The findings from this approach will be used to identify trends, gaps and future directions for the development of UAV technology in the field of surveillance.

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