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Is It A Bird Or A Drone?

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In recent years, the widespread proliferation of micro-drones has introduced new security and civilian threats. These include unauthorized intrusions into restricted airspace such as military bases and airports, where they pose severe risks to aircraft engines and flight paths. Furthermore, drones are increasingly associated with privacy violations, espionage, and potential hostile or malicious uses in both urban and natural environments. This highlights the critical need for reliable, automated, and real-time detection systems capable of identifying these threats and enabling preemptive security measures. One of the main operational challenges in this domain is the difficulty of distinguishing between drones and birds, which occupy the same airspace, exhibit similar flight speeds, and often share significant visual and morphological similarities when observed from a distance as tiny, dark objects against bright skies.

Traditional detection technologies such as radar and acoustic sensors face several limitations, including deployment complexity, high operational costs, and sensitivity to environmental noise. These challenges motivate the exploration of alternative solutions based on computer vision and deep learning techniques, which offer accessible, cost-effective, and highly accurate detection using standard electro-optical sensors.

In this work, we propose a comprehensive, end-to-end computer vision-based system that relies on static image detection and video analysis. Single-frame detection often lacks the visual information necessary to reliably distinguish between a distant bird and a drone. Therefore, our proposed pipeline integrates multiple stages to improve recognition accuracy through spatiotemporal analysis. The system is based on the YOLO11 (You Only Look Once) architecture for robust, real-time object detection and bounding box extraction from video streams and video frames.

The primary goal of this research is to develop an automated spatiotemporal classification model capable of distinguishing between drones and birds with high precision (target ≥ 90%) and recall (target ≥ 95%), significantly reducing false alarms while ensuring real threats are not missed.

Our main contributions to the field include:
An End-to-End Hybrid Architecture: Designing a pipeline that seamlessly transitions from spatial object detection to temporal sequence tracking and classification.

Advanced Motion Feature Extraction: Shifting the classification paradigm from pure morphological appearance to dynamic flight behaviors, successfully identifying the unique motion signatures of drones versus birds.

Optimization for Tiny Objects: Tuning the detection and tracking models to handle objects occupying less than 1% of the image (fewer than 20 pixels) against challenging clear-sky backgrounds.

Specialized Dataset Curation: Compiling and standardizing a dedicated video dataset of drones and birds specifically tailored for spatiotemporal training in unobstructed sky conditions.