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REAL-TIME DETECTION OF MULTI-SCALE MINIATURE UNMANNED AERIAL VEHICLES BASED ON YOLOV9

*Shijie Chen,Xinpeng Lu,Jiashuo Sun, Zhichao Yin, Moufa Hu**

*Ph.D., Associate Researcher

National Key Laboratory of Science and Technology on ATR, College of Electronic Science and Technology, National University of Defense Technology, Changsha ,China
Abstract:
Aiming at the security risks of unregulated and unmanned aerial vehicles (UAVs), this paper proposes a new real-time detection method based on YOLOv9, which integrates reversible functions, programmable gradient information, and a generalized high-efficiency layer aggregation network, and combined with downsampling and local feature training method. Experiments show that the detection accuracy of the method is more than 90% and the processing frame rate is more than 20Hz @640*640.

Keywords: YOLOv9; unmanned aerial vehicle(UAV); real-time detection; Confidence optimization

1.Introduction

With the rapid development of unmanned aerial vehicles (UAVs), UAVs have been widely used in many fields, such as logistics and transportation, agricultural monitoring, and disaster rescue [1]. Miniature UAVs are characterized by compact size, light weight, and high flexibility. They can easily enter narrow spaces for reconnaissance or rescue, and are suitable for performing tasks in complex environments[2]. However, the emergence of unregulated and indiscriminate drones has also emerged, causing many problems for society[3].

Real-time UAV monitoring faces many challenges[4]. Traditional monitoring methods often rely on devices such as radar and optical cameras, but these devices have problems such as limited monitoring range, insufficient real-time performance, and difficulty in target identification when facing a large number of UAVs.YOLOV9, as an advanced target detection algorithm, provides a new solution for real-time UAV monitoring[5].It improves the detection speed while maintaining high detection accuracy, and is able to process large amounts of image data in real time. In this paper, a YOLO-based UAV detection algorithm is proposed to achieve efficient recognition by a single-stage end-to-end deep learning framework for the UAV detection task. The model can efficiently differentiate UAVs from similar objects like birds and kites by fine-tuning it through migration learning on a dataset containing multi-scene and multi-angle UAV images.

2. Real-time detection of multi-scale miniature UAVs based on YOLOv9

In this paper, a new detection method based on YOLOv9 is proposed. The flowchart is depicted in Figure 1.

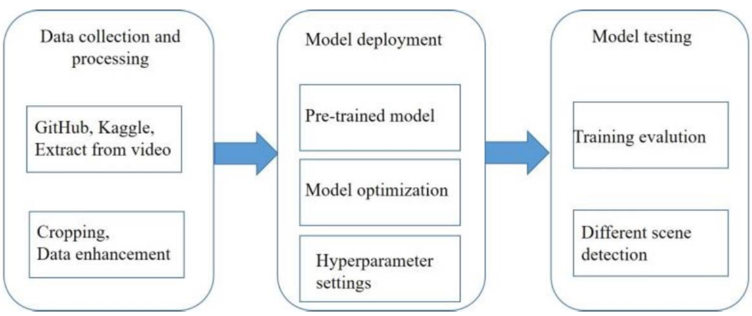


Figure 1 the flowchart of detection method based on YOLOv9

2.1 Data collection and processing

In this paper, LabelMe tool is used for image annotation work. The dataset images in this study are mainly derived from GitHub, Kaggle and other database sites ,as well as extracted from the video at the rate of one frame per second. In addition, this study also adopts the method of highlighting and cropping parts of the images, which makes enhances the data, and can better distinguish the recognized target features as well as the details.

2.2 Model deployment and training

YOLOv9 addresses key challenges in object detection by integrating reversible functions for data integrity, programmable gradient information for accurate gradient updates, and generalized High-efficiency Layer Aggregation networks to simplify feature extraction and speed [6].

After the core network extracts features, the model merges the features, and the head network utilizes these fused features for target recognition [7], achieving high accuracy. However, when the data is transmitted through the multi-layer neural network and changes in space, part of the feature vector will be lost, resulting in incomplete feature information of the target object, thus reducing the recognition efficiency and accuracy. HWD downsampling can effectively solve the problem of local feature pooling, which uses Haar wavelet transform to retain most of the feature information, but also reduces the amount of computation, and improves the accuracy and speed.

In this paper, ImageData from different environments are selected to form the training set, test set and verification sets with a ratio of 8:1:1. The input image size is unified as 640*640, Batch-size is set to 4, and Epoch is set to 200. The works value is set to 0, SGD is selected by the optimizer, and the random number seed is set to 0.

The prediction accuracy of the UAS category reaches 0.85, indicating that it can effectively distinguish the target category from the background.

2.3 Model testing

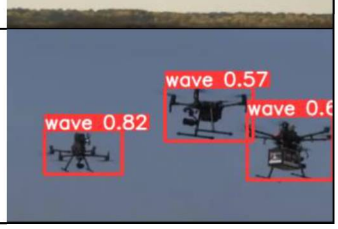
The test work is divided into online and offline sections. The speed and accuracy of the detection are evaluated. In this paper, Intel(R)Core (TM)i7-13650HX CPU and NVIDIA GeForce GTX 4060 GPU is used as the test platform.

3.Results and analysis

Experimental results demonstrate that the YOLOv9-based UAV detection algorithm exhibits robust detection performance in diverse environments, with varying flight altitudes, and heterogeneous external environments. Some results are shown in Table 1 and Tabel2.

The results of four sets of experiments show that the method of this paper enables the detection of micro UAVs. Table 1 shows the recognized UAV position frame and confidence level. Table 2 shows the statistical results. Among them, Daytime, Low Altitude and High Altitude detected all the UAVs, while Wilderness missed only one UAV, and the detection rates are all above 90%. This paper's method handles frames at frame rates of 24 Hz and 28 Hz, which are all over 20 Hz for 640*640 images.

Table 1 - Comparison of detection results in typical scenarios

Scenarios	Original image	Detection result
Daytime		
Low Altitude		

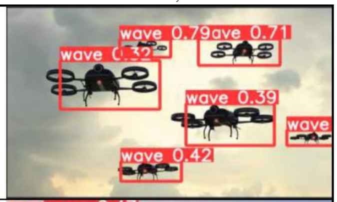
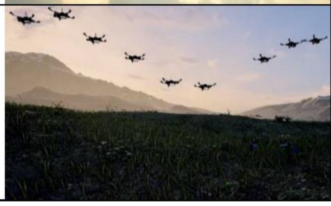
<table>
<tr><td>High Altitude</td><td></td><td>
</td></tr>
<tr><td>Wilderness</td><td></td><td>
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Table 2 - Statistical result of detection in typical scenarios

Scenario	Actual Targets (Units)	Detected Targets (Units)	Precision (%)	Frame Rate (Hz)
Daytime	5	5	100	26
Low Altitude	3	3	100	28
High Altitude	6	6	100	26
Wilderness	11	10	91	24

4 Conclusion

The phenomenon of 'black flights' and 'overflights' occurs frequently. To solve this problem, a real-time detection method based on YOLOv9 was given. The combination of adaptive hierarchical downsampling technology and local feature enhancement training framework resulted in the innovation of a reversible feature reconstruction mechanism, dynamic gradient optimization strategy, and lightweight hierarchical aggregation network. The experimental results show that the method can adapt to complex lighting, dynamic backgrounds, and dense occlusion scenes, which provides a solution for the construction of low altitude safety protection.

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