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Research on Fire Detection Based on the Yolov9 Algorithm

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Abstract—**This paper explores fire detection technology using the YOLOv9 algorithm, highlighting its importance in mitigating the risks to life and property. It reviews traditional methods and discusses the evolution towards deep learning, focusing on YOLOv9 for its speed and accuracy in real-time detection. The algorithm's principles and optimizations, such as Programmable Gradient Information (PGI) and Generic ELAN (GELAN), are detailed. The study includes dataset selection, preprocessing, and model implementation, showcasing YOLOv9's effectiveness in detecting fires. The paper emphasizes practical applications like real-time monitoring and future trends in model optimization and application expansion, contributing to fire safety advancement.**

Keywords—Fire Detection, Yolov9 Algorithm, Object Detection, Deep Learning, Real-time Monitoring

I. Introduction

Fires, as sudden and highly destructive disasters, pose significant threats to the safety of people's lives and properties. Each year, the loss of life and property due to fires is immense, placing a heavy burden on societal economic development and people's livelihoods. According to global fire statistics, millions of fire incidents occur annually, inflicting tremendous harm and loss on people worldwide.

Therefore, effective fire detection and prevention have become one of the critical issues that today's society urgently needs to address. With the rapid development of artificial intelligence technologies, object detection algorithms have been extensively applied in the field of fire detection. Traditional fire detection methods are usually based on image processing and machine learning techniques, including methods based on feature extraction and classification. Commonly used methods include color features, texture features, and shape features. For example, color-based methods detect fires by extracting flame color information from images [1]. Some texture-based methods identify fires by analyzing the texture information of images [2]. Moreover, certain shape-based methods detect fires by analyzing the shape features of the fire region [3].

Object detection technology has evolved from traditional methods to deep learning methods. Traditional methods primarily included feature-based approaches and machine-learning-based approaches. Among them, commonly used machine-learning-based algorithms include Support Vector Machines (SVMs) and Random Forests [4]. While these methods perform well in simple scenarios, their performance is often limited when dealing with complex scenes and multi-category targets. In recent years, the rise of deep learning has brought revolutionary progress to object detection technology. Deep learning methods utilize deep neural networks to learn feature representations from data, achieving significant performance improvements. Region proposal-based methods like Fast R- CNN adopt a two-stage detection strategy, first generating candidate object regions and then classifying and regressing these candidate regions [5]. On the other hand, single-stage detection methods like the YOLO series and SSD directly predict object categories and locations in images through a single neural network, offering higher real-time performance and efficiency [6].

Certain works have made progress in the field of fire detection: [7] proposed a method for fire detection using deep learning technology, combining Convolutional Neural Networks (CNNs) and Recurrent Neural Networks (RNNs), and achieved real-time monitoring and detection of fire scenes in video sequences. Although this method made some progress in terms of real-time performance and accuracy, there are still challenges, such as sensitivity to lighting and viewing angles and performance in complex environments. [8] introduced a smoke and flame detection method based on Convolutional Neural Networks (CNNs), which achieved accurate detection of smoke and flames in videos by training deep learning models. Although this method provided important support for fire monitoring systems, its robustness and real-time performance in complex scenes need further improvement. [9] described a real-time fire detection system based on deep learning, implementing rapid detection and alarm of fires through CNNs and real-time video processing technologies. While the system has achieved certain progress in real-time performance and accuracy, its performance in complex environments and the efficiency of algorithm operation still require further optimization. [10] proposed a Convolutional Neural Network model called FireNet for real-time fire detection, which combines dense convolution and multi-scale feature extraction to achieve efficient fire recognition. Although the FireNet model has made significant strides in terms of real-time performance and accuracy, its robustness and operational efficiency in complex scenarios still need further improvement. [11] provided a comprehensive review and summary of fire detection technologies in industrial scenes, covering both traditional methods and modern techniques based on deep learning. Although this review offers an in-depth understanding of the field of fire detection, specific applications still require the selection of appropriate technologies and methods to be further improved to meet