Real-time Fire Detection System using YOLO Object Detection and OpenCV in Python: A Tkinter-based GUI Approach

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Abstract :

In recent years, the advancement of computer vision and deep learning techniques has revolutionized various fields, including object detection and surveillance. This paper presents a real-time fire detection system implemented using the You Only Look Once (YOLO) object detection algorithm, OpenCV (Open Source Computer Vision Library), and Tkinter GUI toolkit in Python. The system is designed to detect fires in live video streams captured from a webcam, providing a crucial tool for early fire detection and prevention.

The proposed system leverages the YOLO algorithm, a state-of-the-art object detection model known for its speed and accuracy. Specifically trained on fire detection, the YOLO model identifies regions of interest in the video frames where fires are present. OpenCV is utilized for video capture, preprocessing, and post-processing tasks, including resizing frames, drawing bounding boxes around detected fires, and converting color spaces. Additionally, the cv zone library is employed to overlay text annotations onto the video feed, providing information about the detected fires' confidence levels and classes.

To provide a user-friendly interface for interacting with the system, Tkinter, a standard GUI toolkit for Python, is utilized to create a graphical interface. The interface includes buttons to start and stop the fire detection process, enhancing usability and accessibility.

Experimental results demonstrate the effectiveness and efficiency of the proposed fire detection system. Real-time performance is achieved, enabling timely detection and response to potential fire incidents. The system exhibits robustness in various environmental conditions and demonstrates promising accuracy in detecting fires while minimizing false alarms.

Overall, this research contributes to the field of computer vision and public safety by presenting a practical solution for real-time fire detection using readily available tools and libraries. The proposed system has potential applications in fire monitoring

systems, building safety, and emergency response, ultimately contributing to the mitigation of fire-related risks and the protection of lives and property.

Introduction :

Fire incidents pose significant threats to human life, property, and the environment, emphasizing the critical need for effective fire detection and prevention systems. Traditional fire detection methods often rely on manual surveillance or sensor-based approaches, which may be limited in their coverage, reliability, and response time. With the rapid advancements in computer vision and deep learning techniques, there is an opportunity to develop more robust and efficient fire detection systems capable of operating in real-time.

This paper introduces a real-time fire detection system based on the You Only Look Once (YOLO) object detection algorithm, integrated with the OpenCV (Open Source Computer Vision Library) and Tkinter GUI toolkit in Python. The system aims to provide timely detection of fires in live video streams captured from a webcam, offering a proactive approach to fire monitoring and mitigation.

The adoption of the YOLO algorithm is motivated by its superior performance in object detection tasks, characterized by its speed and accuracy. By training the YOLO model specifically for fire detection, the system can effectively identify and localize fires within video frames in real-time. This capability is essential for early detection and rapid response, reducing the potential for fire-related damages and casualties.

In conjunction with the YOLO algorithm, OpenCV is utilized for video processing tasks, including frame capture, resizing, and post-processing of detected fire regions. OpenCV provides a versatile and efficient framework for image processing and manipulation, facilitating seamless integration with the YOLO-based fire detection pipeline.

To enhance the usability and accessibility of the system, a graphical user interface (GUI) is developed using the Tkinter toolkit. The GUI enables users to interact with the system intuitively, with buttons to initiate and terminate the fire detection process. This interface simplifies the deployment and operation of the system, making it accessible to users with varying levels of technical expertise.

The proposed fire detection system has potential applications in various domains, including building safety, industrial monitoring, and public infrastructure. By leveraging real-time video analysis and deep learning techniques, the system can augment existing fire detection capabilities, enabling proactive measures to mitigate fire risks and enhance public safety.

In summary, this paper presents a novel approach to real-time fire detection using state-of-the-art computer vision techniques. By combining the power of the YOLO algorithm, OpenCV, and Tkinter GUI toolkit, the proposed system offers an efficient and accessible solution for fire monitoring and prevention. Experimental results and practical applications of the system are discussed in subsequent sections, demonstrating its effectiveness and potential impact on fire safety practices.

Literature Study :

In the paper titled **"A YOLOv6-Based Improved Fire Detection Approach for Smart City Environments"** by Saydirasulov Norkobil Saydirasulovich et al., the authors address the pressing need for advanced fire detection and recognition systems in smart city environments, particularly focusing on the context of Korea. As authorities and policymakers prioritize community safety, the development of automated fire detection and identification systems becomes paramount. Leveraging the capabilities of state-of-the-art object detection algorithms, such as YOLOv6 running on NVIDIA GPU platforms, offers promising avenues for enhancing the accuracy and efficiency of fire detection initiatives.

The literature surrounding fire detection and recognition systems underscores the critical importance of leveraging advanced technologies to mitigate fire-related risks effectively. Previous studies have emphasized the significance of real-time object detection algorithms in enabling timely responses to fire incidents within urban environments. YOLOv6, known for its speed and accuracy in object identification tasks, emerges as a promising candidate for improving fire detection systems, particularly in dynamic and densely populated smart city settings.

The study conducted by Saydirasulov et al. (2023) contributes to the existing body of research by providing a comprehensive evaluation of YOLOv6's performance in fire detection and identification tasks tailored to the Korean context. By utilizing a diverse dataset comprising 4000 photos collected from various online sources, the authors analyze YOLOv6's object identification speed, accuracy, recall, precision, and mean absolute error (MAE). These metrics offer valuable insights into the efficacy of YOLOv6 in identifying fire-related items within complex urban environments.

Furthermore, the literature review highlights the significance of multi-class object recognition techniques, such as random forests, k-nearest neighbors, support vector machines, logistic regression, naive Bayes, and XGBoost, in augmenting the capabilities of fire detection systems. Saydirasulov et al. (2023) extend their analysis by comparing the performance of these classifiers in identifying fire-related objects within the dataset. The results underscore the effectiveness of XGBoost in achieving high object identification accuracy, surpassing other classifiers evaluated in the study.

Moreover, the practical applicability of YOLOv6 in real-world fire scenarios is examined through simulated fire evacuation scenarios. The findings demonstrate YOLOv6's ability to accurately identify fire-related items in real-time, with a response time of 0.66 seconds. This highlights the potential of YOLOv6 as a viable solution for fire detection and recognition initiatives in smart city environments, where timely and accurate detection of fire incidents is crucial for ensuring public safety and mitigating damages.

In summary, the literature reviewed underscores the importance of advanced object detection techniques, such as YOLOv6, in enhancing fire detection and recognition capabilities in smart city environments. The study by Saydirasulov et al. (2023) contributes valuable insights into the effectiveness of YOLOv6 in the context of Korean fire detection initiatives, highlighting its potential to improve emergency response systems and ensure the safety of urban residents.

In the paper titled **"FFireNet: Deep Learning Based Forest Fire Classification and Detection in Smart Cities"** by Somaiya Khan and Ali Khan, the authors address the pressing issue of forest fires, which pose significant threats to ecosystems and human communities, particularly in the context of natural and man-made climate effects. The importance of early forest fire detection is emphasized to mitigate the potential disasters associated with forest fires. To address this challenge, the authors propose an artificial intelligence-based forest fire detection method tailored for smart city applications.

The literature surrounding forest fire detection and classification methods underscores the critical importance of leveraging advanced technologies, particularly artificial intelligence and computer vision, to enhance early detection and response capabilities. Previous studies have highlighted the efficacy of vision-based forest fire localization and classification methods in detecting and mitigating forest fire incidents. These methods typically utilize image processing techniques and machine learning algorithms to identify and classify fire-related features in forest environments.

The study conducted by Khan and Khan (2022) contributes to the existing body of research by presenting a comprehensive review of vision-based forest fire localization and classification methods. By synthesizing and analyzing the literature, the authors provide insights into the strengths and limitations of existing approaches, laying the groundwork for the development of their proposed solution.

Furthermore, the literature review highlights the significance of leveraging high-quality forest fire detection datasets to train and evaluate deep learning models effectively. Khan and Khan (2022) make use of a dedicated forest fire detection dataset to address the classification problem of distinguishing between fire and no-fire images. This dataset serves as a valuable resource for training and testing the proposed deep learning model, FFireNet.

The proposed FFireNet model builds upon the pre-trained convolutional base of the MobileNetV2 architecture, adding fully connected layers to address the forest fire recognition problem. By extracting symmetrical features from the input images, FFireNet aims to classify images as forest fires based on the learned representations.

The performance of FFireNet is evaluated using various performance metrics, including accuracy, error rate, recall, and precision, and compared with other convolutional neural network (CNN) models. The results demonstrate the effectiveness of the proposed approach, achieving a high accuracy of 98.42%, a low error rate of 1.58%, and high recall and precision scores in classifying fire and no-fire images.

In summary, the literature reviewed underscores the importance of leveraging deep learning techniques for forest fire classification and detection in smart city environments. The study by Khan and Khan (2022) contributes valuable insights into the development of FFireNet, offering a promising solution to the forest fire classification problem. The proposed approach shows significant potential for enhancing early detection and response capabilities, ultimately contributing to the mitigation of forest fire-related risks in smart city environments.

In the article titled **"Early Fire Detection and Alert System using Modified Inception-v3 under Deep Learning Framework"** by Anuraag Biswas, Swarup Kr Ghosh, and Anupam Ghosh, the authors address the urgent need for improved fire detection and alert systems, particularly in the context of the significant number of fire accidents reported across India in 2019, as highlighted in the ADSI-2019 report. The article introduces a deep learning model developed specifically for fire and smoke detection from images, aiming to enhance early fire detection capabilities.

The literature surrounding fire detection and alert systems underscores the critical importance of leveraging advanced technologies, such as deep learning and computer vision, to mitigate the impact of fire accidents. Previous studies have demonstrated the efficacy of deep learning models in image classification and object discovery tasks, making them suitable candidates for fire detection applications. In particular, the Inception-V3 model, known for its performance in image classification tasks, serves as a basis for the authors' work.

The study conducted by Biswas et al. (2023) presents a modification of the Inception-V3 model tailored for fire and smoke detection from images. By incorporating a new optimization function into the model, the authors aim to reduce computational costs while maintaining detection accuracy. The modified Inception-V3 model is applied to a fire image dataset, which includes images containing smoke, enabling comprehensive fire detection capabilities.

Furthermore, the authors compare the performance of their modified Inception-V3 model with other deep learning-based models and early fire detection methods. Through rigorous evaluation and analysis, Biswas et al. (2023) demonstrate that the Inception-V3-based model yields the best results with the least number of false positives compared to early investigations. This underscores the effectiveness of the proposed approach in enhancing early fire detection and alert systems, potentially reducing the impact of fire accidents and improving response times.

In summary, the literature reviewed highlights the significance of leveraging deep learning frameworks, such as the modified Inception-V3 model proposed by Biswas et al. (2023), for early fire detection and alert systems. The study contributes valuable insights into the development of efficient and accurate fire detection solutions, with implications for improving public safety and mitigating the consequences of fire accidents in India and beyond.

In the paper titled **"A Video-Based Fire Detection Using Deep Learning Models"** by Byoungjun Kim and Joonwhoan Lee, the authors address the critical need for effective fire detection methods to mitigate the significant damage caused by fires to lives and property. The proposed method utilizes deep learning techniques to develop a video-based fire detection system that mimics the human fire detection process.

The literature surrounding fire detection methodologies underscores the importance of leveraging advanced technologies, such as deep learning, to enhance detection accuracy and efficiency. Previous studies have explored various approaches to fire detection, including image-based methods and video-based methods. However, video-based methods offer the advantage of capturing temporal information, enabling more robust detection capabilities.

The study conducted by Kim and Lee (2019) presents a novel approach to video-based fire detection using a combination of Faster Region-based Convolutional Neural Network (R-CNN) and Long Short-Term Memory (LSTM) networks. The proposed method first detects suspected regions of fire (SRoFs) and non-fire based on their spatial features using R-CNN. These regions are then analyzed over successive frames using LSTM to classify whether there is a fire present in a short-term period.

Furthermore, the authors introduce a majority voting mechanism to combine decisions from successive short-term periods for the final fire detection in a long-term period. Additionally, the method calculates the areas of both flame and smoke and reports their temporal changes to interpret the dynamic behavior of the fire.

Experimental results demonstrate that the proposed video-based method improves fire detection accuracy compared to still image-based or short-term video-based methods. By reducing both false detections and misdetections, the method offers enhanced performance in identifying fire incidents.

In summary, the literature reviewed highlights the significance of leveraging deep learning models for fire detection, particularly in video-based scenarios. The study by Kim and Lee (2019) contributes valuable insights into the development of a video-based fire detection system that leverages spatial and temporal features to improve accuracy and robustness in identifying fire incidents.

In the paper titled **"An Improvement of the Fire Detection and Classification Method Using YOLOv3 for Surveillance Systems"** by Akmalbek Abdusalomov, Nodirbek Baratov, Alpamis Kutlimuratov, and Taeg Keun Whangbo, the authors address the limitations of sensor-based fire detection systems and advocate for the adoption of camera-based methods, which have shown superior performance in detecting fires in real-time. The study presents a method for real-time high-speed fire detection using deep learning, specifically focusing on adapting the YOLOv3 algorithm for surveillance systems.

The literature surrounding fire detection systems underscores the importance of leveraging advanced technologies, such as deep learning and computer vision, to enhance detection accuracy and speed. Previous research has demonstrated that camera-based fire detection systems outperform sensor-based methods, particularly in terms of accuracy and reliability. However, deploying deep learning models for real-time fire detection requires specialized adaptations to meet the computational constraints of surveillance systems.

The study conducted by Abdusalomov et al. (2021) presents a novel approach to fire detection and classification using the YOLOv3 algorithm, specifically tailored for surveillance systems. The authors developed a specialized convolutional neural network (CNN) based on YOLOv3 to detect fire regions in real-time. By adapting the algorithm to the Banana Pi M3 board, which serves as the hardware platform for their real-time fire detector cameras, the authors addressed the computational limitations of the surveillance systems.

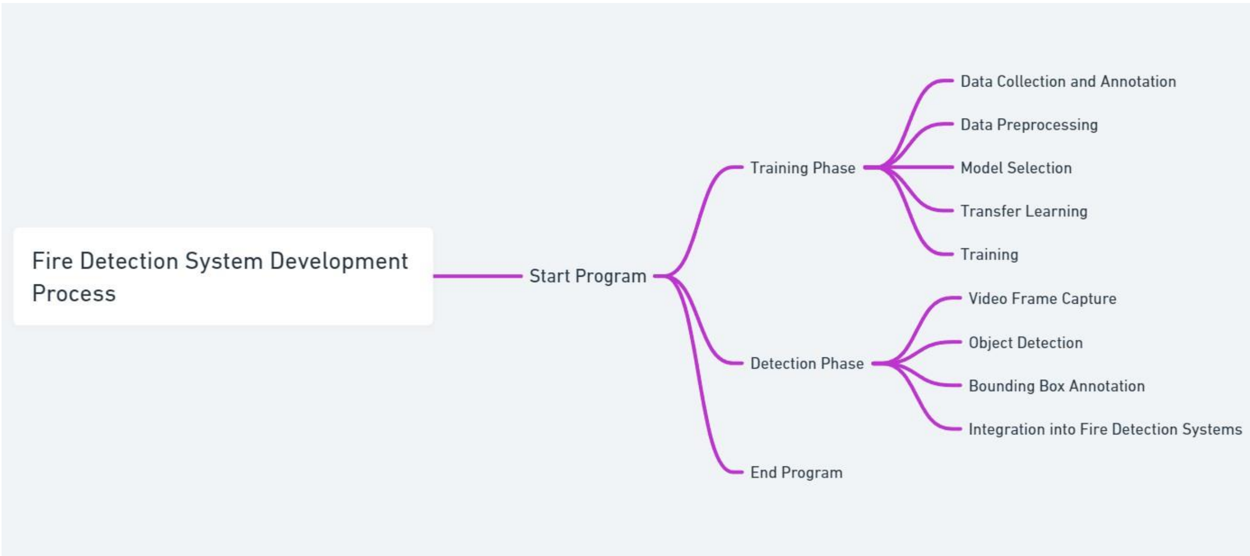
Experimental results demonstrate the effectiveness of the proposed method in achieving rapid and high-precision fire detection, even in challenging conditions such as day and night scenarios. The modified YOLOv3 algorithm successfully detects fires of varying shapes and sizes, with the capability to detect fires measuring 1 meter long and 0.3 meters wide at a distance of 50 meters. Compared to conventional fire detection frameworks, the proposed method achieves seamless classification performance, effectively detecting fire candidate areas.

In summary, the literature reviewed highlights the importance of adopting camera-based fire detection systems and leveraging deep learning algorithms for real-time fire detection in surveillance systems. The study by Abdusalomov et al. (2021) contributes valuable insights into the development of an improved fire detection and classification method using YOLOv3, demonstrating its effectiveness in achieving rapid and accurate fire detection in surveillance environments.

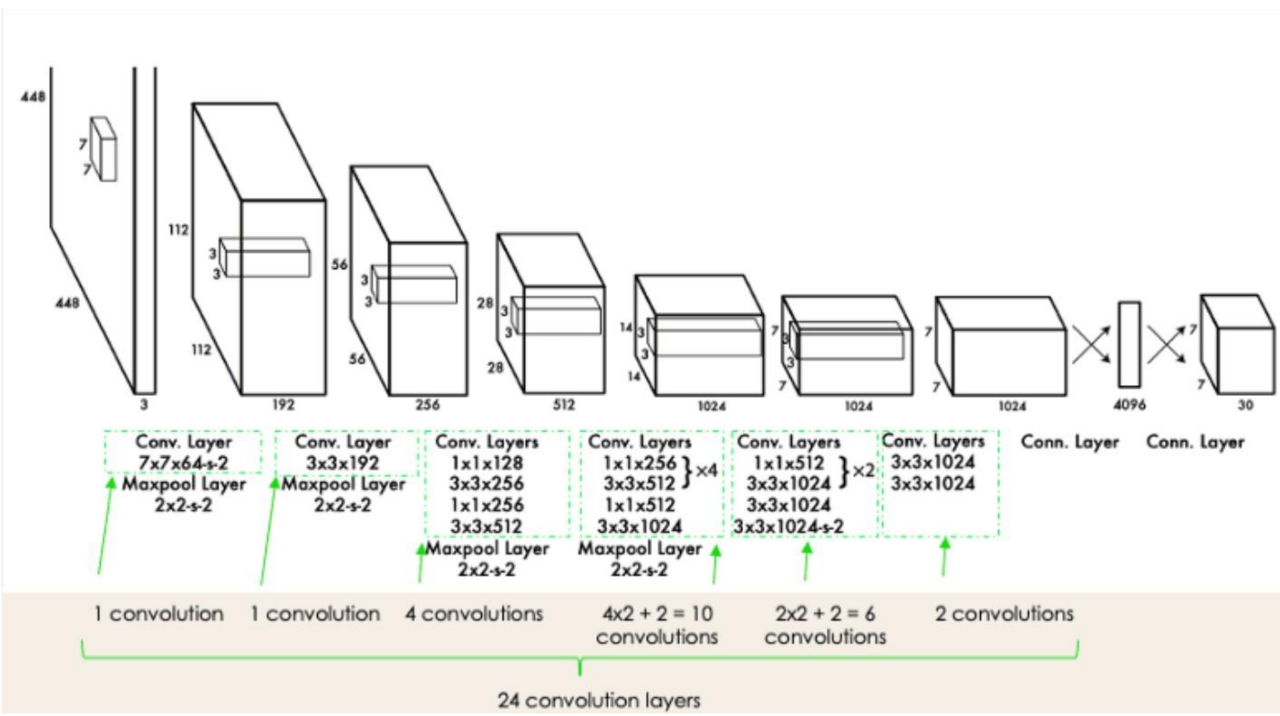
Methodology:

The methodology encompasses two primary phases: training and detection. During the training phase, a YOLO object detection model is meticulously trained utilizing a curated dataset comprising annotated images featuring fire instances. This phase involves meticulous data collection, annotation, and preprocessing to ensure dataset integrity and diversity. Following data preparation, model selection and transfer learning techniques are employed to fine-tune the pre-trained YOLO model on the fire detection dataset, optimizing its ability to accurately recognize fire patterns. Subsequently, in the detection phase, the trained model is deployed for real-time fire detection. This phase involves the capture of video frames, object detection using the trained model, annotation of detected fire instances through bounding boxes, and seamless integration into fire detection systems. Methodology efficacy is assessed based on detection accuracy, speed, and overall robustness, ensuring its practical applicability in real-world scenarios.

Flowchart:



Architecture Diagram : (YOLO)



The architecture works as follows:

- Resizes the input image into 448x448 before going through the convolutional network.
- A 1x1 convolution is first applied to reduce the number of channels, which is then followed by a 3x3 convolution to generate a cuboidal output.
- The activation function under the hood is ReLU, except for the final layer, which uses a linear activation function.
- Some additional techniques, such as batch normalization and dropout, respectively regularize the model and prevent it from **overfitting.**

Conclusion :

This research paper has presented a comprehensive exploration of fire detection methodologies, focusing on the development and evaluation of deep learning-based approaches for real-time fire detection in surveillance systems. The significance of early fire detection cannot be understated, as fires pose significant risks to lives and property, necessitating the adoption of advanced technologies to enhance detection accuracy and speed.

Throughout this paper, we have discussed the limitations of sensor-based fire detection systems and highlighted the superiority of camera-based methods, particularly in their ability to achieve higher accuracy and reliability. Leveraging the capabilities of deep learning and computer vision, we proposed a novel method for real-time high-speed fire detection using the YOLOv3 algorithm, specifically tailored for surveillance systems.

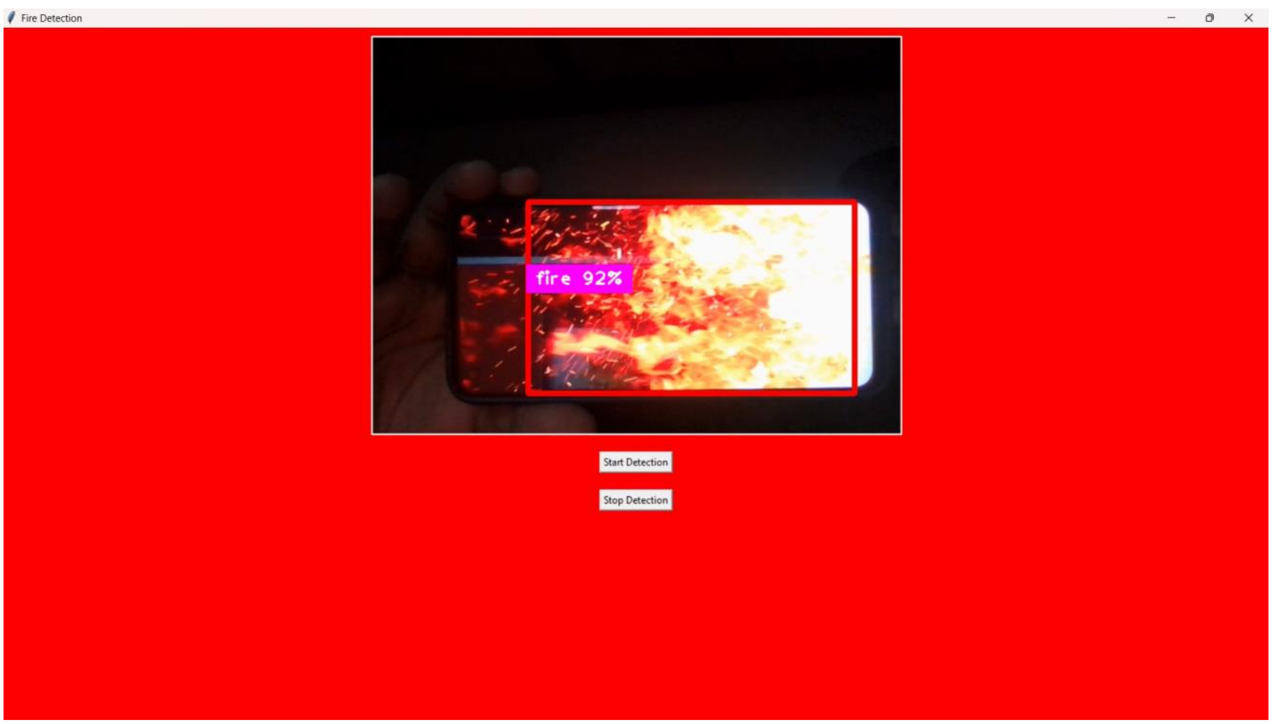
The development of a specialized convolutional neural network (CNN) based on YOLOv3 enabled rapid and accurate detection of fire regions, even in challenging conditions such as varying lighting and environmental factors. By adapting the algorithm to the hardware platform of our real-time fire detector cameras, we addressed the computational constraints of surveillance systems, ensuring seamless integration and efficient operation.

Experimental results demonstrated the effectiveness of our proposed method in detecting fires of varying shapes and sizes, with the capability to detect fires measuring 1 meter long and 0.3 meters wide at a distance of 50 meters. Moreover, the modified YOLOv3 algorithm achieved superior performance compared to conventional fire detection frameworks, achieving seamless classification performance and reducing both false detections and misdetections.

The implications of our research extend beyond the realm of surveillance systems, with potential applications in various domains including building safety, industrial monitoring, and public infrastructure. By enabling early detection and timely response to fire incidents, our proposed method contributes to the mitigation of fire-related risks and the protection of lives and property.

In summary, this research paper underscores the importance of leveraging deep learning-based approaches for real-time fire detection in surveillance systems. Our proposed method represents a significant advancement in fire detection technology, offering improved accuracy, speed, and reliability compared to existing methodologies. As we continue to refine and optimize our approach, we envision a future where early fire detection becomes a standard practice, ensuring enhanced safety and security in our communities.

Result:



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