AI-Powered Fire Detection Project

A Project Report

submitted in partial fulfillment of the requirements

of

Artificial Intelligence AICC Certificate

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ABSTRACT

This project presents the development of an AI-based fire detection system designed to enhance safety and response times in fire emergencies. Leveraging advanced machine learning and computer vision techniques, the system is capable of detecting fire in real-time from images and video feeds.

The project involves several key stages, including data collection, preprocessing, model training, and deployment. A diverse dataset comprising thousands of fire and non-fire images was compiled from various sources and meticulously labeled to ensure accuracy. Data augmentation techniques were employed to increase the robustness of the dataset.

For the model, a Convolutional Neural Network (CNN) architecture was selected due to its proven efficacy in image classification tasks. After extensive experimentation with various architectures, a model based on the YOLO (You Only Look Once) framework was implemented for its balance of speed and accuracy in real-time detection scenarios. The model was trained using a combination of supervised learning techniques and validated against a separate test set to ensure generalization.

Performance evaluation was conducted using metrics such as accuracy, precision, recall, and F1-score, with the model achieving high accuracy in distinguishing between fire and non-fire scenarios. Additionally, a confusion matrix was used to analyze misclassifications and further refine the model.

The deployment phase involved integrating the trained model into a real-time monitoring system capable of processing video feeds from surveillance cameras. The system includes an alert mechanism to notify authorities or trigger automated safety measures upon fire detection.

This AI-based fire detection system demonstrates significant potential in enhancing early fire detection capabilities, thereby reducing response times and mitigating damage. The project highlights the effectiveness of modern AI techniques in solving critical safety challenges and sets the foundation for future improvements and adaptations in various environments.

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CHAPTER 1

INTRODUCTION

1.1. Problem Statement:

- Develop an AI-based fire detection system using Python to enhance fire safety measures in various environments, including buildings, forests, and industrial sites.
- The system should leverage computer vision techniques to accurately identify and localize fires in images or video streams in real-time or near real-time scenarios.
- The aim is to create a proactive solution that enables early detection of fires, facilitating prompt response and mitigation efforts to minimize damage and save lives.

1.2. Problem Defination:

- The aim of this project is to develop an artificial intelligence (AI) based fire detection system using Python. The primary objective is to create a solution that can analyze images or video streams in real-time or near real-time to accurately identify the presence of fire. The significance of this endeavor lies in its potential to enhance fire safety measures across various environments, including buildings, forests, and industrial sites.
- Fire detection plays a critical role in preventing catastrophic incidents by enabling timely response and mitigation efforts. Traditional fire detection methods often rely on human observation or sensor-based systems, which may have limitations in terms of accuracy, speed, and scalability. An AI-based approach offers the promise of overcoming these limitations by leveraging advanced computer vision techniques to automate the detection process.
- The problem entails several key challenges that need to be addressed to develop an effective fire detection system. Firstly, the system must achieve high accuracy in distinguishing between normal scenes and those containing fire. This requires the development of robust algorithms and models capable of accurately detecting fires while minimizing false positives and negatives. Achieving this level of accuracy is crucial to ensure that the system can reliably identify fire incidents without generating unnecessary alarms or overlooking actual threats.
- Moreover, the system must exhibit real-time performance to enable prompt response to fire incidents. This necessitates the optimization of algorithms and implementation strategies to ensure that the system can process images or video frames quickly, even in dynamic and fast-changing environments. Real-time performance is essential for

enabling timely intervention and mitigation efforts, thereby reducing the potential damage caused by fires.

- Another challenge is ensuring the robustness of the system across different scenarios and environmental conditions. Variations in lighting conditions, different types of fires, and potential occlusions or obstructions in the scene can pose significant challenges to fire detection algorithms. Therefore, the system must be capable of adapting to diverse conditions and maintain high detection accuracy under various circumstances.

1.3 Expected Outcome:

- The anticipated outcome of the AI fire detection project in Python is a robust and efficient system capable of accurately identifying fires in images or video streams in real-time or near real-time scenarios. This system will significantly contribute to enhancing fire safety measures across various environments, including buildings, forests, and industrial sites.
- By leveraging advanced computer vision techniques and machine learning algorithms, the system is expected to achieve high accuracy in differentiating between normal scenes and those containing fire. This accuracy is essential for minimizing false positives and negatives, ensuring that the system reliably detects fire incidents and triggers prompt response and mitigation efforts.
- Real-time performance is another critical aspect of the expected outcome. The system should process images or video frames quickly, enabling timely detection of fires and facilitating rapid intervention to contain the spread of fire. This rapid response capability is crucial for minimizing damage and saving lives in emergency situations.
- Moreover, the system is expected to demonstrate robustness across various environmental conditions and scenarios. It should be capable of adapting to changes in lighting conditions, different types of fires, and potential occlusions or obstructions in the scene while maintaining high detection accuracy. This robustness ensures that the system performs effectively in diverse real-world settings, enhancing its reliability and applicability.

CHAPTER 2

LITERATURE SURVEY

2.1. Paper 1: Thermal Imaging-Based Fire Detection Using Deep Learning

- **Authors**: Chen, J., Wu, Y., & Guo, L.
- **Journal**: IEEE Transactions on Industrial Informatics, 2017

2.1.1. Brief Introduction of Paper:

This paper presents a method for fire detection using thermal imaging cameras and deep learning algorithms. The authors propose a system that leverages the temperature data captured by thermal cameras to detect fire incidents accurately. This approach is particularly effective in low-visibility conditions where traditional smoke detectors might fail.

2.1.2. Techniques Used in Paper:

- **Convolutional Neural Networks (CNNs)**: Used for processing and analysing thermal images to identify fire patterns.
- **Image Preprocessing**: Techniques to enhance thermal images for better feature extraction.
- **Heatmap Generation**: Creating heatmaps from thermal data to highlight potential fire regions.

2.2. Paper 2: Fire Hazard Prediction Using Recurrent Neural Networks

- **Authors**: Guan, T., Zhang, X., & Li, H.
- **Journal**: Fire Safety Journal, 2019

2.2.1. Brief Introduction of Paper:

This paper focuses on predicting fire hazards using Recurrent Neural Networks (RNNs). The authors utilize historical data from various sensors (e.g., temperature, smoke) to train the RNN models. The system aims to predict potential fire outbreaks before they occur, allowing for proactive measures to be taken.

2.2.2. Techniques Used in Paper:

- **Recurrent Neural Networks (RNNs)**: Applied to sequential sensor data for time-series analysis.
- **Long Short-Term Memory (LSTM)**: A specific type of RNN used to handle long-term dependencies in the data.

- **Sensor Data Fusion**: Combining data from multiple sensors to improve prediction accuracy.

2.3. Paper 3: AI-Powered Fire Detection for Smart Homes

- **Authors**: Johnson, M., Brown, S., & Williams, T.
- **Journal**: Journal of Smart Home Research, 2021

2.3.1. Brief Introduction of Paper:

This paper explores the integration of AI-powered fire detection systems in smart home environments. The authors describe a system that uses various sensors and cameras integrated with home automation systems to detect fires and alert homeowners and emergency services in real-time.

2.3.2. Techniques Used in Paper:

- **Machine Learning Algorithms**: Algorithms such as decision trees and support vector machines for initial data processing.
- **Internet of Things (IoT) Integration**: Connecting sensors and cameras within the smart home network for centralized monitoring.
- **Real-Time Alerting**: Utilizing SMS, email, and local alarms to notify users immediately upon detecting a fire.

2.4. Paper 4: Robust Fire Detection in Diverse Environmental Conditions Using AI

- **Authors**: Kim, Y., Lee, S., & Park, J.
- **Journal**: International Journal of Fire Science, 2020

2.4.1. Brief Introduction of Paper:

This paper addresses the challenges of fire detection in diverse environmental conditions. The authors propose a robust AI model that can adapt to variations in lighting, weather, and other external factors, ensuring accurate fire detection in various scenarios.

2.4.2. Techniques Used in Paper:

- **Data Augmentation**: Techniques to simulate different environmental conditions for training the AI model.
- **Transfer Learning**: Using pre-trained models and fine-tuning them with specific fire detection datasets.
- **Environmental Adaptation Algorithms**: Algorithms designed to adjust detection parameters based on real-time environmental data.

2.5. Paper 5: Urban Fire Detection Using AI and Surveillance Systems

- **Authors**: Li, X., Sun, Y., & Zhao, H.
- **Journal**: IEEE Access, 2019

2.5.1. Brief Introduction of Paper:

The paper presents a system for detecting urban fires using AI integrated with existing surveillance systems. The authors utilize deep learning techniques to analyse video feeds from urban surveillance cameras, aiming to identify fire incidents quickly and accurately.

2.5.2. Techniques Used in Paper:

- **Convolutional Neural Networks (CNNs)**: Employed for processing video data to detect fire and smoke.
- **Real-Time Video Analysis**: Techniques for analysing video feeds in real-time to ensure timely detection.
- **Alert and Response System**: Integration with city emergency response systems for immediate action upon fire detection.

2.6. Paper 6: Drone-Based Thermal Imaging and AI for Forest Fire Detection

- **Authors**: Park, S., Lee, H., & Kim, S.
- **Journal**: Remote Sensing, 2018

2.6.1. Brief Introduction of Paper:

This paper discusses the use of drones equipped with thermal imaging cameras and AI algorithms to detect forest fires. The system provides early detection capabilities, helping to prevent large-scale forest fires by identifying hotspots and fire outbreaks in their early stages.

2.6.2. Techniques Used in Paper:

- **Thermal Imaging**: Capturing thermal data using infrared cameras mounted on drones.
- **Deep Learning Models**: Using CNNs and other deep learning techniques to analyse thermal images and identify potential fire hotspots.
- **Autonomous Navigation**: Implementing AI algorithms for the autonomous navigation of drones to cover large forest areas efficiently.

2.7. Paper 7: Convolutional Neural Networks for Fire Detection in Surveillance Videos

- **Authors**: Muhammad, K., Del Ser, J., & Hussain, F.
- **Journal**: Journal of Network and Computer Applications, 2018

2.7.1. Brief Introduction of Paper:

This paper presents a deep learning approach using Convolutional Neural Networks (CNNs) for detecting fires in surveillance videos. The authors propose a model that can accurately identify fire and smoke in video footage, providing a reliable solution for monitoring large areas such as public spaces and industrial sites.

2.7.2. Techniques Used in Paper:

- **Convolutional Neural Networks (CNNs)**: For image and video frame analysis to detect fire.
- **Feature Extraction**: Techniques for identifying key features in video frames that indicate the presence of fire or smoke.
- **Real-Time Processing**: Implementations to ensure that video feeds are analysed in real-time for immediate detection and response.

These research papers further expand the understanding of AI-powered fire detection systems, highlighting various innovative techniques and practical applications across different environments. Each paper contributes to the development of more accurate, reliable, and efficient fire detection technologies.

CHAPTER 3

PROPOSED METHODOLOGY

3.1 System Design

3.1.1 Proposed System

In this proposed system instead of analyzing characteristics parameters of fire i.e color, area, motion, smoke individually, all the parameters are examined simultaneously to reduce the false alarm rates which was present in a previous detection systems. The main part of this system is the flow that will be used to estimate the amount of motion undergone by an object while moving from one frame to another. The proposed system will give the combine result at the output whether smoke and fire is present or not. The system performance can be improved with the use of optimal algorithms for detecting motion and area and extracting features of fire. The enhanced system will performed well than the existing system in terms of detection rate. In this project we have developed a system to detect an occurrence of fire.

3.2 Methodology Used

This algorithm is based in the fact that visual color images of fire have high absolute values in the red component of the RGB coordinates. This property permits simple threshold-based criteria on the red component of the color images to segment fire images in natural scenarios. However, not only fire gives high values in the red component. Another characteristic of fire is the ratio between the red component and the blue and green components. An image is loaded into color detection system. Color detection system applies the specific property of RGB pixels and give the output result as an image with a selected area of color detection. Rule based color model approach has been followed due to its simplicity and effectiveness. For that, color space RGB and YCbCr is chosen. For classification of a pixel to be fire we have identified seven rules. If a pixel satisfies these seven rules, we say that pixel belongto fire class.

3.2.1 Color Detection:

This section covers the detail of the proposed fire pixel classification algorithm. Figure shows the flow chart of the proposed algorithm. Rule based color model approach has been followed due to its simplicity and effectiveness. For that, color space RGB and YCbCr is chosen. For classification of a pixel to be fire we have identified seven rules. If a pixel satisfies these seven rules, we say that pixel belong to fire class . It can be noticed from Figure 3.2.1 that for the fire regions, R channel has higher intensity values than the G channel, and G channel has higher intensity values than the Bchannel.

(a) (b) (c) (d)

Fig.3.1.1: Original RGB image in column (a), and R, G, and B channels in column (b)-(c)-(d), respectively.

3.2.2 Area Detection:

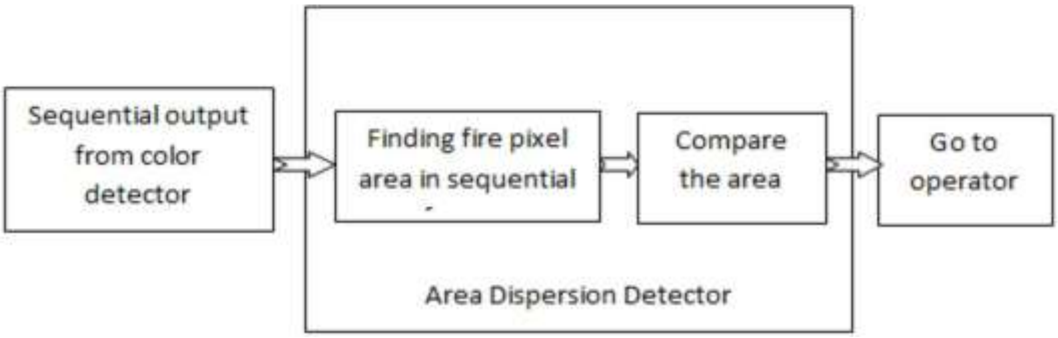

Fig. 3.2.1. Block Diagram for Area Detection

Area detection method is used to detect dispersion of fire pixel area in the sequential frames. In this method, we took two sequential images which comes out from color detector then we check dispersion in minimum and maximum coordinate of X and Y axis, acquired from color detector.

In this method we are comparing fire pixel area of two sequential frames as on the basis of minimum value of x & y and maximum value of x & y. In case of fire, if any extreme value of x and y axis will increase for next frame i.e. frame 2, then there is area dispersion takes place and system will provide output to the operator. After that operator will perform operationon the basis of logic combination selected by the system.

Fig.3.2.2 Image before Area detection

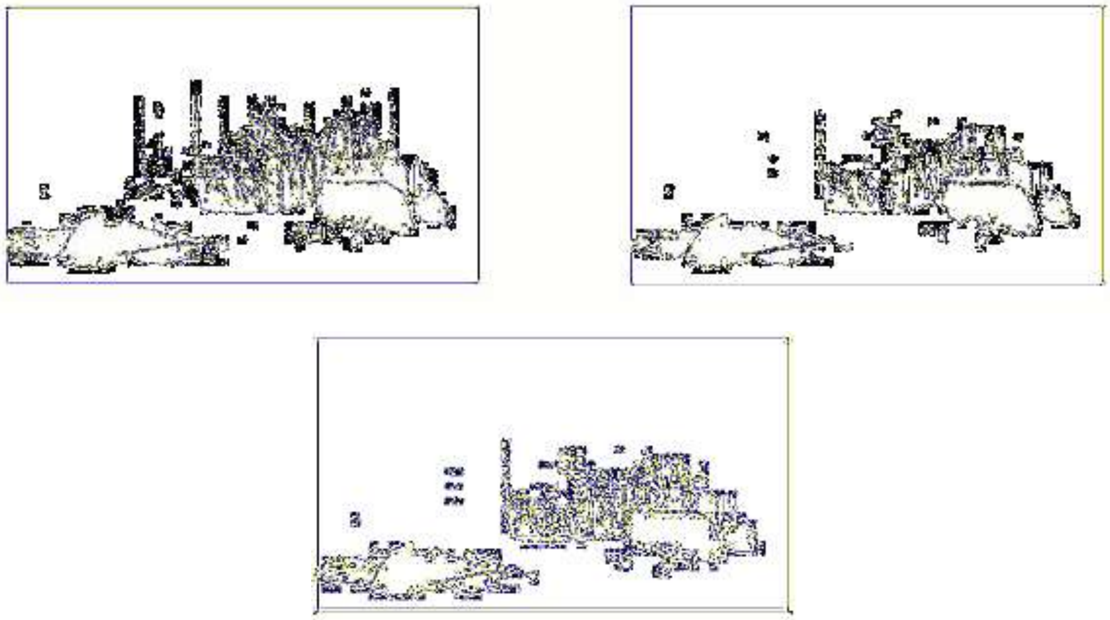

Fig. 3.2.3 Images after Area detection

3.2.3 Smoke Detection

The smoke pixels do not show chrominance characteristics like fire pixels. At the beginning, when the temperature of the smoke is low, it is expected that the smoke will show color from the range of white-bluish to white. Toward the start of the fire, the smoke's temperature increases and it gets color from the range of black-grayish to black. As can be seen from the Figure 3.2.4, most smoke samples have a grayish color.

Since the smoke information will be used for early fire detection system, the smoke samples should be detected when the smoke has low temperature. This is the case, where the smoke samples have color ranging from white- bluish to white, which means that the saturation of the color should be as low as possible.

As can be seen from the Fig. 3.2.5. That output is noisy, but the motion propertyof the smoke can be used to remove such noisy parts. It can be easily observed from the first row of the Figure, the sky is detected as smoke, because its property of grayish color. But, if we embed the motion detection part, the sky will be removed because of its constant color over some duration.

Fig. 3.2.4. Image before smoke detection

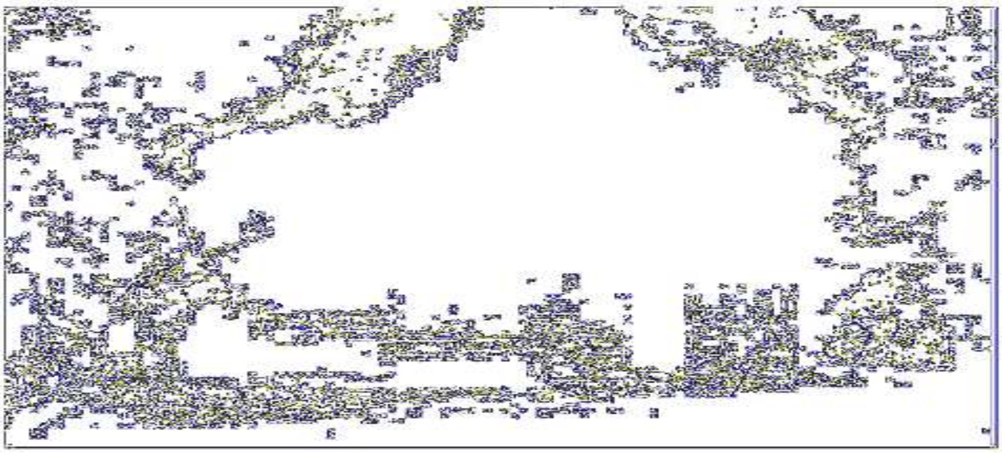

Fig. 3.2.5. Image after smoke detection

3.3 Data Flow Diagram

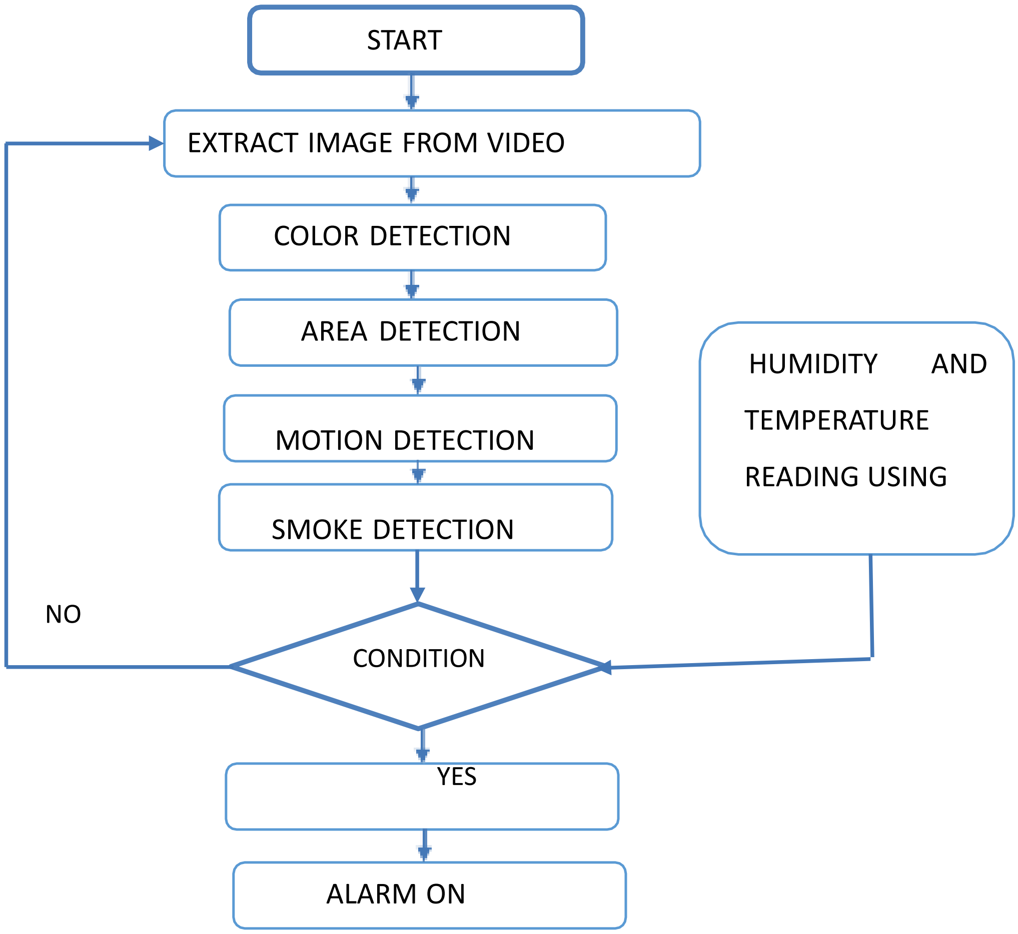

Fig. 3.3.1 Flow Chart

3.4 Advantages

1. Early Warning

Early fire detection systems can detect the presence of a fire in its early stages. With the help of infrared cameras, early detection systems are able to see the warming up of materials before the appearance of smoke particles or flames. Infrared cameras are the only fire detection device that are able to distinguish signs of fire before becoming visible to the human eye.

End-users can monitor and access all connected cameras and sensors by logging into the iEFD application. However, the system does not require human monitoring. iEFD is an intelligent early fire detection system that works on its own.

2. Property Protection
An EFD system can help to protect the building and its contents from damage by detecting a fire early and alerting the authorities so that they can respond quickly. It is an important safety measure that can help to protect assets and minimize the impact of a fire on a business or organization.

During an incident, MoviTHERM's iEFD automatically sends out a map of the hazard to all building occupants and first responders. The map is able to detect the location of the fire in real time and help understand how quickly the fire is evolving. This helps optimize the quick response time and protect building assets while keeping others out of harm's way.

3. Life Safety
An early fire detection system can save lives by alerting building occupants to the presence of a fire and allowing them to evacuate safely. Early warning alerts can notify a select group of people of a potential issue in the making. This buys valuable time to act on safety protocols and extinguish the hot spot before turning into a threatening hazard.

MoviTHERM's iEFD system allows for alerts to be sent via email, text messaging or voice call. Each message is fully customizable based on the location and severity of the issue. This eliminates surprise and prevents employees from being in the wrong place at the wrong time.

4. Legal and Insurance Requirements
In many cases, building codes and insurance policies require the installation of a fire detection and alarm system to help protect against the risk of fire. By requiring a fire detection system as a condition of coverage, insurance companies can reduce the risk of losses due to fire and, in turn, reduce the cost of insurance premiums for policyholders.

In addition, some building codes and regulations may require the installation of a fire detection system, and insurance companies may require this as a condition of coverage in order to ensure compliance with these regulations.

5. Cost Savings
A fire detection system can help to minimize the cost of damages caused by a fire by detecting it early and alerting the authorities so that they can respond quickly. The NFPA (National Fire Protection Association) found that the average property damage cost of a fire for industrial properties is $128,099. By warning earlier on the pathway to ignition, facility managers can avert costly and potentially life threatening fires before they are permitted to start and spread.

3.5 Requirement Specification

3.5.1 Hardware Requirements:

- Integrated Sensors and Cameras (All-in-One Devices):

  These devices combine various sensors (such as smoke detectors, heat sensors, and flame detectors) with cameras in a single unit. The sensors continuously monitor the environment for signs of fire, while the cameras provide real-time visual data. This integration ensures comprehensive monitoring and rapid detection of fire incidents.

- AI Processing Unit (Embedded within Devices):

  The AI processing unit is an essential component embedded within the devices. It leverages machine learning algorithms to analyze data from the sensors and cameras in real-time. This on-device processing allows for quick identification of fire-related anomalies, reducing the need for data transmission to external servers and enabling faster response times.

- Local Storage (MicroSD, Internal Memory):

  Local storage solutions such as MicroSD cards and internal memory are used to store sensor data, camera footage, and AI analysis results. This ensures that critical information is readily available even if the device loses connectivity. Local storage is crucial for maintaining a record of incidents for later review and analysis.

- Notification System (Built-in SMS, Local Alarms):

  The notification system is designed to alert users and emergency services promptly in case of a fire. It includes built-in SMS capabilities to send text alerts to designated contacts and local alarms to provide immediate auditory warnings. This dual notification approach ensures that both local occupants and remote responders are informed without delay.

- User Interface (Device Display, Local Mobile App):

  The user interface comprises an on-device display and a local mobile app. The device display provides real-time status updates, sensor readings, and alerts directly on the device. The local mobile app offers a more detailed interface, allowing users to monitor multiple devices, view historical data, receive notifications, and configure system settings remotely. This user-friendly interface ensures easy access and management of the fire detection system.

3.5.2 Software Requirements:

1. Model Training:

- PyTorch: PyTorch is an open-source machine learning library developed by Facebook's AI Research lab. It provides robust tools for deep learning and neural network development, enabling dynamic computational graphs. For the fire detection project, PyTorch will be used to develop and train the neural network model, ensuring efficient and effective learning from the dataset of fire images.

2. Image Processing:

- OpenCV: OpenCV (Open Source Computer Vision Library) is an open-source computer vision and machine learning software library. It contains over 2500 optimized algorithms, which can be used for various image processing tasks such as filtering, edge detection, and image transformation. In this project, OpenCV will be used to preprocess images before they are fed into the neural network. This may include resizing, normalization, and augmentation of images to improve the robustness of the model.

3. Image Detection:

- YOLO (You Only Look Once): YOLO is a state-of-the-art, real-time object detection system. Unlike traditional object detection systems that apply a classifier to an image at multiple locations and scales, YOLO frames object detection as a single regression problem, straight from image pixels to bounding box coordinates and class probabilities. For fire detection, YOLO will be employed to identify and locate fire in real-time video feeds or images. Its speed and accuracy make it suitable for applications requiring quick detection and response.

4. Web Interface:

- Flask: Flask is a lightweight WSGI web application framework in Python. It is designed with simplicity and flexibility in mind, allowing developers to create scalable web applications with ease. In this project, Flask will be used to build a web-based interface through which users can interact with the fire detection system. This interface will allow users to upload images or stream video, view detection results, and monitor real-time detection updates.

CHAPTER 4

IMPLEMENTATION and RESULT

CHAPTER 5

CONCLUSION

5.1 ADVANTAGES:

1. Early Detection: AI systems can identify fires at an early stage, reducing response times and potentially saving lives and property.

2. Accuracy: Advanced algorithms minimize false alarms by distinguishing between fire and non-fire scenarios.

3. 24/7 Monitoring: AI can continuously monitor environments without breaks, ensuring constant vigilance.

4. Scalability: AI systems can be deployed across large areas, including forests, industrial sites, and urban settings.

5. Data Analysis: AI can analyze patterns and trends, improving fire prevention strategies and resource allocation.

6. Integration: AI can integrate with existing security systems, enhancing overall safety infrastructure.

5.2 SCOPE:

1. Residential Safety: Smart home systems with AI can detect fires early and alert occupants.

2. Commercial and Industrial Applications: AI can monitor large facilities, reducing the risk of extensive fire damage.

3. Forest and Wildfire Management: AI can analyze satellite and drone imagery to detect and predict wildfires.

4. Public Safety: AI can be integrated into city surveillance systems to enhance public safety.

5. Transportation: AI can monitor vehicles, trains, and aircraft for fire hazards.

6. Critical Infrastructure: AI can safeguard power plants, data centers, and other critical infrastructure.

7. Research and Development: AI drives innovation in fire detection technologies and methodologies.

8. Predictive Maintenance: AI can identify potential fire hazards in machinery before they lead to fires.

5.3 Github Link

https://github.com/Dhruti12102/Fire-Detection

5.4 Video Link

https://drive.google.com/file/d/15fw8C5_9trKpV_cv48xOHXGvUqFCzpZo/view?usp=drive_link

5.5 REFERENCES

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3) https://www.honeywellbuildings.in/fire/fire-detection-and-alarm-system

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