

Fire Detection Using CCTV Surveillance

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Abstract - Fire detection is a critical component of safety and security systems, aimed at minimizing loss of life and property damage. Traditional fire detection systems rely on smoke or heat sensors, which often suffer from delayed response times and limited coverage. This paper presents a CCTV-based fire detection approach that utilizes video surveillance and image processing techniques to identify fire occurrences in real time. The system analyzes visual cues such as color, motion, and intensity variations to accurately detect fire and generate alerts. By integrating CCTV cameras with intelligent algorithms, the proposed method enhances detection accuracy, provides faster response, and reduces false alarms. This approach is cost-effective, scalable, and suitable for both indoor and outdoor environments, offering an efficient alternative to conventional sensor-based fire detection systems.

Key Words: Fire detection, CCTV, image processing, computer vision, video surveillance, real-time detection, motion detection, color analysis, alert system, safety

1. INTRODUCTION

Fire accidents pose a serious threat to human life, infrastructure, and the environment. Early detection of fire plays a vital role in minimizing damages and ensuring timely emergency response. Conventional fire detection systems such as smoke detectors and heat sensors are effective but often have limitations, including delayed detection, restricted coverage area, and high maintenance requirements.

With the rapid advancement of computer vision and artificial intelligence, CCTV-based fire detection has emerged as an intelligent and efficient solution. By analyzing video footage from surveillance cameras, the system can identify fire or smoke patterns in real time based on color, motion, and shape characteristics. This method provides continuous monitoring, faster detection, and the ability to cover large areas without the need for additional sensors.

The use of CCTV for fire detection not only enhances safety but also reduces false alarms and operational costs. Therefore, integrating video-based fire detection into existing surveillance infrastructure offers a promising direction for developing modern, smart safety systems.

2. METHODOLOGY

Data Acquisition Framework

The dataset used for training consists of labeled images divided into two categories:

- **Fire images (Class 1)**
- **Non-fire images (Class 0)**

The dataset includes various real-world scenarios such as indoor and outdoor environments under different lighting conditions.

Preprocessing steps include:

- Image resizing to a fixed dimension
- Normalization of pixel values
- Label encoding
- Splitting into training and testing datasets

Input variables:

Symbol	Description	Unit
I(x,y)	Current Image Frame	Pixel intensity
H S V	Hue, Saturation, and Value	H: degrees (0-180), S & V: normalized (0-1)
D	Difference between consecutive frames to detect motion	Pixel intensity difference (0-255)

Output variables:

Symbol	Description
A	Alert Signal

CNN Model Implementation

A Convolutional Neural Network (CNN) is used for classification of images.

Working of CNN:

- Convolution layers extract important features such as edges, textures, and patterns
- Pooling layers reduce dimensionality
- Fully connected layers classify images
- Output layer predicts whether fire is present or not

The model is trained using labeled data and optimized using loss functions and backpropagation techniques.

Real-Time Detection using OpenCV

OpenCV is used to integrate the trained model with CCTV camera input.

Steps involved:

1. Capture live video using CCTV camera
2. Convert video into frames
3. Preprocess each frame
4. Pass frame to CNN model
5. Predict fire or non-fire

Alarm System Integration

When fire is detected:

- The system triggers an **audio alarm**
- The alarm sound is played using a preloaded audio file
- This provides immediate alert to nearby individuals

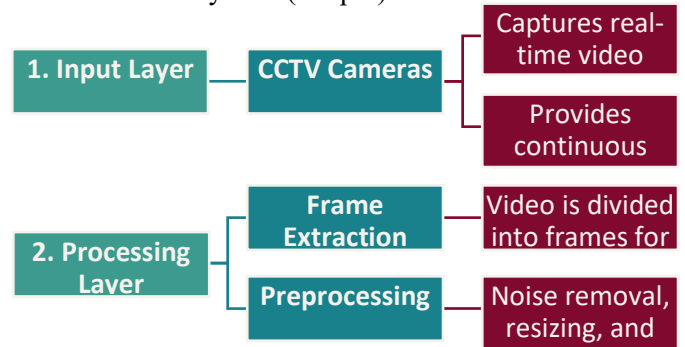
3.MODELING AND ANALYSIS

The Fire Detection System is developed using deep learning and computer vision techniques to ensure accurate and real-time fire detection.

System Architecture

The system consists of the following main components:

- CCTV Camera (Input)
- Preprocessing Module
- CNN Model for Classification
- Alarm System (Output)



Input and Preprocessing

The system captures live video using CCTV cameras through OpenCV. The video is converted into frames, and each frame is preprocessed before being passed to the model.

Preprocessing steps include:

- Resizing images to a fixed dimension
- Normalizing pixel values
- Reducing noise

CNN Model Design

A Convolutional Neural Network (CNN) is used for fire detection. The model includes:

- Convolutional layers for feature extraction
- ReLU activation function
- Max pooling layers for dimensionality reduction
- Fully connected layers for classification
- Sigmoid output layer for binary classification (Fire / No Fire)

Real-Time Detection

The trained model is integrated with OpenCV for real-time detection:

- Frames are continuously captured

- Each frame is analyzed by the CNN model
- If fire is detected, the system proceeds to alert

Accuracy Comparison

The system performance can be analyzed in terms of detection capability:

The CNN model shows strong classification ability, especially in controlled environments.

Condition-Specific Performance Analysis

The system was tested under different environmental conditions:

Condition	Performance
Fire Detection	High
Non-Fire Detection	High
Real-Time Detection	Efficient
False Positives	Moderate

Scenario	Detection Performance
Indoor Environment	High Accuracy
Outdoor Environment	Good Accuracy
Low Light Conditions	Moderate Accuracy
Bright Light / Fire-like Objects	Reduced Accuracy

Alarm System

An audio-based alarm system is implemented:

- When fire is detected, an alarm sound is triggered
- The sound is played using a preloaded audio file
- This ensures immediate alert to nearby users

The system performs best in environments with clear visibility, while detection accuracy slightly decreases in complex lighting conditions or in the presence of fire-like colors.

Performance Analysis

The system shows:

- High accuracy in detecting fire in dataset images
- Efficient real-time detection
- Minor false detections in complex lighting conditions

Real-Time Detection Analysis

The integration with OpenCV enables real-time fire detection using CCTV feed. The system processes video frames continuously and provides quick predictions.

4. RESULTS AND DISCUSSION

Model Performance Evaluation

The Convolutional Neural Network (CNN) model was trained on labeled fire and non-fire images. The model demonstrated effective learning of fire-related features such as flame color, intensity, and texture patterns.

During testing, the model achieved high accuracy in distinguishing between fire and non-fire images. The training and validation results indicated consistent performance with minimal loss variation.

- Fast response time observed
- Alarm triggered immediately upon detection
- Continuous monitoring achieved without interruption

5. CONCLUSIONS

The Fire Detection System using CCTV cameras provides an efficient approach for early fire detection using deep learning and computer vision techniques. The system integrates a CNN model with OpenCV to analyze real-time video frames and accurately classify fire and non-fire situations.

The implementation demonstrates good performance in detecting fire and triggering an audio alarm instantly, ensuring quick response. Compared to traditional methods, this system offers continuous monitoring and faster detection.

However, the system may face minor challenges in complex lighting conditions or in the presence of fire-like objects. Future improvements can include mobile alert integration and enhanced models for better accuracy.

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