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# Real-Time Fire and Smoke Detection System

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**Abstract- Around the world, fire events continue to rank among the top causes of property loss, injuries, and fatalities. Traditional fire detection systems mostly rely on smoke alarms and heat sensors, which frequently identify fires at an advanced stage with little time for evacuation and response. The likelihood of uncontrollable fires, which cause extensive damage and health risks, especially respiratory and skin-related illnesses from extended exposure to toxic smoke, is greatly increased by delayed detection. In order to overcome these obstacles, we suggest a cutting-edge Fire and Smoke Detection System that makes use of artificial intelligence, sensor-based environmental monitoring, and contemporary computer vision techniques to guarantee early fire detection and risk assessment.**

**Keywords- Environmental Monitoring, Health Risk Assessment, Toxic Smoke, Early Fire Warning, Real-Time Monitoring, Fire Safety, Respiratory Diseases,.**

## I. INTRODUCTION

Worldwide, fire dangers remain a prominent cause of devastation, resulting in fatalities, property damage, and serious environmental repercussions. Fire can be challenging to contain due to its quick spread, which highlights the necessity of early detection systems to prevent future catastrophes. Heat sensors and smoke alarms are examples of traditional fire detection techniques that use reactive mechanisms to detect fires only after there has been a noticeable increase in temperature or smoke concentration. These techniques frequently lead to delayed detection, which shortens the amount of time available for firefighting and evacuation operations. Public health and safety are further threatened by the serious respiratory and skin conditions that can result from being exposed to poisonous smoke and dangerous gasses during a fire.

We suggest an intelligent fire and smoke detection system that combines artificial intelligence (AI), computer vision, and sensor-based monitoring to address these issues. A Raspberry Pi serves as the processing unit for this system, which also uses a webcam and a smoke detection sensor ( MQ-135) to continuously monitor the surroundings. Our method, which combines gas concentration measurements with visual flame recognition using machine learning algorithms, improves fire detection accuracy in contrast to conventional detection methods.

In order to identify early indications of smoke and fire, the system continuously analyses sensor readings and camera video. It determines the degree of hazard and categorizes the fire incident's severity upon identification. It also assesses the possible health hazards, especially the effects of breathing in toxic smoke on the skin and lungs. Large-scale damage is less likely thanks to this system's automated alerts and notifications, which are implemented via buzzer alarms and SMS.

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The goal of this research is to create a proactive, economical, and effective fire detection system that can be installed in a variety of sites, such as distant areas, commercial buildings, residential houses, and industrial facilities. The suggested solution provides a more dependable and precise method of preventing fires by combining sensor-based smoke detection with AI-powered image identification. To further increase its capabilities, future developments might incorporate predictive analytics, drone-based fire surveillance, and thermal imaging.

This work explores the design, development, and performance assessment of system, discussing the advantages over conventional fire detection methods and highlighting its potential applications in modern fire safety infrastructure.

## II. LITERATURE SURVEY

**Fire Recognition based on Image Processing using Raspberry pi**

This work examines the use of the Raspberry Pi for real-time fire detection with image processing techniques. In this paper the goal is to develop an effective fire recognition system by analysing visual data captured by a camera using techniques such as colour and texture analysis. The integration of low-cost hardware, which provides a viable option for fire detection in remote or industrial regions, is emphasized. One essential element of the system is its ability to operate in real time with limited processing resources. Overall, the study demonstrates how the Raspberry Pi may be utilized to improve fire defense systems through image processing.

**Image Processing Based Fire Detection System using Raspberry Pi System**

This paper describes image-processing based fire identification system and is developed on a Raspberry Pi. The authors use colour detection, motion analysis, and pattern recognition to identify fire in visual data that was recorded by a camera. The system is meant to be lightweight, affordable, and able to detect fires in real time. By offering early fire warnings in both residential and commercial settings, it aims to improve safety. The study demonstrates how Raspberry Pi may be used practically to create easily accessible fire detection systems.

**Pi Cam Based Smoke/Fire Alerting System**

A fire and smoke detection system utilizing a Raspberry Pi and Pi Cam is presented in the paper. Using image analysis techniques, the system processes real-time video footage to identify smoke or fire. It incorporates an alarm system that, upon discovery, notifies users. The study highlights the solution's affordability and portability, which make it perfect for both domestic and commercial uses. Overall, the study demonstrates how well the Raspberry Pi works to provide an affordable, dependable smoke and fire alarm system.

**Design and Develop Smart Smoke and Fire Detector on Raspberry Pi 3 Connecting Arduino**

It investigates how to combine the Raspberry Pi 3 with Arduino for intelligent smoke and fire detection in the given paper. For real-time processing and alarm creation, the system integrates sensors such as temperature and smoke sensors with the Raspberry Pi's computational capabilities. It seeks to offer an affordable, effective way to detect fires early in both residential and commercial settings. The potential of the system to send notifications by email or mobile device for increased safety is covered in the article. This method demonstrates how Raspberry Pi and Arduino work together to provide a dependable and expandable fire safety solution.

**Deep Learning for Fire and Smoke Detection: Current Trends and Future Directions**

Current Trends and Future Prospects of Deep Learning for Smoke and Fire Detection. Research highlights the use of convolutional neural networks (CNNs) and other deep learning models for real-

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time monitoring. The study investigates recent breakthroughs in deep learning methods for identification of fire and smoke. It investigates a variety of datasets and methodologies used in smoke and fire detection, including the combination of sensor data with video analysis. The authors discuss the challenges with false positives and environmental factors. The research also discusses how deep learning models can improve the exactness and performance of the detection systems. It finishes by describing prospective pathways for future research, with an emphasis on improving model resilience and real-time implementation in various settings.

**An Improved Fire and Smoke Detection Method Based on YOLOv8n for Smart Factories**

The use of YOLOv8n, a cutting-edge deep learning model, to improve fire and smoke detection in industrial settings is examined for the study. The authors address issues like low light levels and changing environmental elements in smart factories by proposing an improved model designed for real-time detection. The study demonstrates gains in detection speed and accuracy above conventional techniques. Additionally, it assesses the model's resilience in intricate industrial environments, ensuring that it is appropriate for applications involving safety. Overall, by using AI-driven solutions, the study advances smoke and fire detection systems.

**Fire and Smoke Detection in Complex Environments**

Difficulties in identifying fire and smoke threats in various, congested, or obstructed places are highlighted in a literature review on these dangers' detection in complicated contexts. For increased accuracy in dynamic contexts, recent research focuses on integrating cutting-edge sensor technologies, such as optical, thermal, and chemical sensors. The application of machine learning techniques has increased the ability of detection systems' capacity to distinguish between genuine threats and false alarms has grown. Furthermore, studies investigate multi-sensor fusion techniques to strengthen detection systems' resilience in challenging environments. Even with improvements, there are still issues with lowering false positives and adjusting to different environmental conditions including humidity, temperature swings, and ventilation.

**Fire and smoke detection from videos**

Thorough analysis of fire and smoke detection methods using video data is provided in the publication. To categorize current techniques according to their methodology, the authors suggest a new taxonomy that focuses on evaluation metrics, characteristics employed, and detection algorithms. The assessment draws attention to the difficulties encountered in the field, including managing changing environmental conditions and guaranteeing real-time performance. It also talks about how improvements in computer vision and machine learning have increased the accuracy of detection. Understanding the most recent methods and their uses is made easier with the help of this paper.

**Real-time fire and smoke detection with transfer learning based on cloud- edge collaborative architecture**

Their research tackles the drawbacks of conventional fire detection techniques, particularly in intricate and changing settings, namely their lengthy response times and high false alarm rates. The authors used pre-trained CNN to construct a deep learning-based strategy. They achieved great accuracy in identifying fire and smoke patterns from video frames while reducing training time by using transfer learning. They created a cloud- edge cooperation architecture to address the issue of edge devices' limited processing capability. The initial lightweight processing in this architecture is handled by edge devices, which then forward certain frames to the cloud for more in-depth examination. In addition to lowering bandwidth consumption and preserving high detection accuracy, this division of labor guarantees low-latency decision- making. Real-world scenarios and a publicly available dataset were used to test the suggested model.

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**Visual fire detection using deep learning: A survey**

An overview of a deep learning techniques of visual fire identification may be found in the publication. To enhance precision of detection system in real-time video streams, it examines a variety of methods of deep learning, such as RNN and CNN. Managing a variety of environmental variables and the requirement for sizable, annotated datasets are among the difficulties discussed in the paper. To improve performance, it talks about developments in data augmentation, transfer learning, and model training methodologies. The survey's final section examines how deep learning models might be used to create dependable and effective fire detection systems.

**Proposed Methodology**

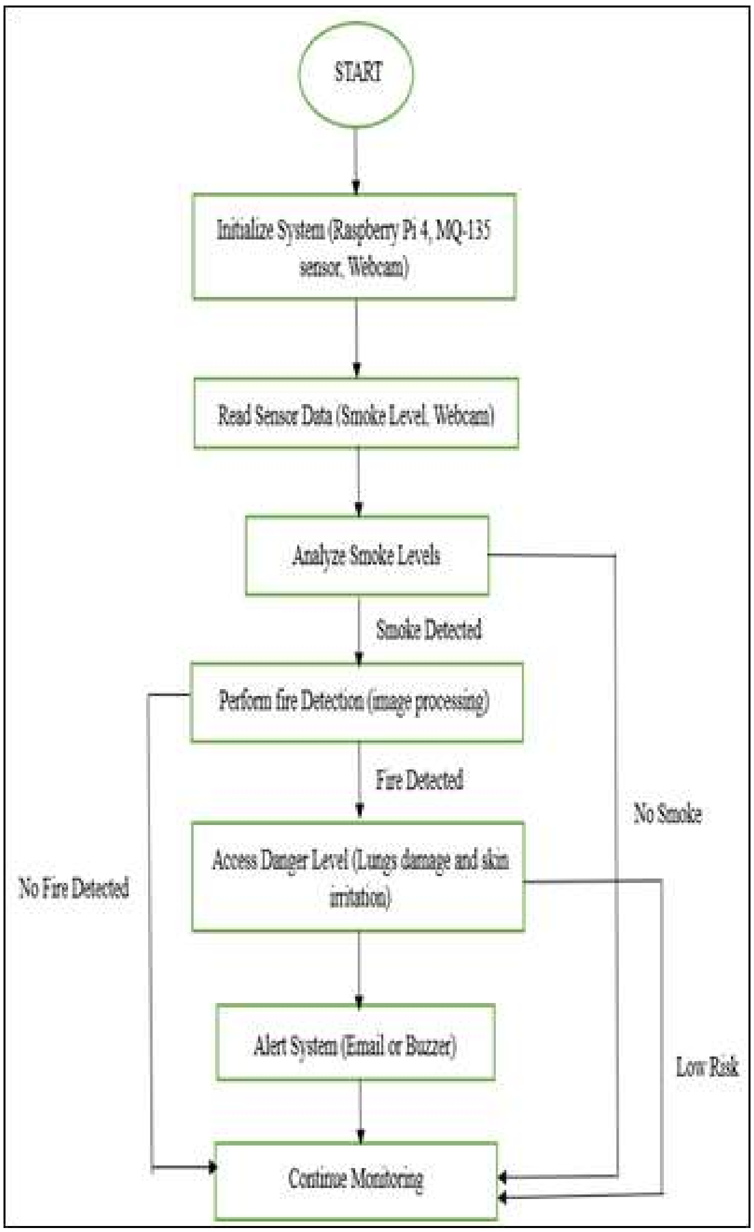


Figure 1: Flowchart

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**Implementation**

- **Hardware Specifications**

**Raspberry Pi**

Figure 2: Raspberry

The Raspberry Pi serves as the system's brain, executing the Python code in charge of automated email notifications, image processing, and sensor data analysis. It uses OpenCV to apply fire detection algorithms, controls the USB webcam for live video streaming, and connects to the Arduino to get sensor data. It also connects to an HDMI touchscreen display for status tracking and real-time visual output.

Arduino UNO

Figure 3: Arduino Uno

The Arduino UNO is used to communicate with environmental sensors. It gathers analog data from the MQ-135 air quality sensor and the IR flame sensor via its analog input pins (A0 and A1). Using the Standard Firmata firmware, the Arduino sends sensor data to the Raspberry Pi via USB, enabling real-time monitoring/identification and decision- making in Python script.

MQ-135 Gas Sensor

Figure 4: MQ-135 Sensor

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A sensitive gas sensor, the MQ-135 can identify a variety of dangerous substances, such as carbon dioxide, alcohol, benzene, smoke, nitrogen oxide (NOx), ammonia (NH3), and more. It produces an analog signal proportional to the air's gas content.

In this project, the MQ-135 is linked to the Arduino's A0 pin and used to detect the presence of air pollutants and smoke, which could indicate a fire or other hazardous situations. The Raspberry Pi processes the sensor readings and displays them on the screen, alerting users if dangerous amounts are discovered.

USB Camera Module


Figure 5: USB Camera (Webcam)

A USB webcam linked to the Raspberry Pi collects continuous video that is processed with OpenCV. The frames are translated to the HSV color space, and fire-like colors (reddish-yellow) are detected using thresholding. The system counts the fire- coloured pixels and assigns the fire intensity to Low, Moderate, or High based on the count. This method offers visual confirmation of fire in addition to sensor- based detection.

HDMI Touchscreen Display

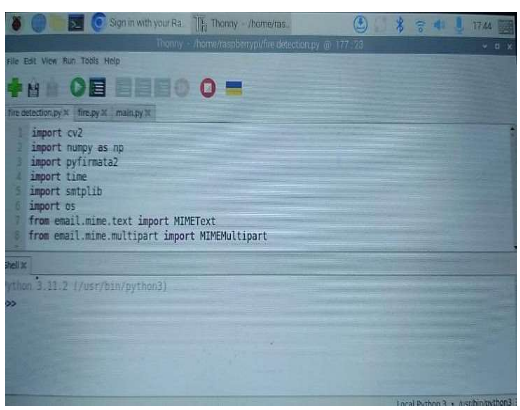


Figure 6: HDMI Display

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The live video feed, sensor data, and fire alert messages are displayed on a touchscreen monitor connected via HDMI. This interface enables users to view the environment in real time, monitor gas levels, and be warned of any possible concerns immediately. It improves user contact and is useful for demonstrations or field deployment.

**Software Used**

- **Programming Language:**

Python

- **Operating System:**

Raspberry Pi Os

The software is powered by Raspberry Pi OS, a Debian- based Linux distribution designed specifically for Raspberry Pi hardware. It natively supports Python and allows you to easily install all essential libraries from the console. Its reliability, lightweight design, and GPIO support make it an ideal platform for running IoT and embedded projects such as this fire and smoke detection system.

**Library used**

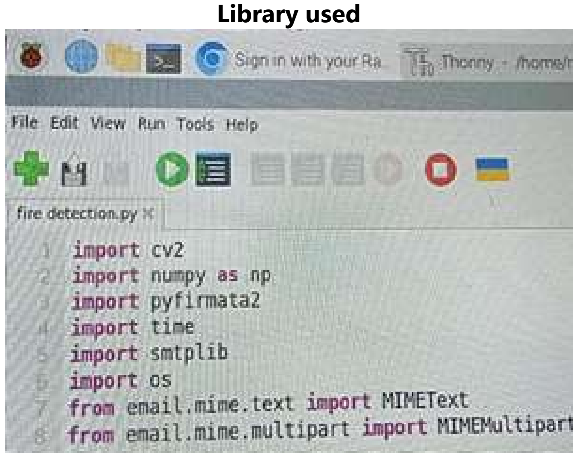


Figure 7: Libraries used

- **import cv2**

In order to do real-time computer vision tasks, such identifying fire in video feeds, the OpenCV library is be imported.

- **import NumPy as np**

NumPy is used to perform efficient numerical computations and array manipulations, which are useful for picture masking and processing.

- **import pyfirmata2**

The pyfirmata2 package is a powerful Python interface that allows your Raspberry Pi (or any other Python- powered computer) to communicate with an Arduino board via USB using the Firmata protocol.

- **Iimport time**

Time-related services include delays and cooldown intervals between email alerts.

- **import smtplib**

A built-in library for sending emails using the Simple Mail Transfer Protocol (SMTP) is the smtplib module in Python. It acts as a client by establishing a connection to an email server (like Gmail), entering your login information, and sending emails to one or more recipients.

**import os**

Allows access to environment variables and operating system features, such as securely accessing email credentials.

- **from email.mime.text import MIMEText**

Used to generate plain-text portions of an email message.

- **from**

email.mime.multipart import MIMEMultipart Allows for the production of complicated email messages with numerous components, such as topic, body, and attachments.

**System Architecture**

**Arduino Uno: Sensor Interface**

The Arduino is linked to analog sensors:

- MQ-135 Gas Sensor on A0 pin detects smoke and hazardous gasses.
- IR Flame Sensor on A1 pin detects heat or flames (optional).
- It continuously reads the analog voltage values from the sensors.

**Communication with Raspberry Pi**

- Arduino is connected to the Raspberry Pi via a USB wire.
- The pyfirmata2 library implements the Firmata protocol.
- The sensor readings are relayed in real time to Python on the Raspberry Pi.

**Video Input via USB Webcam**

- A USB webcam is linked to the Raspberry Pi.
- The Raspberry Pi catches a live video stream with OpenCV (cv2).
- Frames are continuously recorded for fire detection analysis.

**Fire Detection using OpenCV**

- Each video frame is transformed to the HSV color space.
- A color mask is used to detect the orange/yellow hues associated with fire.
- If fire-like color areas are recognized and sufficiently large:
- Fire is classified as low, moderate, or high intensity based on pixel count.

**Sensor Threshold Evaluation**

- Gas sensor values are checked for harmful levels.
- IR sensor signals are examined for fires using voltage thresholds.
- Values that exceed predefined criteria cause alarm circumstances.

**Automated Email Alerts**

- When a fire or elevated gas levels are detected:
- An email is created with smtplib and email.mime.
- Includes the fire intensity, gas sensor value, IR measurement, and warning message.
- Email is sent to the specified receiver via Gmail's SMTP server.

**Touchscreen Display Output**

- A touchscreen HDMI display is attached to the Raspberry Pi.
- The live camera feed is displayed with superimposed text.
- Fire's intensity level
- Gas and infrared sensor values
- This enables real-time visual surveillance of the environment.

**Circuit diagram**

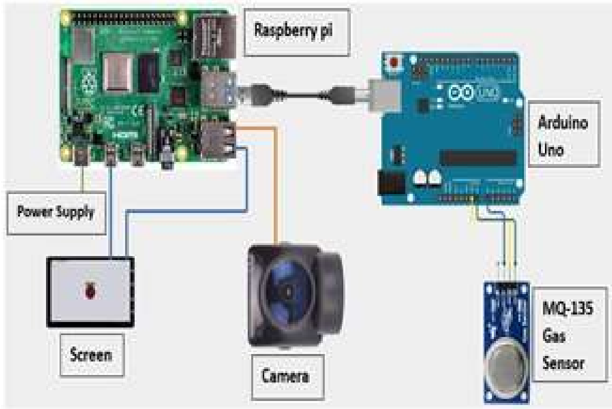


Figure 8: Circuit Diagram of fire and smoke detection

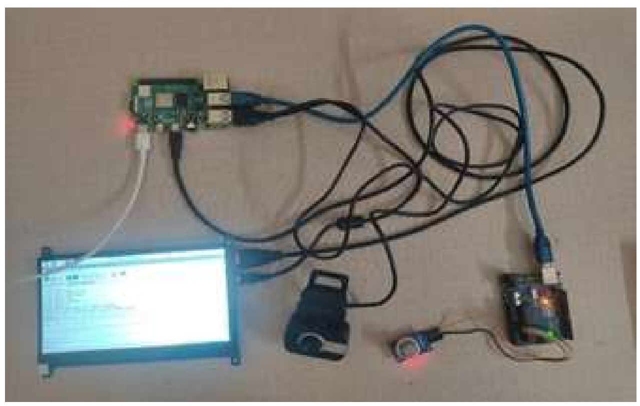

Figure 9: Real connection of fire and smoke detection

**Displaying Results**

High, Moderate and low Fire status
Detected. An alert mail will be sent to the user.


Fig 10: High Fire Detected

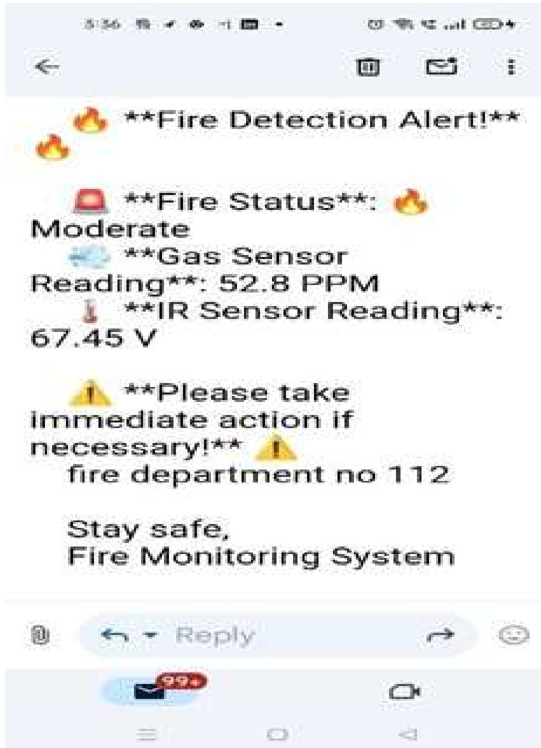


Figure 11: Moderate Fire Detected


Figure 12: Low Fire Detected

Conclusion

The MQ135 gas sensor, Arduino Uno, Raspberry Pi, LCD display, and webcam are all effectively integrated into the designed fire and smoke detection system to offer a dependable, affordable, and real- time alarm mechanism. The MQ135 sensor efficiently identifies dangerous gases linked to fire and smoke. After detection, the Arduino interprets the sensor data and connects to the Raspberry Pi, which turns on the webcam to record live video and instantly emails the image to designated recipients. For local monitoring, the LCD display offers on-site feedback. With its scalable and adaptable approach for improving safety and reducing damage through timely alarms, this system shows great promise for early fire detection in residential, commercial, and industrial environments.

**Future Scope**

- **Real-time Monitoring of Multiple Gas Levels:**

The system may be improved to track the concentration of several dangerous gases in real time, including volatile organic compounds (VOCs), carbon monoxide (CO), ammonia ($NH_3$), nitrogen dioxide ($NO_2$), sulphur dioxide ($SO_2$), and nitrogen dioxide. By integrating many sensors and presenting data on an LCD screen or web dashboard, users can gain a better understanding of air quality and identify dangerous contaminants before they become dangerously high.

- **Identification of Skin Diseases Caused by Gas Exposure:**

Numerous skin-related health problems can result from prolonged or high-level exposure to these gases:

- Skin irritation, dermatitis, and burns are caused by ammonia ($NH_3$).
- Dry skin, rashes, and chemical burns are caused by sulphur dioxide ($SO_2$).
- Eczema and contact dermatitis can be brought on by nitrogen dioxide ($NO_2$).
- VOCs: Induce inflammatory, itchy, and red skin reactions in allergic skin types.
- CO: This condition can cause poor skin oxygenation and poorer wound healing, although it primarily affects internal systems.

- **Skin Diseases Solutions & Medical Assistance Recommendations: Recommended** treatments (e.g., lotions, first-aid suggestions) for symptoms in their early stages. Using integrated maps and medical databases,provide direct suggestions for dermatologists and hospitals in the area. Details regarding the intensity of symptoms and when to get medical help right away Health reports are automatically generated and shared with physicians.

- **Emergency Fire Response Integration:**

When critical fire or smoke levels are detected, automatically send a voice call or alarm to the closest fire station. Provide a brief incident narrative along with the precise location using GPS. For safety audits and analysis, record the alarm time and responder status.

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