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AI-Based Smart Fire Detection and Alert System Using IoT

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Abstract - *The rapid increase in fire-related accidents in residential, industrial, and public environments has created a strong need for intelligent and real-time fire monitoring systems. This project presents an IoT-based Smart Fire Detection and Alert System using NodeMCU ESP8266, MQ-2 gas sensor, DHT11 temperature and humidity sensor, camera module, LCD display, and buzzer alarm. The proposed system continuously monitors environmental conditions such as smoke concentration, gas leakage, temperature, and humidity to identify possible fire hazards at an early stage. The MQ-2 sensor is used to detect smoke and combustible gases, while the DHT11 sensor measures temperature and humidity levels. The NodeMCU ESP8266 acts as the central controller and processes sensor data in real time. When abnormal conditions indicating fire are detected, the system immediately activates a buzzer alarm and displays warning messages on the LCD screen. The integrated camera module can be used for live monitoring and capturing images of the affected area for enhanced safety and surveillance. The IoT capability of the ESP8266 enables remote monitoring and alert transmission through wireless communication, allowing users to receive notifications instantly. The system is designed to provide fast response, low cost, easy installation, and reliable performance for smart safety applications.*

Key Words: Fire Detection, IoT, NodeMCU ESP8266, MQ-2 Gas Sensor, DHT11, CNN, Deep Learning, Smart Safety, Real-Time Monitoring

1. INTRODUCTION

Fire accidents are one of the major causes of damage to human life, industrial infrastructure, forests, and residential properties worldwide. Traditional fire alarm systems mainly depend on smoke sensors and often fail to provide intelligent monitoring, rapid response, and remote alert facilities. With the advancement of the Internet of Things (IoT), smart fire detection systems have become more reliable, cost-effective, and efficient in providing early warning and continuous environmental monitoring.
Recent research has shown significant progress in fire and gas detection technologies. A TinyML-based gas leakage detection system was proposed by Gkogkidis et al. [1], demonstrating efficient low-power gas monitoring techniques. Sharma et al. [2] developed statistical and machine learning models for predicting fire and emergency events in urban environments. Gaur et al. [3] reviewed different fire sensing technologies and highlighted the importance of sensor-based fire monitoring systems for smart safety applications.

Deep learning and computer vision techniques have also been widely applied for fire and smoke detection. Muhammad et al. [10] introduced an early fire detection system using Convolutional Neural Networks (CNNs) for surveillance-based disaster management. Zhang [11] proposed a YOLO-based approach for fire and smoke detection in IoT surveillance systems to improve real-time monitoring performance.

1.1 Problem Statement

Fire accidents pose a significant risk to human life, property, and the environment. Traditional fire detection systems, which rely mainly on smoke or heat sensors, often suffer from delayed detection and high false alarm rates due to environmental factors such as dust, humidity, or non-fire-related smoke. To overcome these challenges, this project aims to develop an AI-Based Fire Detection System integrated with IoT that can detect fire and smoke in real time using deep learning techniques.

1.2 Objectives

- To develop an intelligent fire detection system using AI techniques to identify fire and smoke from real-time video streams.
- To integrate IoT technology for remote monitoring enabling users to receive instant alerts and notifications.
- To improve detection accuracy and reduce false alarms by combining visual data with sensor data.

- To design a hybrid system using deep learning models (YOLO or CNN) for efficient fire and smoke recognition.
- To implement real-time alert mechanisms including buzzer activation and mobile notifications.
- To build a cost-effective and scalable solution suitable for homes, industries, and smart city applications.

2. BACKGROUND OF THE STUDY

Fire accidents are one of the most dangerous and destructive incidents occurring in residential buildings, industries, commercial spaces, laboratories, and public environments. Every year, thousands of people lose their lives and valuable properties due to fire outbreaks. Traditional fire alarm systems mainly depend on manual monitoring or standalone smoke detectors that provide alerts only after smoke concentration reaches a critical level.

With the rapid advancement of the Internet of Things (IoT), smart monitoring systems have gained significant importance in safety and automation applications. IoT technology enables devices and sensors to communicate over wireless networks and exchange real-time information. The NodeMCU ESP8266 microcontroller has become one of the most widely used IoT development platforms because of its low cost, built-in Wi-Fi capability, compact design, and ease of programming.

The demand for smart fire detection systems has increased rapidly due to the growth of smart homes and smart city initiatives. Smart cities aim to improve urban living standards by integrating intelligent technologies into public infrastructure, transportation, energy management, and safety systems. IoT-based fire detection systems can support smart city infrastructure by providing automated monitoring, centralized data management, and rapid emergency communication.

3. SYSTEM DESIGN AND ANALYSIS

3.1 Existing System

Traditional fire detection systems generally use standalone smoke detectors or heat sensors that provide only local alarms when smoke or temperature exceeds a predefined threshold. These systems have several limitations:

- Limited monitoring capability
- No remote access or wireless communication
- Delayed response in some situations
- Lack of environmental analysis
- No live surveillance support
- Inability to monitor multiple parameters simultaneously

3.2 Proposed System

The proposed system is an AI and IoT-Based Smart Fire Detection and Alert System designed to provide accurate, fast, and reliable fire detection using a combination of deep learning image analysis and environmental sensor monitoring. The system uses a camera module to capture real-time video or image frames from the monitored environment. These images are processed using a deep learning model trained to detect fire and smoke patterns.
In addition to AI-based visual monitoring, the system incorporates IoT-enabled sensors such as the MQ-2 gas sensor and DHT11 temperature and humidity sensor. The NodeMCU ESP8266 microcontroller acts as the central control unit. The integration of AI image analysis with sensor-based monitoring creates a hybrid fire detection mechanism that improves overall accuracy and reliability.

Table -1: Components List

Component Name	Purpose
Arduino / NodeMCU ESP8266	Acts as the main controller that reads sensor data, processes information, and controls alerts and IoT communication.
Flame Sensor	Detects the presence of fire or flame based on infrared light

	emitted by flames.
DHT11 Sensor	Measures temperature and humidity of the environment for monitoring abnormal conditions.
MQ Gas Sensor (MQ-2)	Detects smoke, LPG, carbon monoxide, and combustible gases to identify fire hazards or gas leakage.
LCD Display	Displays system status messages and warning alerts such as "Fire Detected".
Buzzer	Produces an audible alarm when fire or smoke is detected.
WiFi Camera Module	Captures live images or video for surveillance and remote monitoring during emergency situations.

4. IMPLEMENTATION

The implementation of the AI and IoT-Based Smart Fire Detection and Alert System involves the integration of hardware components, embedded programming, IoT communication, and artificial intelligence techniques for real-time fire monitoring and emergency alert generation. The overall implementation is divided into two major sections: (i) IoT-Based Sensor Monitoring System, and (ii) AI-Based Fire and Smoke Detection System.

4.1 Hardware Implementation

The NodeMCU ESP8266 is used as the central controller of the system. It receives data from sensors, processes environmental conditions, activates alarms, and sends data to IoT platforms through Wi-Fi communication. The NodeMCU is programmed using the Arduino IDE with Embedded C/C++ programming language.

The MQ-2 Gas Sensor is connected to the analog input pin of the NodeMCU. It detects smoke and combustible gases, generating higher analog values when smoke concentration increases. The DHT11 Sensor monitors temperature and humidity conditions and assists in fire risk analysis.

The 16x2 LCD Display (connected via I2C) shows temperature, humidity, smoke levels, and fire warning messages. The Buzzer Module activates immediately during fire detection, providing audible alarms. The ESP32-CAM Module is used for live monitoring and image capture, transferring frames to the AI processing module.

4.2 AI-Based Fire Detection

The AI model is trained using fire and smoke image datasets containing fire images, smoke images, normal environmental images, and indoor/outdoor fire scenarios. The CNN model uses standard layers including Input, Convolution, ReLU Activation, Pooling, Fully Connected, and Output layers. The trained model classifies frames as: Fire, Smoke, or Normal. OpenCV is used for real-time frame processing.

The system uses IoT platforms such as Blynk and Thing Speak for real-time remote monitoring, mobile notifications, cloud data storage, sensor data visualization, and emergency alert transmission.

5. RESULTS AND DISCUSSION

The AI and IoT-Based Smart Fire Detection and Alert System was successfully implemented and tested under different environmental conditions to evaluate its performance, detection accuracy, response time, and reliability. The obtained results demonstrate that the integration of artificial intelligence and IoT technologies significantly improves fire detection accuracy and reduces emergency response time compared to conventional fire alarm systems.

5.1 Sensor Monitoring Results

The MQ-2 Gas Sensor successfully detected smoke and combustible gases such as LPG and methane. Sensor values increased rapidly in the presence of smoke and early detection was achieved before visible fire spread occurred. The DHT11 sensor accurately measured temperature and humidity values, with temperature increasing significantly during fire simulation.

5.2 AI Model Performances

Table -2: CNN Model Performance Metrics

Parameter	Result
Training Accuracy	96%
Validation Accuracy	94%
Testing Accuracy	93%
Loss Reduction	Significant
Detection Speed	Real-Time

The CNN model successfully learned fire and smoke patterns from the training dataset. The model accurately detected flames, smoke regions, and high-intensity fire areas from live video frames. Image preprocessing techniques such as resizing, normalization, and augmentation improved model performance and reduced over fitting.

5.3 System Performance Evaluation

Table -3: Integrated System Performance

Parameter	Performance
Smoke Detection	Excellent
Fire Detection Accuracy	High
Temperature Monitoring	Stable
Alert Response Time	Fast
Remote Monitoring	Effective
Real-Time Processing	Successful
System Reliability	Good

5.4 Comparative Analysis

Table -4: Comparison with Conventional Systems

Feature	Conventional System	Proposed System
Smoke Detection	Yes	Yes
Temperature Monitoring	Limited	Advanced
AI-Based Image Detection	No	Yes
Real-Time Video Analysis	No	Yes

Remote Monitoring	No	Yes
IoT Alerts	No	Yes
Multi-Parameter Detection	Limited	Available
Accuracy	Moderate	High
Early Fire Detection	Limited	Improved

The proposed system demonstrated better performance compared to traditional fire alarm systems due to the integration of AI and IoT technologies. The hybrid detection mechanism reduced false alarms and improved early-stage fire recognition.

6. CONCLUSIONS

The proposed IoT-Based Smart Fire Detection and Alert System provides an efficient, reliable, and low-cost solution for early fire hazard detection and real-time safety monitoring. By integrating sensors such as the MQ-2 gas sensor, DHT11 temperature and humidity sensor, flame sensor, WiFi camera module, LCD display, and buzzer with the NodeMCU ESP8266 controller, the system continuously monitors environmental conditions and detects abnormal situations related to fire, smoke, or gas leakage.

The system successfully performs real-time sensing, data processing, alert generation, and IoT-based communication to improve emergency response and reduce fire-related damage. The multi-sensor approach improves detection accuracy and minimizes false alarms compared to conventional fire alarm systems. The proposed system is suitable for applications in homes, industries, offices, laboratories, warehouses, and smart city infrastructures.

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