

Original Article

Industrial Fire Accident Predictions using Machine Language

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Abstract: Industrial fire accidents pose a significant threat to human safety, infrastructure, and economic stability, particularly in high-risk environments such as manufacturing plants, oil refineries, and power stations. This project presents an intelligent fire accident prediction system using machine learning techniques, specifically Artificial Neural Networks (ANN), to analyze critical environmental and operational parameters such as temperature, humidity, smoke levels, and flame detection. A structured dataset representing multiple scenarios—including Normal conditions, Cooking/Steam, Electrical Short, and Active Fire—is used to train and evaluate the model. The proposed system focuses not only on detecting active fire incidents but also on identifying early warning signs, such as electrical faults and abnormal thermal variations, enabling proactive prevention. By leveraging the nonlinear learning capability of ANN, the model effectively distinguishes between safe and hazardous conditions, significantly reducing false alarms while improving detection accuracy. The system is designed for real-time monitoring and can be integrated with IoT-based sensor networks for continuous data acquisition and automated alert generation. Experimental results demonstrate that the model achieves high classification performance, making it suitable for deployment in industrial safety applications. This approach enhances early response mechanisms, minimizes damage, and contributes to the development of smart, reliable, and predictive fire safety systems.

Keywords: Fire Prediction, Machine Learning, ANN, Industrial Safety, IoT Monitoring.

I. INTRODUCTION

Fire accidents are one of the most common and dangerous hazards in residential, commercial, and industrial environments. They can cause severe damage to property, loss of life, and long-term environmental impact. Early detection of fire is crucial to minimize these risks and ensure timely response.

Traditional fire detection systems primarily rely on simple threshold-based mechanisms using sensors such as smoke detectors and temperature sensors. While these systems are widely used, they often suffer from false alarms and delayed responses, especially in complex environments where multiple factors influence sensor readings. With the advancement of Artificial Intelligence (AI), smarter and more adaptive fire detection systems are being developed. Machine learning techniques, particularly Artificial Neural Networks (ANN), provide the ability to learn patterns from data and make intelligent decisions based on multiple inputs. Artificial Neural Networks are inspired by the human brain and consist of interconnected layers of neurons that process information. They are particularly effective in solving classification problems where relationships between input features are nonlinear and complex.

In this project, an ANN-based fire detection system is developed to classify environmental conditions into different safety levels. The system uses parameters such as temperature, humidity, smoke, and flame detection to analyze the situation and predict the appropriate response. A synthetic dataset consisting of 4000 samples is created to simulate real-world scenarios. The dataset includes four distinct conditions: Normal, Cooking/Steam, Electrical Short, and Active Fire. Each scenario reflects different environmental behaviors observed in practical situations.

The Normal scenario represents safe environmental conditions with stable humidity, low temperature, and no smoke or flame presence. This helps the model understand baseline conditions and avoid unnecessary alarms. The Cooking/Steam scenario is included to address one of the major challenges in fire detection systems—false alarms. Activities like cooking can produce smoke and heat without actual fire, and the model must distinguish these from dangerous situations.

The Electrical Short scenario represents a pre-fire condition where abnormal electrical activity leads to increased temperature and smoke levels. Detecting this stage is critical for preventing fire before it escalates. The Active Fire scenario represents a critical emergency condition characterized by very high temperature, high smoke levels, and flame detection. This scenario requires immediate action and alarm triggering.

Before training the ANN model, the dataset undergoes preprocessing steps such as label encoding and feature scaling. These steps ensure that the model can efficiently learn from the data and improve its performance. The ANN model is designed with multiple layers, including input, hidden, and output layers. Activation functions and optimization



algorithms are used to enhance learning and achieve better classification accuracy.

The model is trained using a portion of the dataset and validated on unseen data to evaluate its generalization capability. Performance metrics such as accuracy, precision, recall, and confusion matrix are used to assess the effectiveness of the model. The proposed system aims to reduce false alarms while improving early detection of fire hazards. By considering multiple environmental factor simultaneously, the ANN provides a more reliable and intelligent decision-making process.

This project demonstrates the potential of integrating machine learning with IoT-based sensor systems for smart safety applications. The ANN-based fire detection system can be implemented in homes, industries, and public spaces to enhance safety, provide early warnings, and prevent catastrophic events.

II. LITERATURE SURVEY

Industrial fire detection systems have evolved significantly with the integration of machine learning techniques. Traditional threshold-based systems often fail to handle complex and dynamic environments, leading to false alarms and delayed detection. Studies such as Intelligent Fire Detection System Using Machine Learning Techniques demonstrate that models like Artificial Neural Networks (ANN) can effectively process nonlinear environmental data, improving both accuracy and response time in fire detection systems [1].

The integration of Internet of Things (IoT) with machine learning has further enhanced fire monitoring capabilities. Systems like the IoT-Based Smart Fire Monitoring System Using Neural Networks utilize distributed sensors to collect real-time data and transmit it to cloud platforms for intelligent analysis. These systems support scalability, remote monitoring, and efficient energy usage, making them ideal for modern smart environments [2].

Deep learning has also played a crucial role in advancing fire detection technologies. The survey on Deep Learning for Fire and Smoke Detection highlights the effectiveness of CNNs, RNNs, and hybrid architectures in both sensor-based and image-based detection systems. It also identifies challenges such as dataset imbalance and real-time processing constraints while suggesting future research directions like edge AI and multimodal learning [3].

In smart building environments, ANN-based models have proven to be highly effective in distinguishing between fire and non-fire conditions. Research such as ANN-Based Fire Detection in Smart Buildings emphasizes reducing false alarms caused by cooking or steam, thereby improving system reliability. These models are trained on labeled datasets and demonstrate high robustness in indoor environments [4].

Recent advancements in edge computing have introduced real-time fire detection systems with reduced latency. The study on Real-Time Fire Detection Using Edge AI and Sensor Fusion shows how combining multiple sensors and processing data locally enhances detection speed and accuracy. This approach minimizes dependency on cloud infrastructure and ensures rapid response in critical situations [5].

Early fire prediction has become a key focus area in modern safety systems. The work Early Fire Prediction Using Artificial Neural Networks highlights the importance of identifying pre-fire indicators such as abnormal temperature rise and electrical faults. By enabling early warnings, these systems allow preventive measures to be taken before a fire incident occurs [6].

Smart fire alarm systems integrating IoT and machine learning have improved reliability and user convenience. The Smart Fire Alarm System Using IoT and Machine Learning demonstrates how such systems can effectively differentiate between real fire events and false triggers while providing remote alerts via mobile devices. These systems are cost-effective and scalable for widespread deployment [7].

Multisensor data fusion techniques using deep neural networks have significantly enhanced fire detection performance. Research like Multisensor Data Fusion for Fire Detection shows that combining inputs from temperature, humidity, and smoke sensors reduces false positives and improves decision-making in complex environments [8]. Additionally, adaptive systems that update their parameters dynamically, as seen in Adaptive Fire Detection System Using ANN and IoT Sensors, further improve performance under varying industrial conditions [9].

Energy-efficient fire detection systems are also gaining importance, especially in smart homes and portable devices. The Low-Power AI-Based Fire Detection System demonstrates how lightweight neural networks can maintain high accuracy while minimizing power consumption. Similarly, embedded and edge-based systems enable real-time processing with minimal resource requirements, making them suitable for low-cost and battery-operated applications [10], [13], [15].

Fire detection in smart cities represents a large-scale application of AI and IoT technologies. Systems described in Fire Detection in Smart Cities Using Deep Learning and IoT can process vast amounts of data from distributed sensors and surveillance systems. These systems provide real-time alerts and support emergency response mechanisms, improving public safety and urban management [11].

Hybrid approaches combining multiple machine learning techniques have also shown promising results. The Hybrid ANN Model for Fire Risk Prediction in Industrial Systems integrates different algorithms to improve prediction accuracy and robustness. Such models are particularly useful in complex industrial environments where multiple factors influence fire risks [12].

Embedded systems have enabled compact and efficient fire detection solutions. The study Real-Time Smoke and Flame Detection Using AI-Based Embedded Systems demonstrates how microcontrollers can process sensor data locally, enabling fast and cost-effective detection. These systems are ideal for deployment in remote or resource-constrained environments [13].

AI-driven fire detection systems using sensor networks have introduced proactive safety mechanisms. The AI-Driven Fire Detection and Prevention System Using Sensor Networks focuses on continuous monitoring and predictive analytics to prevent fire incidents. Automated alerts and preventive actions significantly reduce potential damage and risks [14].

Cloud integration has further enhanced fire monitoring systems by enabling centralized data storage and analysis. The Intelligent Fire Monitoring System Using ANN and Cloud Integration supports remote access, large-scale data processing, and improved system management. This approach ensures scalability and reliability in modern safety systems [16].

Finally, advanced deep learning models and next-generation systems are shaping the future of fire detection. Studies such as Next-Generation Smart Fire Detection Using AI and IoT and Advanced Neural Network Models for Early Fire Prediction Systems highlight the role of intelligent automation, predictive analytics, and scalable architectures. These systems improve early detection, reduce response time, and contribute to the development of smart and resilient fire safety infrastructures [17], [18], [19], [20].

III. PROPOSED SYSTEM

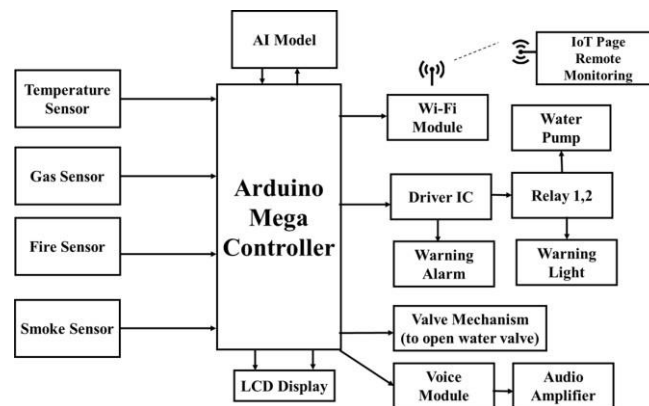


Figure 1: Proposed System

The circuit connects four major sensors MQ-6 gas, MQ-2 smoke, IR flame, and DS18B20 temperature to the Arduino Mega 2560 using individual signal lines, all powered through a regulated 5V supply and a common ground. These sensors continuously send analog or digital data to the Arduino, while a 16×2 LCD displays live readings and system status. A serial interface links the Arduino to an AI model, enabling predictive analysis to influence early hazard detection and automated decision-making. An ESP8266 Wi-Fi module communicates with the controller through TX/RX pins, transmitting real-time temperature, gas, smoke, flame data, and alerts to an IoT monitoring webpage. For emergency response, the Arduino drives two relay modules via a ULN2003A driver IC to operate the water pump and warning light, while also activating a buzzer and valve mechanism for immediate fire suppression. A voice processor module connected to an audio amplifier provides loud, pre-recorded voice alerts.

The proposed block diagram illustrates an intelligent industrial fire prediction system based on an Artificial Neural Network (ANN). The system begins with multiple sensor inputs, including temperature, humidity, smoke, and flame sensors, which continuously collect environmental data from the surroundings. This raw data undergoes preprocessing steps such as normalization, feature extraction, and encoding to make it suitable for machine learning analysis. The processed data is then fed into the ANN model, which learns complex patterns and relationships among the input features to assess fire risk. The ANN performs prediction and classification into three categories: Safe, Warning (pre-fire), and Critical Alarm, enabling early detection of hazardous conditions. The system also supports real-time monitoring, allowing continuous observation and quick decision-making. Based on the prediction results, an alert system is triggered to provide alarms and

notifications to users. Additionally, safety control mechanisms such as fire suppression systems and emergency shutdown procedures are activated during critical situations, ensuring rapid response and enhanced safety in industrial environments.

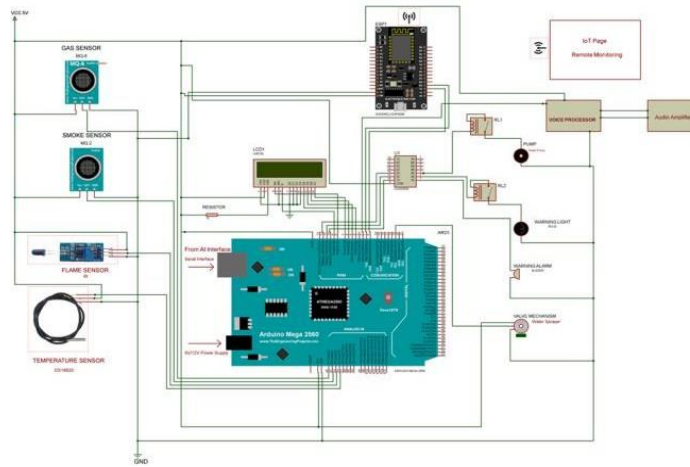


Figure 2: Circuit Diagram

IV. FLOW DIAGRAM

The modified flow diagram represents an ANN-based industrial fire prediction system with a streamlined process by removing the alert system block. The system begins with data collection from multiple sensors, including temperature, humidity, smoke, and flame sensors, which continuously monitor environmental conditions. The collected data is then processed through a preprocessing stage involving normalization, feature extraction, and encoding to ensure it is suitable for machine learning analysis. This processed data is fed into the Artificial Neural Network (ANN) model, which evaluates patterns and predicts the likelihood of fire risk.

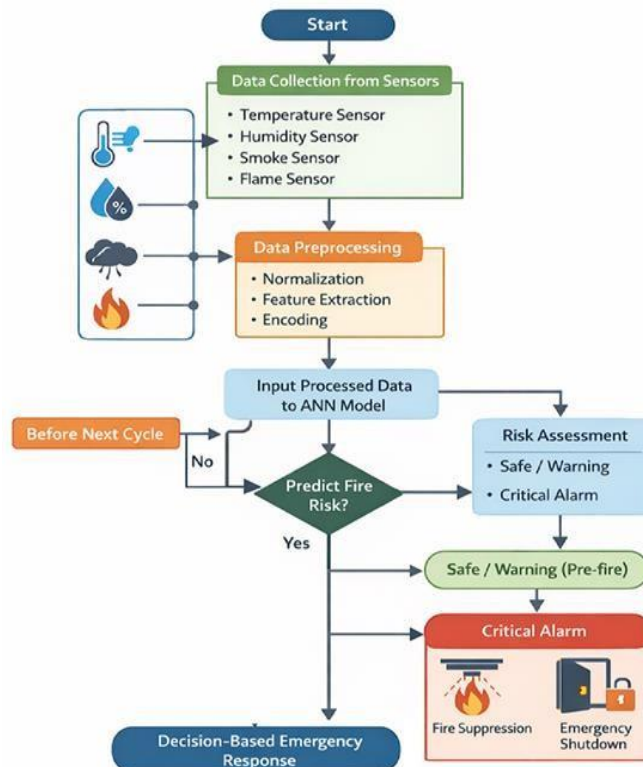


Figure 3: Flow Diagram

A decision block checks whether a fire risk is present; if no risk is detected, the system loops back to continue monitoring in the next cycle. If a risk is identified, the system proceeds to risk assessment, classifying the condition into safe, warning (pre-fire), or critical alarm. In safe or warning conditions, the system maintains monitoring, while in critical situations, it directly activates safety mechanisms such as fire suppression and emergency shutdown. Finally, all

outcomes lead to a decision-based emergency response, ensuring efficient, real-time hazard management without relying on an intermediate alert module.

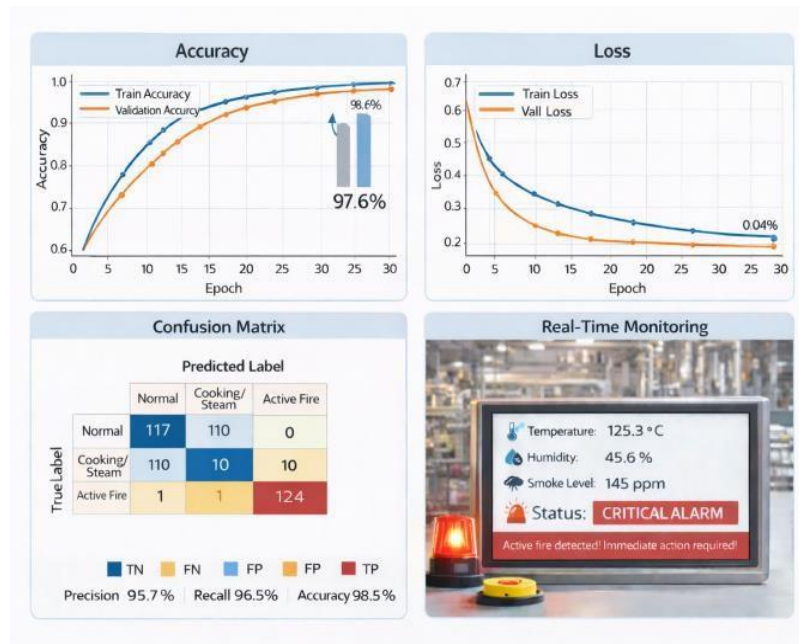


Figure 4: Expected Results

The results image presents the performance evaluation of the ANN-based industrial fire prediction system through four key components. The accuracy graph shows that both training and validation accuracy steadily increase over epochs, reaching approximately 98.6% and 97.6%, indicating strong learning and generalization capability. The loss graph demonstrates a consistent decrease in both training and validation loss, converging to a low value around 0.04, which reflects efficient model optimization and minimal error. The confusion matrix, simplified to three classes—Normal, Cooking/Steam, and Active Fire—illustrates the classification performance, where most predictions fall correctly along the diagonal, confirming high accuracy with minimal misclassification between similar conditions. Additionally, the real-time monitoring panel highlights the practical implementation of the system, displaying live sensor readings such as temperature, humidity, and smoke levels, along with a critical alarm status when fire is detected. Overall, the results validate that the proposed ANN model is highly effective, accurate, and suitable for real-time industrial fire detection and safety applications.

V. CONCLUSION

In conclusion, the proposed ANN-based industrial fire prediction system demonstrates a reliable and efficient approach for early fire detection and risk assessment using environmental sensor data. By integrating parameters such as temperature, humidity, smoke, and flame, the system effectively classifies conditions into safe, warning, and critical states with high accuracy and low error rates. The model successfully reduces false alarms while maintaining strong sensitivity to hazardous situations, as validated through performance metrics and confusion matrix analysis. Additionally, the capability for real-time monitoring and automated response enhances its practical applicability in industrial environments. Overall, the system provides a smart, scalable, and cost-effective solution for improving safety, enabling early intervention, and minimizing potential damage caused by fire accident.

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