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Fire Guard-AI: Intelligent IoT-Enabled Fire Prediction and Emergency Response System for Firecracker Industrial Safety

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***Abstract*— Firework manufacturing plants work under the condition where even a slight change in the parameters of temperature, humidity, or gas concentrations could lead to severe accidents. In such industrial areas like Sivakasi, which houses many firework manufacturing plants, continuous safety monitoring becomes crucial. Explosions can happen because of the leakages of gas or the building up of pressure. Such incidences can also be caused by increased temperatures or any accidental fires. Environmental sensing and predicting can be of much use in avoiding such situations. This research paper talks about an environment sensing and explosion prediction and alerting system based on IoT sensors along with Machine Learning model. MQ-2 gas sensor helps sense combustible gases, while DHT11 sensor measures humidity. BMP280 sensor monitors the temperature and the atmospheric pressure, whereas MLX90640 detects any abnormal heating conditions. All these sensors will transmit their data using ESP8266 board to a XGBoost Classification Machine Learning Model hosted in the cloud, and it would predict whether the current environmental conditions are safe or potentially hazardous. In case it detects explosion-prone conditions, then there would be an immediate generation of alarm via buzzer. The proposed system shows efficient predictive ability and consistent performance.**

***Keywords*— Industrial Safety, Explosion Risk Prediction, IoT Monitoring, Machine Learning, XGBoost Classifier, Environmental Sensors.**

I. INTRODUCTION

Industries using chemicals that may be flammable require rigorous surveillance. There is handling of flammable powders and reactive materials in fireworks factories regularly. Even a slight change in the environmental parameters like excessive heat, moisture, gas release, or sparks may cause hazardous situations. Although these mechanisms give off warning signals, they are often reactive in nature. The alarm gets activated only after the limit has been reached. This could lead to serious consequences in hazardous industries.

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In this project, the intelligent monitoring system for risk of explosion based on ESP8266 will be developed. Humidity is detected by DHT11 sensor, while temperature and pressure are measured using BMP280 sensor. The level of gases will be detected by MQ-2 sensor, and, in addition to that, an MLX90640 sensor for thermal detection can be used for more safety. The dataset for the model is collected from research papers and then fed into the XGBoost classifier. The model is trained and stored as an API to the cloud. During the process of model use, all data from sensors will be transmitted to the cloud via Wi-Fi network, and after processing, the result will be given.

II. Related Work

Mohana et al. designed a fire monitoring system using IoT sensors and machine learning algorithms to predict fires ahead of time. This system is responsible for monitoring temperatures, humidity levels, and smoke concentration [1]. Mekni developed an IoT fire detection and monitoring system using sensors that monitor temperatures, humidity levels, smoke concentrations, and the presence of humans indoors. This is a real-time monitoring system that improves indoor fire safety [2]. Lin et al. introduced an improved YOLOv9 algorithm for detecting small fires and sparse smoke in forests. Experiments revealed increased fire detection accuracy with reduced complexity of the model [3].

Recent advancements in machine learning approaches for fire detection have been discussed by Diaconu, focusing on the importance of multi-sensor fusion and intelligent algorithms for better detection performance [4]. Truong et al. developed a fire rescue system using thermal and infrared sensing technology to detect the presence of humans in smoky conditions, thus helping in emergency rescue operations [5]. A novel framework of anomaly detection that utilizes the combination of XGBoost and LSTM algorithms has been presented by Chen et al. The model was able to perform efficient feature selection and anomaly detection in industrial sensor data [6]. Pekşen and Yurtsever presented a predictive fire prevention system for electrical panels based on IoT devices and machine learning techniques. They employed environmental factors like gas concentration, temperature, humidity in their system [7].

Le et al. designed an Industrial IoT intrusion detection system with the help of XGBoost algorithm and showed excellent classification capability of the system in dealing with industrial sensor data [8]. Tanoue and Almeida performed systematic research on the use of fuzzy logic and ML in fire detection. The results indicated that multiple sensors along with intelligent algorithms can enhance the accuracy of fire detection and minimize false alarms [9]. Wang et al. introduced DATFNets, transformer-based networks for fire detection in complicated environments. The results of experiments demonstrated enhanced fire features recognition and localization [10]. Wan et al. designed an early warning system for fire prevention in offshore wind turbines with the help of transfer learning and XGBoost. The system successfully detected fire risks in terms of environment and operations [11]. Darshana et al. designed an AI-based adaptive traffic control system for emergencies with the help of YOLOv8 and fuzzy logic [12].

III. Proposed System

In this project, we developed an AI-based Explosion Risk Prediction and Alert System for fireworks manufacturing environments. The system continuously monitors environmental conditions and predicts whether the surrounding atmosphere is safe or prone to explosion.

A. Sensor-Based Environmental Monitoring

In this method, we used an ESP8266 microcontroller along with multiple environmental sensors to monitor real-time conditions inside the manufacturing area.

B. Sensors Used

In the suggested approach, multiple sensors are employed to constantly monitor the environment in the industrial setting. MQ-2 gas sensor will detect the concentration of combustible gases while the DHT11 sensor will measure the humidity level. The BMP280 sensor will be used to measure temperature and pressure while the MLX90640 sensor will detect heat abnormalities.

After completing the connections, the code was uploaded to the ESP8266 using Arduino IDE. Once powered on, the sensors begin collecting environmental data continuously. The readings are displayed on the serial monitor for monitoring purposes. The system checks gas levels, humidity percentage, temperature value, pressure reading, and flame status at regular intervals.

C. Machine Learning-Based Explosion Prediction

IIn this approach, instead of relying on straightforward threshold-based logic, machine learning is used for predicting the risk of explosions. An XGBoost classifier is trained using the dataset from the research paper. Once training is completed, the classifier is then deployed into the cloud environment as an API service. In the process of executing the system, data from sensors will be sent to the cloud server via Wi-Fi.Input Features Given to Model:

XGBoost algorithm uses gas concentration, humidity, temperature, pressure, and thermal heat intensity as the input variables. With the help of these environmental factors, the XGBoost algorithm determines if the environment is either Safe (0) or Explosion Risk (1). The output is passed back to the ESP8266 microcontroller.

Figure 1 illustrates the workflow of the suggested system. The sensor information will be gathered and analyzed by utilizing a machine learning algorithm in order to forecast explosions.

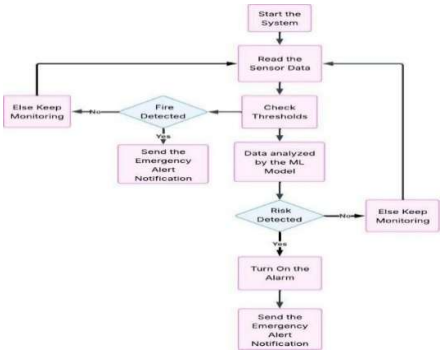

Fig 1. Working Flowchart of the Proposed System

D. Alert and Safety Mechanism

Once the prediction result is obtained from the cloud, the system will assess the state of the environment. When the prediction result equals 0, which means safe, the system will keep on monitoring the environment. However, when the prediction result is 1, meaning risk of explosion, the ESP8266 triggers the buzzer. The warning system allows employees to take precautions even before a hazardous scenario turns into an emergency. The system runs continually and updates the prediction results in real-time. As the model factors in various environmental conditions at once, the system is more reliable than threshold warnings.

IV. RESULT

In this project, we monitor industrial environmental conditions using an ESP8266 microcontroller with sensors such as MQ-2 for gas detection, MLX90640 thermal sensor for heat-based fire detection, DHT11 for humidity, and BMP280 for temperature and pressure measurement. The sensor data is read through the Arduino IDE and processed to determine whether the environment is safe or risky. If abnormal conditions are detected, a buzzer alert is activated. dataset is taken from research paper used to training a machine learning algorithm for predicting explosion risk.

Figure 2 shows the confusion matrix generated after training of the XGBoost algorithm. This matrix helps in understanding the efficiency of classification provided by the model.

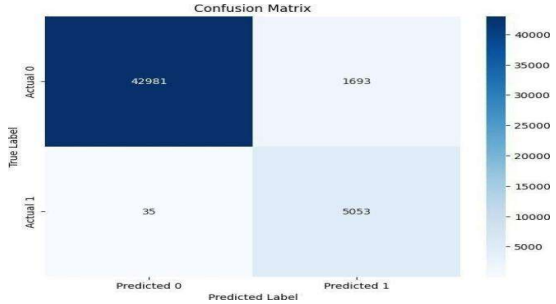

Fig 2. shows the confusion matrix of the trained model using XGBoost algorithm.

Figure 3 shows the system operating normally with the buzzer OFF

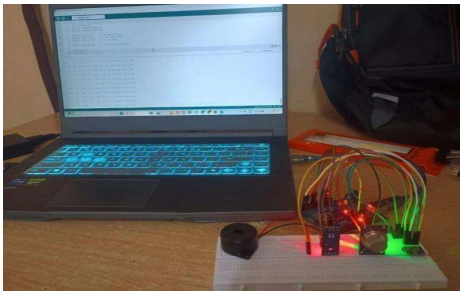

Fig 3. Shows that the Buzzer is OFF when the Thermal Status shows no Fire.

Figure 4 shows the buzzer activated when a fire condition is detected.

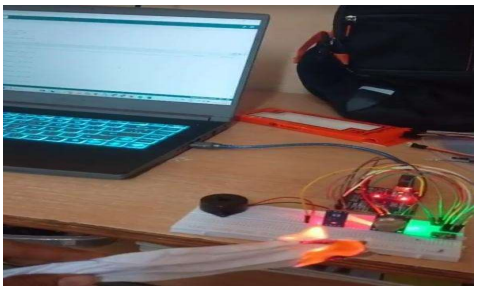

Fig 4. Shows that the Buzzer is ON when the Thermal Status shows Fire.

Figure 5 shows the system operating under normal conditions without any alerts

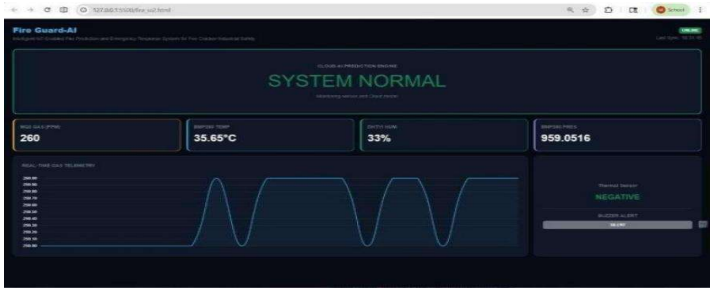

Fig 5. The UI will display Safe if the Sensor are Less than the threshold

Figure 6 illustrates the display on the dashboard while the system is in the alert mode. It will generate an alarm or warning message once values exceed the safety threshold.

Fig 6. The UI will display Alert if the Sensor are higher than the Threshold.

Figure 7 depicts the notification message received via Telegram when an emergency situation is detected by the system.

Fig 7 shows the emergency alert notification in Telegram received from the Esp8266

V. CONCLUSION

The proposed Fire Guard-AI system was developed to enhance safety in hazardous industrial environments such as fireworks manufacturing units. The system combines real-time environmental monitoring with machine learning-based prediction to identify potential explosion risks at an early stage. Environmental parameters are monitored using MQ-2, DHT11, BMP280, and MLX90640 sensors, while an XGBoost classifier is used to classify conditions as safe or hazardous. The trained model is deployed on a cloud server through a Flask API, enabling the ESP8266 to transmit sensor data and receive prediction results in real time. When a hazardous condition is detected, the system immediately activates a buzzer alert to warn workers. The proposed system reduces the need for continuous manual supervision while improving industrial safety. The results demonstrate that the integration of IoT and machine learning can provide an effective, scalable, and cost-efficient solution for explosion risk prediction and emergency response.

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