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Real Time Industrial Safety Prediction Using Smart Helmet

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Abstract: *Real-Time Industrial Safety Prediction using a Data Science and AI-enabled Smart Helmet enhances worker safety in hazardous environments like mining and manufacturing, where risks such as toxic gas exposure, high temperature, and falls are common. The system uses an ESP32 microcontroller with gas, temperature, and motion sensors to monitor conditions in real time. It analyses the data using predefined thresholds to detect unsafe situations. When a risk is identified, a buzzer alert is triggered to warn the worker, and data is sent to a cloud platform via Wi-Fi for remote monitoring. The system also performs basic predictive analysis to identify potential hazards early. Overall, the smart helmet is a cost-effective and efficient solution that ensures safety through real-time monitoring and local alerts, even with limited connectivity.*

Keywords: Smart Helmet, Industrial Safety, Real-Time Monitoring, Wearable Technologies

I. INTRODUCTION

Industrial environments such as mines, construction sites, and factories expose workers to hazards like toxic gases, extreme temperatures, and accidental falls. Traditional safety helmets provide only basic physical protection and lack real-time monitoring and alert capabilities.

To address this limitation, a smart helmet integrated with IoT and embedded systems is proposed to enhance worker safety through continuous monitoring of environmental and worker conditions. Sensors are used to measure parameters such as gas levels, temperature, and motion.

The collected data is processed by an ESP32 microcontroller to detect unsafe situations based on predefined thresholds. If any abnormal condition is identified, the system immediately alerts the worker through a buzzer, enabling quick response and preventing accidents.

In addition, the system transmits data to a cloud platform via Wi-Fi for remote monitoring and analysis. This helps supervisors track safety conditions, analyse trends, and take preventive measures, making the smart helmet a proactive and effective solution for industrial safety.

II. LITERATURE SURVEY

2.1. SMART HELMET WITH REAL-TIME GAS AND HEALTH MONITORING

Publication Year: 2024

Author: Sharma, V., Singh, A., & Patel, M.

Journal Name: International Journal of Computer Applications (IJCA)

This system integrates IoT technology into a smart stick to assist blind individuals. It uses ultrasonic sensors for obstacle detection and GPS modules for location tracking. The system can send emergency alerts to caregivers through GSM. The device enhances safety and allows real-time monitoring of the user's location

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2.2. INDUSTRIAL SAFETY MONITORING USING WIRELESS SENSOR NETWORKS

Publication Year: 2022 Authors: K. Rao and T. Joseph
Journal Name: International Journal of Engineering Research
This study focuses on monitoring industrial environments using wireless sensor networks. It detects hazardous gases and temperature variations, providing continuous safety monitoring and improving risk management in industries.

2.3. EMBEDDED SMART HELMET FOR HAZARDOUS WORK ENVIRONMENTS

Publication Year: 2020 Authors: S. Gupta and R. Mehta
Journal Name: International Journal of Embedded Systems
This paper presents a smart helmet integrated with gas sensors and a microcontroller. It provides real-time alerts when unsafe conditions are detected, enhancing worker protection in hazardous environments.

2.4. IOT-BASED WEARABLE SAFETY MONITORING SYSTEM

Publication Year: 2019 Authors: Y. Zhang et al. Journal Name: IEEE Xplore
This research proposes an IoT-enabled wearable safety system that collects and transmits data to the cloud. It enables real-time monitoring and analysis, supporting better decision-making for safety management.

2.5. FALL DETECTION AND ALERT SYSTEM USING EMBEDDED IoT DEVICES

Publication Year: 2023 Authors: D. Singh et al. Journal Name: IEEE Xplore
This research proposes on Implemented accelerometer- based fall detection with real time alert generation.

III. METHODOLOGIES

3.1. ESP32 Microcontroller: The ESP32 microcontroller acts as the core processing unit of the Smart Helmet system. It is responsible for collecting data from all connected sensors, processing the information, and enabling wireless communication through Wi-Fi or Bluetooth. Its high processing capability and low power consumption make it suitable for real-time industrial monitoring applications. The ESP32 ensures seamless integration between hardware components and cloud-based or monitoring systems.

3.2. Gas Detection Sensor (MQ Series): Gas sensors such as MQ-2 or MQ-135 are used to detect the presence of hazardous gases like carbon monoxide, methane, and other toxic substances in industrial environments. These sensors continuously monitor air quality around the worker. If the gas concentration exceeds a predefined safety threshold, the system immediately triggers an alert, ensuring early detection of dangerous conditions and preventing potential accidents.

3.3. Temperature Sensor: A temperature sensor (such as LM35 or DHT11) is used to monitor environmental temperature in real time. High temperatures in industrial areas can indicate fire hazards or unsafe working conditions. The sensor provides continuous temperature readings, and when abnormal temperature levels are detected, the system generates warnings to alert the worker and control unit.

3.4. Vibration / Accident Detection Sensor: A vibration or accelerometer sensor is integrated into the helmet to detect sudden impacts or abnormal movements that may indicate an accident. In case of a fall or collision, the sensor detects the sudden change in motion and sends an emergency alert. This enables quick response and assistance, reducing the severity of injuries.

3.5. IoT Communication Module: The system uses IoT technology to transmit real-time data from the helmet to a remote monitoring system. Using ESP32's built-in Wi-Fi capability, sensor data is sent to cloud platforms or

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dashboards where supervisors can monitor worker safety conditions continuously. This real-time communication enhances decision- making and allows immediate action during emergencies.

3.6. Alert System (Buzzer & Notifications): An alert mechanism is incorporated using a buzzer and digital notifications. When unsafe conditions such as gas leakage, high temperature, or accidents are detected, the buzzer provides immediate audible alerts to the worker. Simultaneously, notifications can be sent to supervisors or emergency contacts, ensuring rapid response to critical situations.

3.7. Machine Learning-Based Prediction: Machine learning algorithms can be applied to analyze historical and real-time sensor data to predict potential hazards. By identifying patterns such as rising temperature trends or gradual gas leakage, the system can provide early warnings before critical situations occur. This predictive approach enhances safety by preventing accidents rather than just reacting to them.

3.8. Helmet Detection Mechanism: The system ensures that the worker is wearing the helmet before entering hazardous zones. This can be implemented using pressure sensors or switch mechanisms within the helmet. If the helmet is not worn properly, the system restricts operation or sends alerts, enforcing safety compliance in industrial environments.

IV. SYSTEM ARCHITECTURE

4.1. Helmet Monitoring Module: The Helmet Monitoring Module ensures that the worker is properly wearing the smart helmet before entering the industrial environment. It uses sensors such as pressure or contact switches to detect helmet usage. If the helmet is not worn correctly, the system can restrict access or generate alerts. This module enforces safety compliance and ensures that workers follow mandatory protective measures.

4.2. Environmental Monitoring Module: This module continuously monitors environmental conditions such as gas concentration and temperature using sensors like MQ gas sensors and temperature sensors. It detects hazardous situations such as toxic gas leaks or excessive heat in real time. The collected data is processed by the ESP32, and if unsafe levels are detected, alerts are generated immediately to prevent accidents.

4.3. Accident Detection Module: The Accident Detection Module uses vibration or accelerometer sensors to identify sudden impacts, falls, or unusual movements of the worker. In case of an accident, the system quickly detects the abnormal condition and triggers emergency alerts. This ensures that immediate assistance can be provided, reducing response time and minimizing injury risks.

4.4. Data Processing and Control Unit: The ESP32 microcontroller acts as the central processing unit of the system. It collects data from all sensors, processes it, and determines whether the conditions are safe or hazardous. Based on predefined thresholds, it controls the alert mechanisms and communication modules. This unit ensures real-time decision- making and efficient system operation.

4.5 Communication Module (IoT Connectivity): This module enables wireless communication between the smart helmet and external monitoring systems using Wi-Fi. Sensor data is transmitted to cloud platforms or dashboards, allowing supervisors to monitor worker safety remotely. In case of emergencies, alerts and notifications are sent instantly, ensuring quick action and improved safety management.

4.6. Alert and Notification Module: The Alert Module provides immediate warnings when unsafe conditions are detected. It includes a buzzer for local alerts to the worker and can also send notifications to supervisors or emergency

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contacts. This dual alert system ensures both the worker and management are informed in real time, enabling faster response to hazardous situations.

4.7. Location Tracking Module: A GPS module can be integrated to track the real-time location of workers. In case of accidents or emergencies, the system sends location details along with alerts, helping rescue teams reach the worker quickly. This feature is especially useful in large industrial areas such as mines and construction sites.

4.8. Predictive Safety Analysis Module: This module uses machine learning techniques to analyze collected sensor data and predict potential hazards. By identifying patterns such as increasing gas levels or rising temperatures, it can generate early warnings before dangerous situations occur. This transforms the system from reactive monitoring to proactive safety management.

V. FLOWCHART

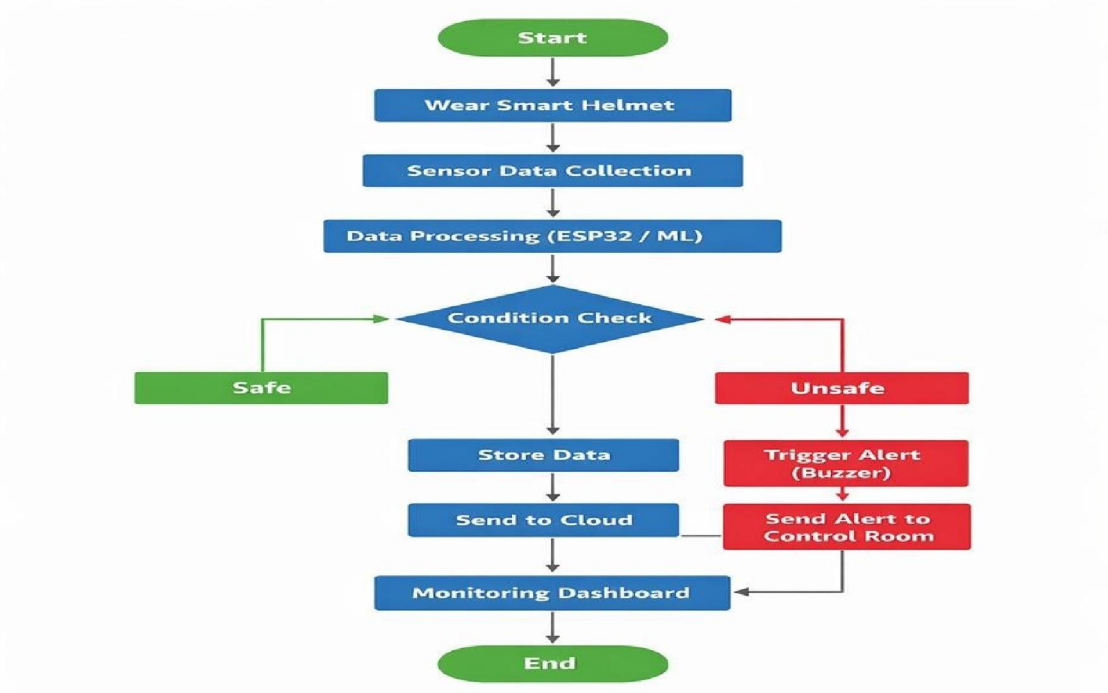

Fig 1-flowchart

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VI. RESULT AND DISCUSSION

6.1 OUTPUT

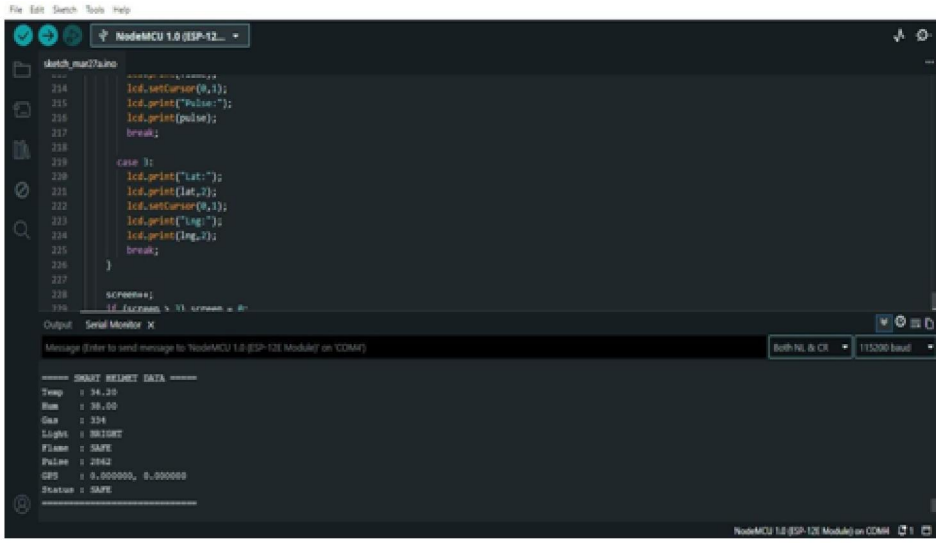

Fig 1- Transmitter Side

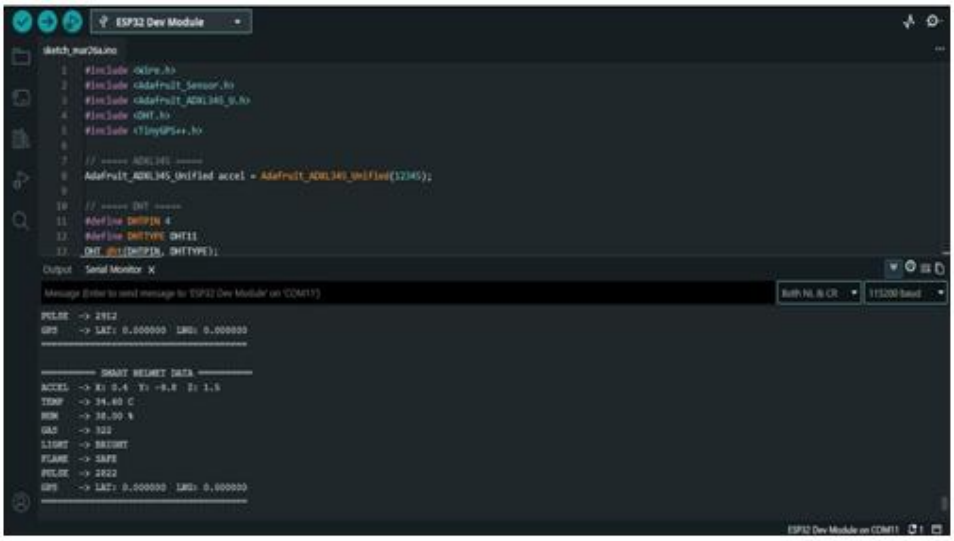

Fig 2-Receiver Side

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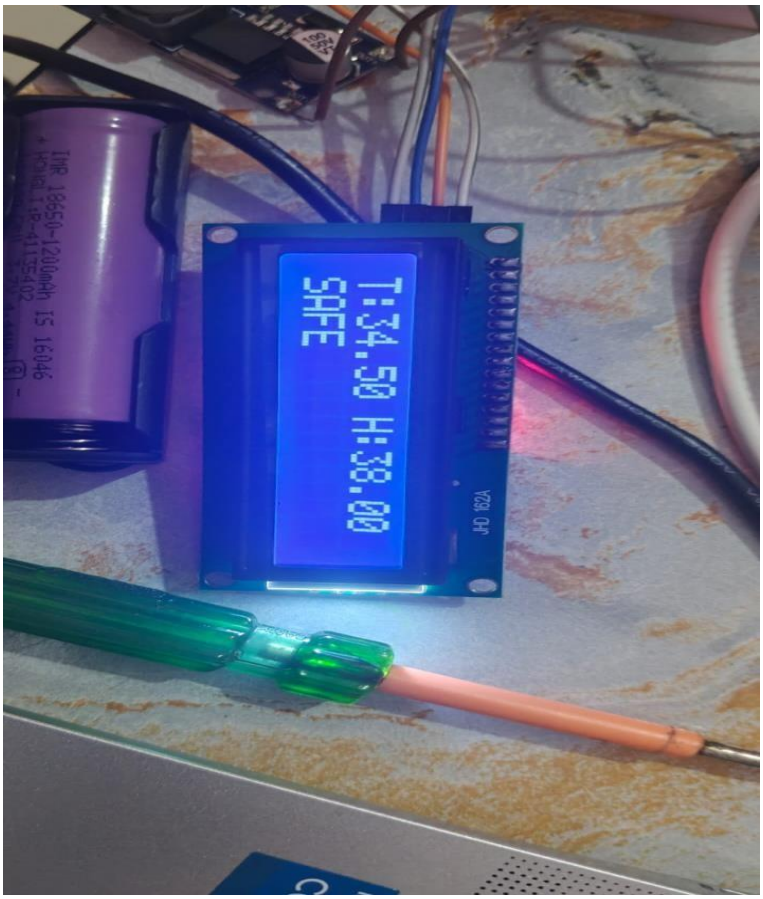

Fig 3-OLED Display

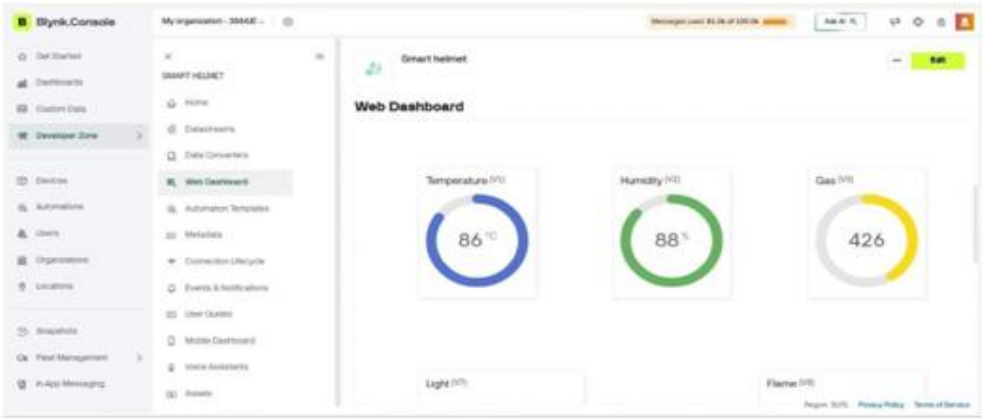

Fig 4-Web Dashboard View

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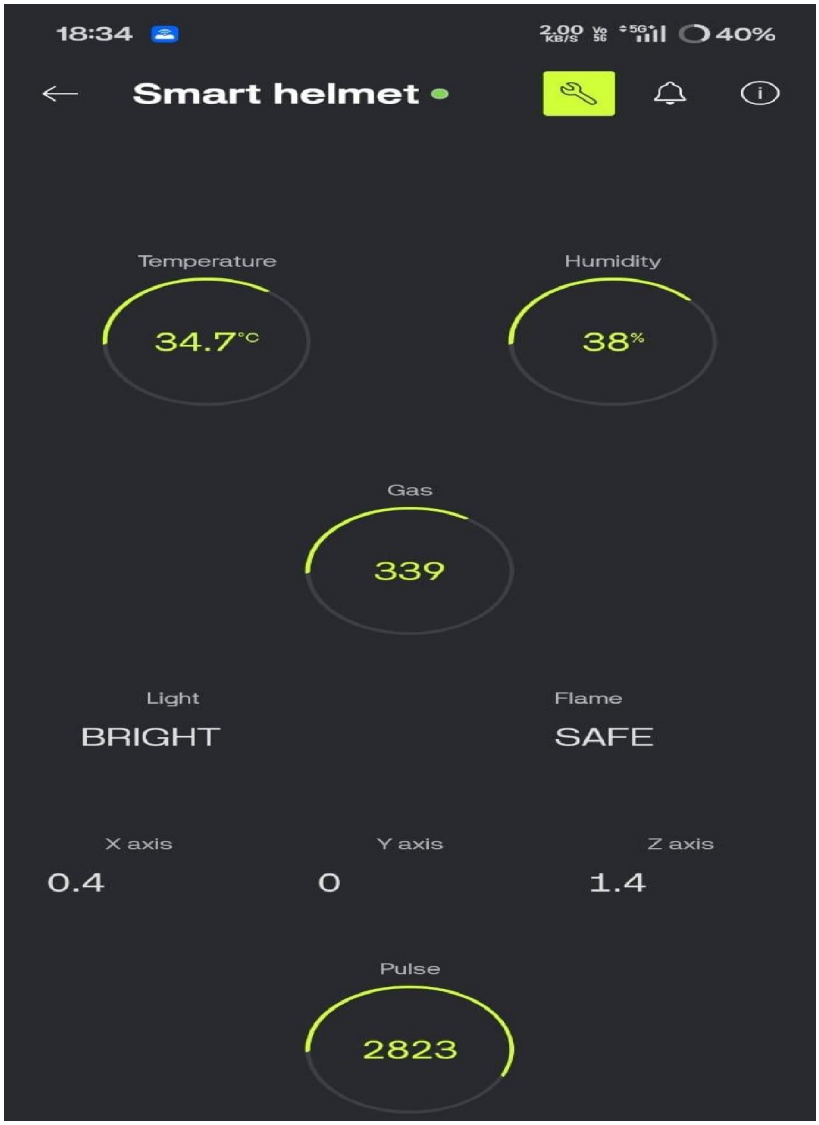

Fig 3-Mobile Friendly Dashboard View

6.2 PERFORMANCE ANALYSIS

The performance of the proposed system, "Real-Time Industrial Safety Prediction using Smart Helmet," was evaluated using key metrics such as accuracy, response time, reliability, and system efficiency. The system effectively identifies hazardous conditions including gas leakage, abnormal temperature variations, and helmet compliance through real-time sensor data analysis.

The machine learning model demonstrates strong predictive capability, producing results that closely align with actual environmental conditions while minimizing false alerts. The response time of the system is rapid, enabling immediate detection of unsafe situations and prompt alert generation, which is critical in industrial safety applications. Furthermore, the integrated dashboard provides near real-time visualization of sensor data, ensuring continuous monitoring and improved situational awareness.

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The system maintains stable performance during prolonged operation, indicating high reliability and consistent data transmission between hardware and the monitoring interface. The use of IoT and machine learning enhances the system's capability to predict and prevent potential hazards more effectively than conventional safety systems.

However, the performance may be affected by external factors such as sensor calibration and network stability. Overall, the proposed system demonstrates a robust, efficient, and scalable solution for real-time industrial safety monitoring, making it suitable for practical deployment in industrial environments.

VII. CONCLUSION

The Real-Time Industrial Safety Prediction using Smart Helmet is an effective and innovative solution developed to improve worker safety in hazardous industrial environments. The system successfully integrates sensors, ESP32 microcontroller, IoT technology, and Machine Learning to provide real-time monitoring and alert mechanisms. The smart helmet continuously monitors parameters such as gas levels, temperature, motion, and heart rate. It detects unsafe conditions and immediately alerts the worker using a buzzer, helping to prevent accidents. The use of Machine Learning enhances the system by predicting whether the working condition is safe or unsafe based on sensor data. The system also enables cloud-based monitoring, allowing supervisors to track safety conditions and take necessary actions. The proposed solution overcomes the limitations of traditional safety systems by providing early detection, real-time alerts, and intelligent analysis. Overall, the system improves workplace safety, reduces risks, and ensures better protection for workers in industrial environments.

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