IoT-Based Health Monitoring Jacket for Mine Workers

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Abstract—**Mining is one of the most dangerous working environments, where laborers are exposed to risks such as toxic gas leakage, fire accidents, high temperatures, and sudden health issues. Ensuring their safety in real time is a major challenge with traditional monitoring systems. To address this problem, this paper presents an IoT-based smart safety jacket designed to continuously monitor both environmental and health conditions of mine workers.**

The proposed system integrates multiple sensors, including gas sensors for detecting harmful gases, a temperature sensor for monitoring body and surrounding conditions, a heart rate sensor for tracking the worker's health, and a flame detection sensor for identifying fire hazards. These sensors are connected to a microcontroller, which collects and processes the data and sends it to a mobile application using IoT technology. A user-friendly interface developed using Blynk allows supervisors to monitor real-time data such as gas levels, temperature, heart rate, and GPS location of workers.

Whenever any abnormal condition is detected, such as increased gas concentration, presence of flame, or irregular heart rate, the system immediately triggers alerts through a buzzer as well as mobile notifications. This helps in taking quick action and reducing thechances of serious accidents. The system is designed to be lightweight, cost-effective,

and easy to use, making it suitable for practical deployment. Overall, the proposed smart jacket improves worker safety by providing continuous monitoring and faster emergency response in hazardous environments.

In addition to real-time monitoring, the system also enables continuous data logging, which can be useful for analyzing worker safety trends over time. The collected data can help supervisors identify risky patterns, improve safety protocols, and take preventive measures before accidents occur. This makes the system not only reactive but also proactive in ensuring workplace safety. Furthermore, the proposed design is flexible and can be adapted to other hazardous environments such as construction sites, chemical industries, and industrial plants. With the integration of IoT and wearable technology, the smart jacket contributes to the development of safer and smarter workplaces. Its simplicity, affordability, and effectiveness make it a practical solution for enhancing worker protection and reducing risks in real-world applications.

I. INTRODUCTION

Mining is considered one of the most hazardous occupations in the world due to the extreme and unpredictable conditions in which workers operate. Mine workers are frequently exposed to dangerous gases such as carbon monoxide and methane, high temperatures, low oxygen levels, and the constant risk of fire or explosions. In addition to environmental hazards, workers may also experience physical stress, fatigue, and sudden health issues due to the demanding nature of the job. Despite the availability of conventional safety equipment, many accidents still occur because of the lack of continuous monitoring and delayed emergency response. Therefore, ensuring the safety and well-being of workers in such environments remains a major challenge for industries.

In recent years, advancements in Internet of Things have opened new possibilities for improving industrial safety systems. IoT enables the connection of physical devices, sensors, and communication technologies to collect and exchange real-time data. This technology can be effectively used to design smart wearable systems that continuously monitor both environmental and physiological parameters of workers. By integrating IoT with wearable devices, it becomes possible to detect hazardous conditions instantly and provide timely alerts, thereby reducing the risk of serious accidents.

This paper proposes an IoT-based smart safety jacket specifically designed for mine workers. The jacket is equipped with multiple sensors, including gas sensors to detect harmful gases, a temperature sensor to monitor environmental and body conditions, a heart rate sensor to track the health status of workers, and a flame detection sensor to identify fire hazards. These sensors are connected to a microcontroller, which processes the collected data and transmits it to a mobile-based monitoring system. The monitoring interface is developed using Blynk, allowing supervisors to observe real-time data such as gas levels, temperature, heart rate, and GPS-based location of workers.

The main objective of this system is to provide continuous monitoring and immediate alert generation in case of abnormal conditions. When the system detects unsafe situations such as high gas concentration, presence of flame, or irregular heart rate, it triggers alerts through a buzzer and sends notifications to the mobile application. This ensures quick response and helps in preventing accidents or minimizing their impact.

Compared to traditional safety systems, the proposed smart jacket offers a more efficient and integrated solution by combining environmental sensing, health monitoring, and real-time communication. It is designed to be lightweight, cost-effective, and easy to use, making it suitable for practical deployment in mining environments. Furthermore, the system can be extended to other hazardous work areas such as construction sites and industrial plants, where worker safety is a critical concern.

II. LITERATURE REVIEW

[1] IoT-Based Wearable Health Monitoring System for Industrial Workers (Mehta et al., 2013)

Mehta et al. proposed a wearable health monitoring system aimed at improving the safety of industrial workers by continuously tracking physiological parameters such as heart rate and body temperature. The system enabled remote monitoring using IoT technology, allowing supervisors to observe worker health conditions in real time. While the approach was effective for health tracking, it did not include environmental monitoring features such as gas detection or fire sensing, which are critical in hazardous environments like mines.

[2] Smart Jacket with GPS and Health Monitoring for Laborers Working in Unsafe Zones (Mishra et al., 2022)

Mishra et al. developed a smart jacket that integrates GPS tracking and health monitoring to enhance worker safety. The system provides real-time location tracking and basic physiological monitoring, along with an emergency alert mechanism. However, the system lacks environmental hazard detection such as toxic gas sensing and flame detection, limiting its applicability in mining environments where such risks are common.

[3] Integrated Smart Helmet and Jacket System for Enhanced Worker Safety and Health Monitoring in Hazardous Environments (2025)

This study introduced an integrated wearable system combining a smart helmet and jacket to monitor both environmental and health conditions. The system enhances safety by providing multiple layers of protection and monitoring. Although it offers improved functionality, the increased complexity and cost of integrating multiple devices may reduce its practicality for large-scale deployment.

[4] Sensor-Based Worker Safety Monitoring System (Rao et al., 2022)

Rao et al. focused on developing a sensor-based monitoring system for improving worker safety using wireless communication technologies. The system emphasized real-time monitoring and alert generation. However, it did not provide a fully integrated solution combining environmental sensing, health monitoring, and location tracking within a single wearable device.

[5] Wearable Health Monitoring System (Haritha et al., 2018)

Haritha et al. proposed a wearable system that monitors physiological parameters such as heart rate and body temperature. The study demonstrated the effectiveness of wearable devices in detecting health abnormalities. However, it did not consider environmental hazards such as gas leakage or fire risks, which are essential in industrial safety applications.

[6] Wearable Systems for Monitoring the Health Condition of Soldiers (2017)
This research focused on monitoring soldiers' health in extreme environments using wearable sensors. The system provided reliable real-time monitoring of physiological parameters and communication capabilities. However, such systems are typically designed for defense applications and may not directly address industrial hazards or cost constraints.

[7] Wireless Detection System for Health and Military Application (Yallalinga and Benni, 2017)
Yallalinga and Benni developed a wireless detection system for monitoring health conditions and transmitting data in real time. The system demonstrated efficient communication between devices but lacked integration with environmental hazard detection systems, which are necessary for industrial and mining safety.

[8] Monitoring of Soldier's Health and Transmission of Secret Codes (Raza and Liaquat,2016)
Raza and Liaquat proposed a system for monitoring soldiers' health and securely transmitting data. The research highlighted the importance of real-time monitoring and secure communication. However, the system was primarily focused on military applications and did not address environmental risks such as gas leaks or fire hazards.

III. METHODOLOGY

The development of the proposed IoT-based smart safety jacket for mine workers is carried out using a structured methodology consisting of multiple phases. These phases ensure proper design, implementation, and evaluation of the system to achieve reliable performance in hazardous environments. The methodology is divided into five main stages: system design, hardware implementation, software development, testing and calibration, and performance evaluation.

1. System Design

In the system design phase, the overall architecture of the smart safety jacket is conceptualized by integrating both hardware and software components. The ESP32 microcontroller is selected as the central processing unit due to its built-in Wi-Fi capability, low power consumption, and sufficient input/output pins for sensor integration.
The system is designed to monitor both environmental and physiological parameters of mine workers. Key parameters identified include temperature, gas concentration, heart rate, flame presence, and worker location. Sensors such as the DHT11 temperature sensor, gas sensor (MQ series), pulse sensor, flame sensor, and GPS module are selected based on their sensitivity, accuracy, response time, and compatibility with the ESP32.
A block diagram and circuit diagram are developed to illustrate the interaction between sensors, the microcontroller, power supply, and IoT communication system. The system also includes a mobile-based monitoring platform using Blynk for real-time data visualization and alerts.

2. Hardware Implementation

After finalizing the design, the system moves to the hardware implementation stage. In this phase, all sensors are connected to the ESP32 microcontroller according to the circuit diagram.

- The DHT11 sensor is connected for temperature monitoring
- The pulse sensor is used to measure heart rate
- The gas sensor detects harmful gases in the environment
- The flame sensor detects fire hazards
- The GPS module provides real-time location tracking

All components are powered using a battery supply connected to the ESP32. Proper wiring and grounding are ensured to avoid signal noise and instability.
The ESP32 collects real-time data from all sensors and processes it based on predefined conditions. If any abnormal condition is detected, such as high gas concentration or flame presence, the system activates alert mechanisms such as a buzzer.
Special attention is given to compact design and proper placement of sensors within the jacket to ensure accurate readings and user comfort.

3. Software Development

In the software development phase, embedded programming is carried out using Arduino IDE for the ESP32 microcontroller. The software is designed to perform three major operations: data acquisition, decision-making, and communication.

• Data Acquisition

The ESP32 continuously reads data from all connected sensors, including temperature, heart rate, gas levels, and flame detection signals. The data is filtered and stored for processing.

• Control Algorithm

The system compares sensor readings with predefined threshold values. If any parameter exceeds the safe limit, appropriate actions are triggered. For example:

- High gas level → alert generated
- Flame detection → buzzer activated
- Abnormal heart rate → notification sent

• Communication and User Interface

The processed data is transmitted via Wi-Fi to a mobile application developed using Blynk. The app displays real-time values and sends notifications in emergency situations.

Efficient programming techniques such as conditional statements, timers, and interrupt handling are used to ensure smooth system operation.

4. Testing and Calibration

After integration of hardware and software, the system undergoes testing and calibration to ensure accuracy and reliability.

Each sensor is calibrated individually:

- Temperature sensor is tested under different conditions
- Gas sensor is exposed to controlled gas levels
- Pulse sensor is tested with real human input
- Flame sensor is tested using a small flame source

The system is tested under simulated mining conditions to evaluate:

- Sensor response time
- Accuracy of readings
- Alert generation timing
- Stability during continuous operation

This phase ensures that the system performs reliably in real-world conditions.

5. Performance Evaluation

The final phase involves evaluating the performance of the developed smart safety jacket. The evaluation is based on the following parameters:

- Monitoring Accuracy: Accuracy of sensor readings compared to standard values
- System Responsiveness: Time taken to detect hazards and generate alerts
- Reliability: Continuous operation without failure
- Energy Efficiency: Power consumption of the system
- Safety Improvement: Ability to reduce risks and provide timely alerts

The results show that the system is capable of providing real-time monitoring and rapid response, making it suitable for enhancing safety in mining environments.

Detailed Design

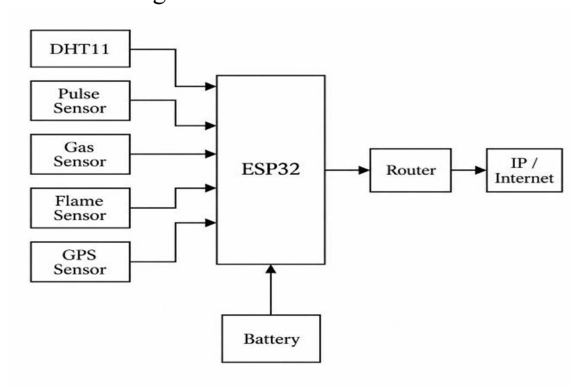


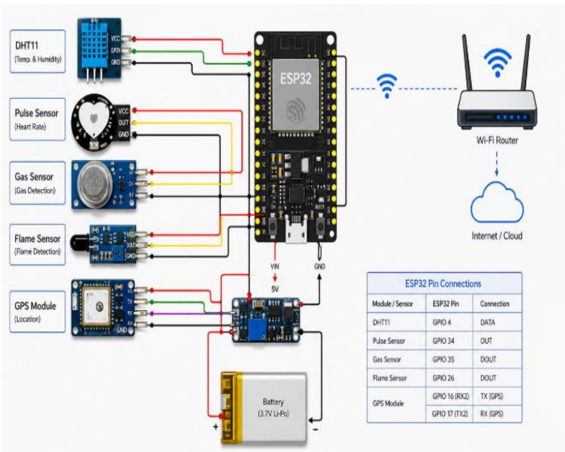
Fig.1 Block Diagram of Proposed System

IV. SIMULATION SETUP

The proposed IoT-based smart safety jacket system was designed and implemented using the ESP32 microcontroller integrated with multiple sensing modules. The system enables real-time monitoring of environmental and physiological parameters and transmits the data to a remote monitoring platform.

1. System Configuration

The system consists of an ESP32 microcontroller interfaced with multile sensors, including a DHT11 sensor for temperature and humidity monitoring, a pulse sensor for heart rate measurement, a gas sensor for detecting harmful gases, a flame sensor for fire detection, and a GPS module for location tracking. The ESP32 acts as the central processing unit, responsible for data acquisition, processing, and communication.



2. Hardware Integration

All sensors are connected to the ESP32 through designated GPIO pins as per the system design. The DHT11 sensor is interfaced with GPIO 4, the pulse sensor with GPIO 34, the gas sensor with GPIO 35, and the flame sensor with GPIO 26. The GPS module is connected using UART communication, where its TX and RX pins are interfaced with GPIO 16 and GPIO 17 of the ESP32, respectively.

Proper wiring practices are followed to ensure stable connections, and a common ground is maintained across all components to minimize signal noise and ensure reliable operation.

3. Power Supply Arrangement

The system is powered using a 3.7V lithium-ion battery. Since the ESP32 requires a higher input voltage, a boost converter module is used to regulate the voltage to 5V, which is supplied to the VIN pin of the microcontroller. The sensors operate at 3.3V, ensuring compatibility with the ESP32 logic levels. This arrangement provides stable and efficient power distribution throughout the system.

4. Communication and Data Transmission

The ESP32 utilizes its built-in Wi-Fi capability to establish a connection with a wireless network. Sensor data is transmitted to a cloud-based monitoring platform developed using Blynk. The application enables real-time visualization of various parameters, including temperature, gas levels, heart rate, flame detection status, and GPS-based location tracking.

5. Operational Workflow

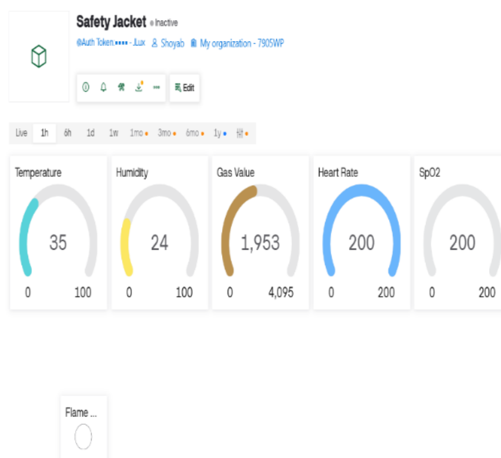
During system operation, the ESP32 continuously collects data from all connected sensors and processes it based on predefined threshold values. If any parameter exceeds the safe limit, the system initiates an alert mechanism. This includes activating a buzzer and sending notifications to the mobile application. Simultaneously, the GPS module updates the location data, enabling accurate tracking of the worker during emergency situations.

6. Testing and Validation

The system was tested under simulated conditions to evaluate its performance and reliability. Various test scenarios were implemented to analyse sensor response, data transmission, and alert generation. The system demonstrated stable performance, accurate data acquisition, and minimal delay in communication.

7. Performance Observation

The implemented system showed effective real-time monitoring and rapid response to hazardous conditions. The integration of multiple sensors with IoT communication ensured continuous tracking and timely alerts. The results confirm that the system is suitable for enhancing safety in mining and other hazardous working environments.



V. CONCLUSION

This paper presented the design and implementation of an IoT-based smart safety jacket for mine workers, aimed at enhancing safety in hazardous working environments through real-time monitoring and alert mechanisms. The proposed system integrates multiple sensing modules, including temperature and humidity monitoring using the DHT11 sensor, gas detection using an MQ-series sensor, heart rate monitoring through a pulse sensor, flame detection for fire hazards, and GPS-based location tracking. All sensors are interfaced with the ESP32 microcontroller, which serves as the central processing and communication unit.

The system enables continuous acquisition and transmission of environmental and physiological data to a cloud-based monitoring platform developed using Blynk. The Blynk interface provides a user-friendly dashboard for real-time visualization of key parameters such as temperature, humidity, gas concentration, heart rate, and oxygen saturation (SpO_2). As observed in the output interface, the system successfully displays live sensor values with minimal delay, demonstrating effective wireless communication and data handling capabilities.

The experimental results indicate that the system responds efficiently to changing environmental conditions. For instance, the gas sensor readings reflect variations in air quality, while the heart rate sensor provides continuous monitoring of the worker's physiological condition. The flame detection module ensures immediate identification of fire hazards, and the alert mechanism triggers notifications and buzzer activation when predefined threshold limits are exceeded. Additionally, the integration of GPS enhances the system by enabling accurate tracking of workers' locations, which is crucial during emergency situations and rescue operations.

The proposed smart safety jacket offers a compact, cost-effective, and reliable solution for improving worker safety in mining and other hazardous environments. By combining IoT technology with wearable systems, the solution ensures continuous monitoring, rapid hazard detection, and timely response, thereby reducing the risk of accidents and improving overall workplace safety.

The inclusion of the Blynk-based monitoring interface further validates the practical applicability of the system, as it allows remote supervision and real-time decision-making. Overall, the developed system demonstrates strong potential for real-world deployment and can be further enhanced with advanced features such as predictive analytics, AI-based risk assessment, and integration with industrial safety management systems.

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