Journal of Artificial Intelligence and Computing (JAIC)
ISSN (p): 3005-3358
Volume: 1, Number: 2, Pages: 13- 17, Year: 2023

IoT Based Smart Helmet for Unsafe Event Detection for Mining Industry

Ali Hamza, Muhammad Haris Rauf, Muhammad Hashir and Muhammad Kounain

Electrical Engineering Department, Government College University, Lahore, 54000, Pakistan
Corresponding author: Muhammad Haris Rauf (Email: harisrauf2@gmail.com)

Received: 10/05/2023, Revised: 20/10/2023, Accepted: 12/11/2023

Abstract--**The major goal of this project is to design a system that could detect and communicate with the control room in case of an emergency. Methane, Carbon Monoxide and Hydrogen Sulfide gases are hazardous for humans and are present in higher concentrations in mines. This system will help overcome this problem and help detect the gases at an early stage. Coal mining can cause several adverse effects on the environment. For instance, Toxic gases may be released into the air, causing suffocation, gas poisoning, roof collapse, and gas explosions. Considering all these viewpoints, the designed system is an IoT-based smart Helmet for Unsafe Event Detection for the Mining Industry for monitoring abnormal conditions. Some of the abnormal conditions include the leaking of hazardous gases and rise/fall in temperature and humidity levels. After detecting gases, the next essential step is communicating the collected sensor data to the control room using an appropriate wireless communication module. The features in our system increase the life expectancy of the coal miners by warning them about danger using a buzzer alarm and giving the information to the control room for immediate help.**

Keywords: Smart helmet, Internet of Things, detection, mining industry, wireless fidelity.

I. INTRODUCTION

The Internet of Things (IoT) is the network of devices connected to the Internet. IoT does not contain a single device, software, or technology; it combines devices and objects with sensors that gather data and information from different devices and implement analytics to share the most important information with applications to address particular demands. That helps us to offer recommendations and detect problems before they happen [1-5].

IoT is applied in every sector to enhance, facilitate, automate, and manage various processes. A smart helmet is one such application of IoT that helps and benefits coal miners and protects them from unsafe events during coal mining. Mining is a multifaceted industry that includes complex processes conducted in tunnels underground. This includes many risk factors that could harm mine workers' health [6-12].

The coal mines produce large amounts of gases with distinct chemical properties and behaviours, so it is required to classify them as suffocating, toxic, and combustible. Classification of these gases is Combustible gases: Methane and Hydrogen—toxic gases: Carbon monoxide and hydrogen sulphide. The mixture of these gases in the underground atmosphere of the coal mines can produce flammable environments; rather than relying on the percentages of concentration of each gas, it can explode violently. Table 1 below shows the explosive concentration limits for the gases found in the coal mines' atmosphere [1, 13-17].

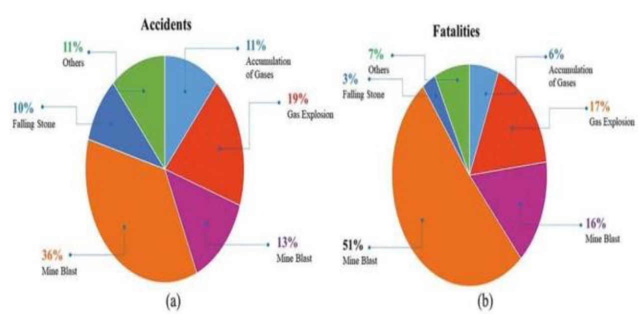
Gas	Explosivity Limits		Stoichiometric Limits
	Lower Limit[%]	Upper Limit[%]	Gas[%]
Methane	5.0	14.0	5.9
Carbon Monoxide	12.5	74.2	13.8
Hydrogen Sulphide	4.0	74.2	4.3
Carbon Dioxide	0.03	25	1.53

Table 1: shows the explosive concentration's limits

II. PROBLEM STATEMENT

How might we detect abnormal conditions early in the mine and communicate them to the control room to prevent fatalities." The mining industry is essential to the world's economy. However, it is not one of the safest industries to work in. The life of miners is always at risk. This project attempts to help the miners in distress so that they receive immediate help. 3% of fatalities Last, the accumulation of gases caused 11% of accidents and 6% of fatalities

Figure 1: Cause-Wise statistic of fatalities in the Mining



Industry

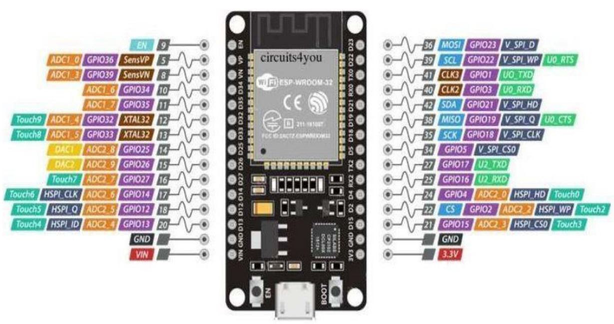
III. PROPOSED SOLUTION TO EXISTING PROBLEMS

In this design, an ESP8266 microcontroller will be used for wireless communication. This provides WiFi dual-mode Bluetooth connectivity to the devices. Its two CPU cores are individually controlled, and those CPU cores operate at the clock frequency of 80 to 240 MHz that is adjustable.

The ESP8266 combines a Wi-Fi transmitter and receiver. In this way, it connects to a Wi-Fi network and with the Internet and can set up its network, and other devices like micro controllers can directly connect to it. ESP8266 uses serial communication. It has three serial ports named UART0, UART1, and UART2 [18-23].

UART stands for Universal Asynchronous Receiver Transmitter. It serves the main purpose of transmitting and receiving serial data. To do the communication, two UARTs need to communicate with each other directly. On the transmission side, parallel data from a controlling device is converted into serial data and then transmitted to the receiving side of UART. On the receiving side, received data is converted into parallel again and sent to the device on receiving side. Tx pin of the transmission side UART is used to flow data to the Rx pin of the receiving UART [7, 24-28].

Figure 3: Pin Configuration of ESP8266



IV. DESIGN AND ARCHITECTURE

Our goal is to design a smart helmet for coal miners that aims to detect the gases present in mine like methane, carbon monoxide, carbon dioxide, hydrogen sulphide, etc and communicate to the control room. The block diagram of the proposed circuit is in Figure 4.

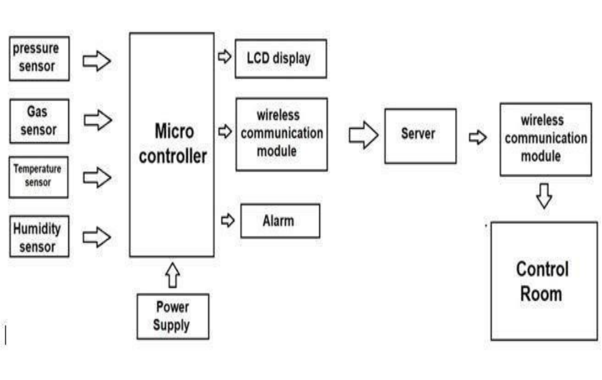


Figure 4: Block diagram of the complete system.

V. FATAL GASES IN COAL MINE

As we know that the gas explosion is one of the major causes of the underground mine disaster. As these gases are colorless, odourless, and highly combustible, they leak during mining, and if they are left uncontrolled, they can explode violently and result in a mine blast. So, it is necessary to detect them at an early stage. Therefore, MQ2, MQ135, and MQ136 are used to detect the level of Methane, Carbon Monoxide, Carbon Dioxide, and Hydrogen Sulphide, respectively, as these gases are present in more concentration than others. Also, the DHT11 sensor is used to monitor the temperature in the mine. These are semiconductor-type sensors. At the same time, if gases level is increased above a threshold, the alert alarm will turn on.

Sensors Used	Gases
MQ-2	Methane and Carbon Monoxide
MQ-135	Carbon Dioxide
MQ-136	Hydrogen Sulphide
DHT11	Temperature and Humidity

Table 2: Sensors used for Respective Gases

VI. SYSTEM ARCHITECTURE

Following is the simulation of our circuit in which the sensors are connected with Arduino to detect the gas. Whenever the gas is detected, it will be displayed on the LCD, and the buzzer will turn on, alerting the workers in the mine. This simulation has been made with MQ2 and MQ-135 sensors because of the unavailability of the libraries of other sensors in Proteus.

But in the hardware design, all required components will be used. In Figure 5, it can be seen that the simulation is in the initial stage, and the LCDs the message " Gas Detector," which means that at this stage, the gas sensors are not sensing any gases, and LCD is ready to display the results after detection.

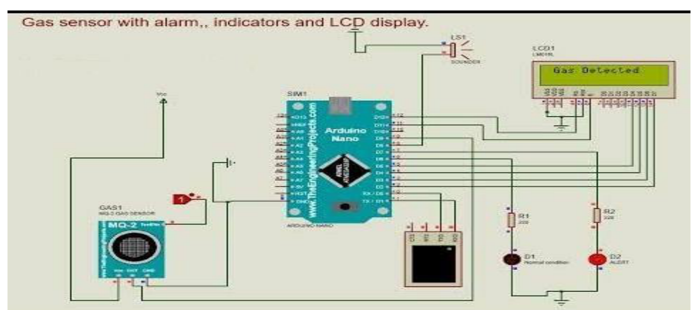


Figure 5: Simulation for Gas Detector

In Figure 6, it can be seen that the toggle switch connected to the sensor MQ-2 is high. The sensed data is sent to Arduino which makes the LCD show the message " Gas Detected " and that means the gas is detected. Similar results can be observed from the MQ-135 sensor in this simulation.

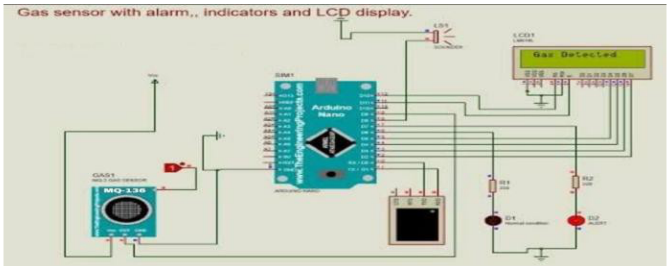


Figure 6: Simulation for Gas Detected

Arduino Nano has been used for the detection circuit to obtain sensor values as an input. The layout of the board is shown in the figure. Pins used are power pins, ground pins, analog input pins to get data from A0 to A2, digital pin 7 to get data from a temperature and humidity sensor, and pins for I2c, such as A5 and A4.

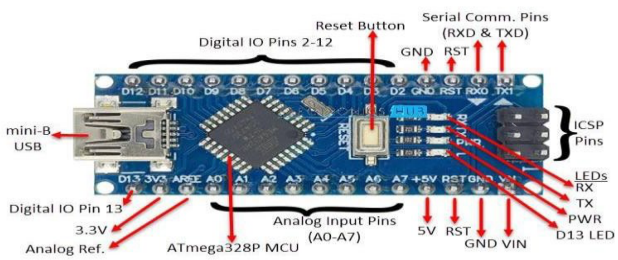


Figure 7: Arduino-nano-Board-Layout

VII. IMPLEMENTATION AND TESTING

Practically our project is implemented in three steps:
Step 1: Detection of gases, temperature, and humidity
The MQ series of gas sensors have been used to detect gases, and a temperature sensor to check the rise/fall in temperature and humidity in coal mines. If the danger in the mine has been confirmed, an alarm will be turned on to alert the miners to evacuate the mine. Initially, we displayed concentrations of gases on LCD to obtain results.
Note:
The concentration of gases could not be detected in real time because:

- Gases are required in large concentrations to test the detection circuit.
- Anyone needs professional training to handle those fatal gases as we are not trained professionals so it will be dangerous to handle those gases on university premises.
- Even if you are trained, you need a license from the government to buy those gases from labs.

The prototype of our designed detected circuit is shown below;

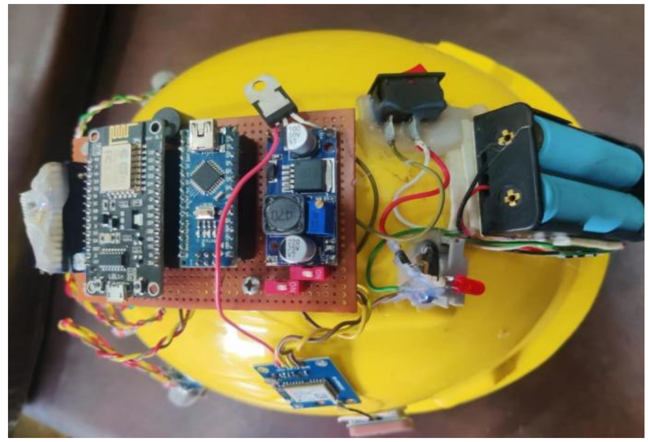


Figure 8: Hardware Implementation

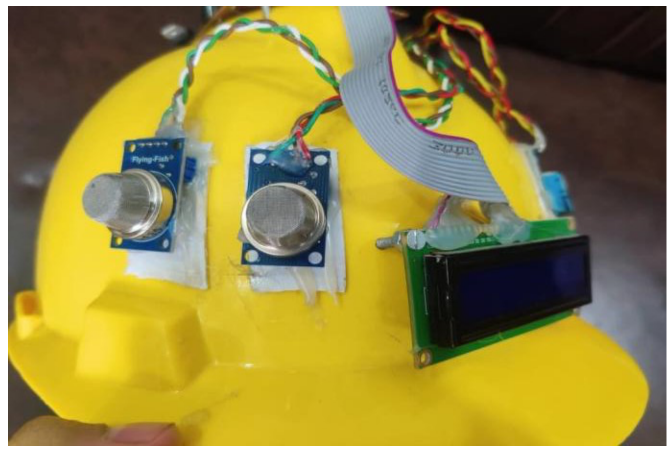


Figure 9: Hardware Implementation

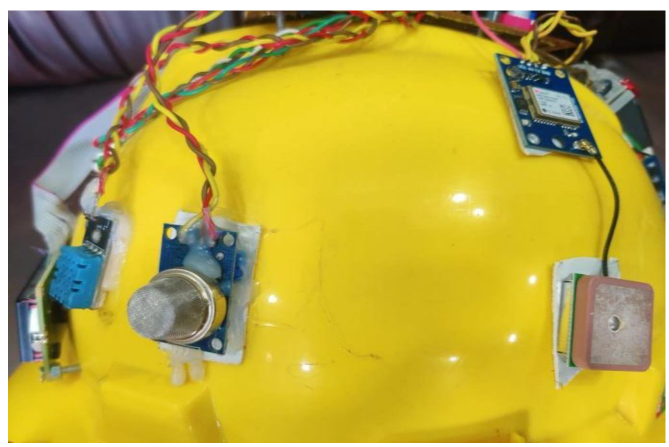


Figure 10: Interfacing

The sensor values obtained on the Arduino are stored in an array in string data type.

for this purpose, we have connected Arduino GND Pin with ESP32 GND Pin. Also, we have connected Arduino with a battery bank for power supply. To exchange data between ESP32 and Arduino, the baud rate is kept at 115200 and 9600 bits per second, respectively. Using the ESP32 as an Access Point, a web server is developed by creating an Html page. The control room can access the ESP32 web server by typing the ESP32 IP address on a browser in the local network [29].

Figure 11: GPS Location shown on app

The value of sensors are set to the threshold up to which the gases become fatal for the miners. If any of the dangerous gases exceed the threshold limit in the mine, the buzzer turns ON and alerts the miners for their safety. Besides this, the status about the detection of gas updates on the webserver too. In this way, the immediate help is send to the miners from the control room.

Figure 12: Implementation

Initially, the detection circuit was implemented on the breadboard to test the proper working of sensors, and the detected values were displayed on the LCD. Then, the ESP32 was connected with the detection circuit to test the communication with the control room.

In the end, the overall circuit of detection and interfacing was implemented on the helmet. The figure below shows the final prototype of our project.

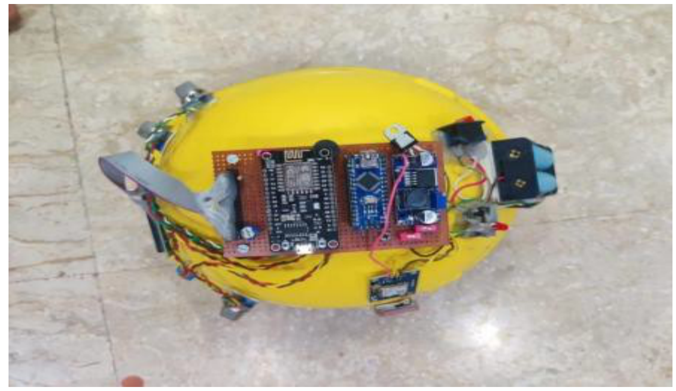


Figure 13: Implementation on Helmet (Top View)

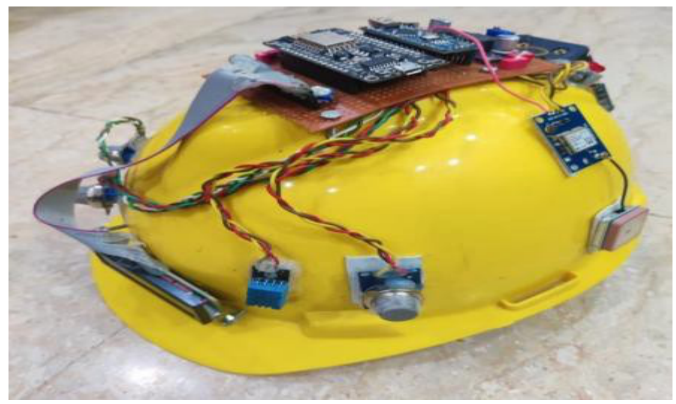


Figure 14: Implementation on Helmet (Side View)

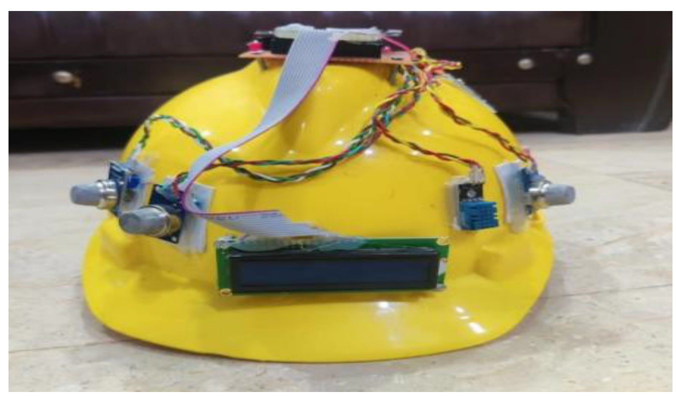


Figure 15: Implementation of Helmet

VIII. CONCLUSION

Different sensors have detected the deadly gases of the coal mine, e.g., MQ2 is detecting methane, carbon monoxide and smoke, MQ135 is sensing carbon dioxide, MQ136 is detecting hydrogen sulphide, and DHT11 is monitoring the change in temperature and humidity in the mine. After detecting these conditions in case of calamity, the helmet's buzzer turns ON and alerts the miners.

As communication has been recognized as the major source of a problem in times of disaster, the data from the mine has been communicated and interfaced with the control room. The data is shown on a web server page accessed in the control room by its IP address. The web server page shows the concentration value and the status of each gas, temperature and humidity. In case the concentration of gas reaches the threshold limit, the value gets updated on the web server, and the status changes to" Gas Detected."

IX. FUTURE WORK

A helmet can be designed to fit components instead of placing them on the top for future work. Moreover, the prototype has been designed, and in the future, multiple similar nodes can be manufactured so that a large amount of data from different locations is analyzed by the server to get better and more precise results.

ACKNOWLEDGMENT

First, all render gratitude to Allah Almighty, who is the most merciful and gracious, who gave us confidence, strength and ability to complete this task. The way of excellence through the goal is achieved, succeeded only with the cooperation, courage and help provided to us by our supervisor Dr Noor Muhammad Sheikh who has contributed in the concept of the project. We thank him for the guidance throughout the course of the study. The Department Electrical Engineering GC University, Lahore provided us necessary instruments and other resources to deliver research work. We also express our thanks to the department and to the Head of Department as well who also helped us in completing our project via using the innovative techniques. Finally, we express thanks to our family for their love and generously providing us moral and financial support.

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