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Smart Wearable Device for Enhancing Safety and Efficiency of Coal Miners

Jasmine K.[1], Sanjith Krishna S.[2], Subashini B.[3], Swethaa Shree V.[4], Rajavarma R.[5]

[1]Assistant Professor, Electronics and Communication Engineering, Kumaraguru College of Technology, Coimbatore, India

[2,3,4,5]Electronics and Communication Engineering, Kumaraguru College of Technology, Coimbatore, India

E-mail: [1]jasmine.k.ece@kct.ac.in, [2]sanjithkrishna.22ec@kct.ac.in, [3]subashini.19ec@kct.ac.in, [4]swethaashree.19ec@kct.ac.in, [5]raja.19ec@kct.ac.in

Abstract

The task of ensuring worker safety in underground coal mines has never been simple. It has always been challenging to ensure worker safety in underground coal mines. Coal miners are seriously injured or killed as a result of numerous fatal and non-fatal accidents all over the world. Accidents occur as a result of lack of monitoring of mining areas and failure to implement proper safety measures. In this review, the coal miner's smart wearable safety device is implemented. A smart wearable safety device that will monitor the miner's health and provides precautionary measures for the miner's safety has been developed with the advent of the Industrial Internet of Things (IIoT). Integrating smart wearable safety devices with various health sensors such as a pulse rate sensor, temperature sensor, blood oxygen sensor, gas sensor, and camera, and then connecting it to Node MCU, and the internet enhances the safety of coal miners. Sensors constantly transmit sensor data to the cloud, and if an unusual situation arises, it notifies the responsible person in the control room as well as the miners. Since deep underground mining is especially susceptible to toxic gases, low levels of oxygen, and hazardous gases, the MQ gas sensor family can detect them. The proposed system is primarily used to improve working conditions inside coal mines and to ensure workers' safety.

Keywords: Coal Miner Safety, Wearable Device, Sensors, Camera, IIoT

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1. Introduction

An intelligent wearable safety device is being developed that monitors the health of miners and also provides precautions for miner safety. The developed system will be implemented primarily to improve working conditions in the mines and ensure worker safety. Because mining takes place deep underground, it can be more vulnerable to toxic fumes, low oxygen levels, and noxious gases [1][2][3]. A smart wearable safety device is equipped with different internal sensors to sense the health parameters of miners working in mine by using Arm cortex (RP2040). After collecting the data, the sensor is connected to the ESP8266 Node MCU, which includes an inbuilt Wi-Fi module, for processing and sending the sensor data to a server. The responsible authority can then make decisions based on the signals received from the sensor [4][5]. Through a number of techniques, wearable technology has the ability to drastically reduce the risk to miners while increasing output [6][7].

- Confidentiality: Only authorised parties should have access to sensitive information.
- Integrity: Information sent over the AMI (Advanced Metering Infrastructure) must be true and accurately reflect the information it is based on, free from unwanted tampering.
- Design complexity can be lowered and made more compact.
- Low-cost implementation.

With the rise of the Industrial Internet of Things (IIoT), a smart wearable safety device has been created that uses the IoT idea to monitor the miner's health and suggest preventative actions for their safety. Including a camera, temperature sensor, blood oxygen sensor, CO2 sensor, and other health sensors in a smart wearable safety device before connecting it to a Node MCU, which connects the WiFi module to the internet [8][9][10]. Sensor data is continuously sent to the cloud by the sensors, and if anything odd happens, it not only alerts the miners but also the alerts the person in the control room [11][12].Due to the fact that mining is done deep underground, where it is more likely to be exposed to toxic gases, low oxygen levels, and other dangers, the MQ gas sensor family can be used to detect hazardous gases [13]

The system's main goals are to protect worker safety and enhance working conditions in coal mines .

2. Literature Review

In this study, the low-power wide area network (LPWAN)-based real-time monitoring system is created for the unfavourable environment as well as the high labour intensity, the demanding physical workload, and the bad health of coal mine workers. The long short term memory (LSTM) is the foundation for the prediction technique for the health state of miners, thus an intelligent sensing node integrated with edge computing capabilities has been developed [9]. But the complexity of modifying the algorithm is a disadvantage [2].

The research paper focuses on creating a smart system meant to be attached to the helmets worn by coal miners working underground. This intelligent system intends to continuously monitor and assess several crucial hazardous factors present in these mines in real-time. The parameters it will track include humidity levels, temperature, and the concentrations of gases like sulphur dioxide and methane [4]. If certain threshold limits for these factors are exceeded, it could potentially lead to dangerous situations such as flooding, suffocation due to lack of oxygen, gas poisoning, and cave-ins or roof collapses [13].

This research involves designing a prototype system aimed at detecting various parameters related to the health and safety of miners. It can sense the presence of hazardous gases, monitor the miners' pulse rates, provide real-time updates on temperature and humidity levels, as well as pinpoint the precise depth location and global positioning of each miner [13]. However, a limitation of this research is that it lacks the capability to conduct live video monitoring through a camera [8].

This research proposes a novel solution aimed at enhancing industrial safety and promoting employee health in the workplace. It introduces a new garment, termed as a "smart jacket," which integrates advanced technologies such as the Internet of Things (IoT) and Wireless Body Area Network (WBAN) [6]. However, a limitation of this project is that it is primarily focused on monitoring the health parameters of miners, thereby restricting its scope [7].

3. Block Diagram

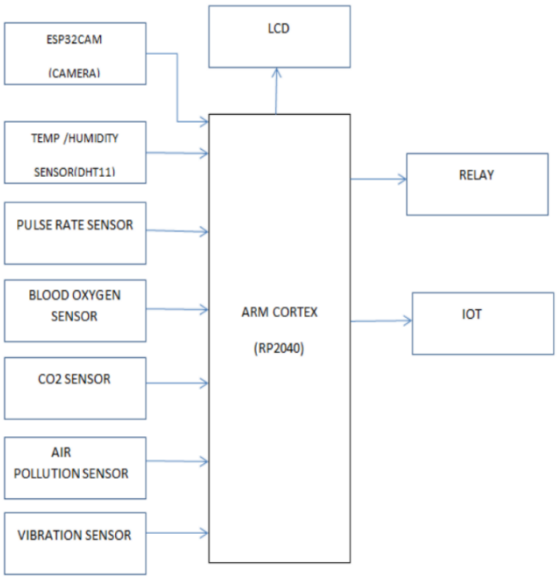

Figure 1. Block Diagram of the Proposed System

This microcontroller collects data from sensors, which is then displayed on an LCD. The NodeMCU is connected to the RP2040, and a camera is used to monitor all the values.

4. System Requirements

A. Hardware Requirements

1. RP 2040
2. Power supply
3. 16x2 LCD display
4. DHT 11 Sensor
5. Pulse rate sensor
6. CO2 sensor
7. Dust sensor
8. MAX 30100 -O2 sensor

9. Node MCU

10. Relay

11. Vibration sensor

12. ESP32-cam

B. Software Requirements

1. Arduino IDE

2. Embedded C

3. Blynk app

5. System Working

Gas sensors, temperature, and humidity sensors, dust sensors, pulse rate sensors, oxygen sensors, LCDs, and vibration sensors are all included in the safety coat. A gas sensor is used to find out the awareness of different gases, together with carbon dioxide (CO_2), carbon monoxide (CO), and methane (CH4), internal in a coal mine. To estimate the crucial temperature factors within the mine, a temperature sensor DHT11 may be used. A humidity sensor is used to calculate the quantity of moisture that is present all through the mine at various locations, and it also encourages us to keep up the ventilation inside a mine. In the event that a mine worker faints or experiences a drop in blood pressure due to a lack of oxygen, the device will also detect their pulse rate and assist in getting them immediate medical attention.

This complete information set might be visualized on a liquid crystal display and fed into the ESP-8266 wi-fi shield module, whose primary characteristic is to configure itself with the router and acquire a dynamic IP address. The entire set of data will be wirelessly transmitted to the given IP once it has been assigned. Through an application, the data the sensors collect are gathered and sent to the PC display in the control room. Cameras are used to monitor the minefield in real time. If the values are higher than the advised values, and an alarm flag is sent to the safety division as well as to that specific person when the vibration sensor in their coat vibrates. For the benefit of all the excavators, these data are gathered and stored. The computer in the control room considers all of the qualities that are acquired with the qualities displayed in the database. It is done independently for every one of the people.

6. Results

The ability of the prototype to identify carbon monoxide and methane in domestic gas is being tested. The equipment was moved closer to the domestic gas source for this purpose. When the gas concentration exceeded the predetermined threshold limit values, the gadget was found to have successfully activated the alarm. Since the car exhaust has higher temperatures and humidity levels, the temperature and humidity sensor test equipment were placed closer to the vehicle exhaust. To check the heart rate sensor, just place your finger on the heart rate sensor and this sensor can show you the current heart rate. To check the dust sensor, we need to add dust to the sensor, which shows the dirt or dust value on the LCD. The device triggered an alarm when the oxygen, heart rate and gas sensor readings exceeded the set threshold limit values. This will also help in tracking the miner and if for some reason there is a panic scenario, the team outside the mine can easily see how many miners have come out and how many remain in the mine.

Figure 2. Final Representation of Gas Detection and Monitoring using RP2040 Controller

A. Data Acquisition in Software

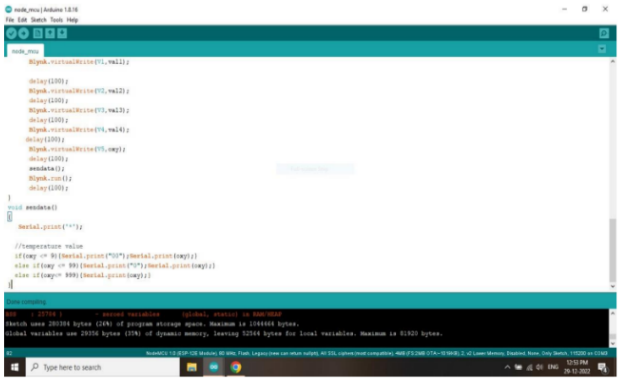

Figure 3. A Snapshot of the Code Compiling Process from the IDE

The figure accompanying this study outlines the system architecture for data acquisition in an RP2040 project aimed at gathering sensor data from devices including the DHT11, CO2 sensor, dust sensor, and MAX30100-O2 sensor, all integrated with the Blynk IoT cloud platform through the ESP8266 Wi-Fi capabilities. In the data acquisition process, the RP2040 serves as the central controller, interfacing with each sensor using their respective communication protocol. Data collection occurs at regular intervals, followed by processing, which may involve calibration or filtering to ensure accuracy. The processed data is then transmitted to the Blynk IoT cloud platform through Wi-Fi connectivity, leveraging Blynk's libraries and APIs for seamless integration. Critical to this process is the detailed configuration of sensor connections, calibration steps, and programming logic, addressing any challenges encountered during development. This comprehensive approach facilitates real-time monitoring and analysis of environmental parameters, enhancing industrial safety and employee health in hazardous workplaces.

B. Results Displayed in Blynk App

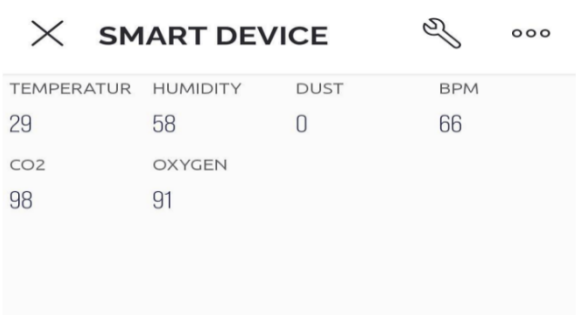

Figure 4. A Snapshot of the Results Page on the Blynk Infrastructure Access Portal

7. Conclusion

This study covers the safety status of coal mining and other prevalent risks in coal mines. We propose using IoT-based smart safety jackets for miners and controlling gases in coal mines to maintain a clean and safe environment. Various factors affect a miner's health, such as gas leaks, temperature fluctuations, humidity, and pulse rate. Numerous accidents in this type of work have been reported, requiring expensive and time-consuming rescue operations. To address this problem, we have developed a prototype system for live monitoring and continuous pulse rate tracking. This proposed study provides an overview and comparison of different methods for detecting unforeseen incidents and rescuing coal miners or other laborers in confined spaces. The suggested system aims to provide necessary health status parameters for miners. The research findings indicate that this wearable safety device effectively alerts users when temperature, humidity, CH4, and CO levels exceed safe limits

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