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An IOT Enabled Health Monitoring and Work Guidance System for Mine Workers

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***Abstract*—As with any industrial enterprise, underground mining operations require an effective and robust safety system. Underground miners encounter numerous hazards, including working in low-light circumstances, exposure to air pollutants, and the risk of fire and explosion. This project provides a solution by establishing a smart and safe mining system that can monitor the worker's body temperature, heart rate, oxygen saturation level, temperature, and pressure, and release of poisonous gases. There are two nodes in the system. A node monitors the workers' health conditions, while another inspects the work site before workers enter the field. The sensor modules connected to the NodeMCU can detect abnormal conditions based on threshold values. As soon as NodeMCU detects a threshold value crossing, an alert message is sent to the mining control room. For inspection of the site before workers enter, rover equipped with environmental sensors and a camera is used. Using the raspberry pi, an operator in the control room can also view the transmitted live video and sensed information to ensure the safety of workers.**

I. Introduction

The world has an intensively varying natural resources and a huge mining industry. Underground mining by workers could be extremely hazardous, and the risks increase as the depth from the ground increases. Mining is already looking into the future of automation. Digitization might not be a new concept to this sector, but the industry is still trying to find out how to make it the greatest. In the mining industry, workers' safety, proper communication and supervision are very important. Mine fires, explosions, gas intoxications, electric burns are the major causes of disaster in Underground Mines. These regions consists of emissions of Particulate Matter(PM) and gas like Carbon Monoxide(CO), Methane (CH_4), oxides of nitrogen and Sulphur which are harmful to health. Different types of mining activities generate PM in various ranges. Methane is highly inflammable which is present in air around 5% to 14%. White damp or CO which is 0.1% can cause demise within a few minutes. To protect the workers from such a risky environment, certain physiological parameters have to be examined. Coronary heart rate and Body temperature are the common health monitoring works. On the other hand, temperature, pressure and amount of gas are the different parameters to check the mining site. In this paper, we present a mobile environmental and physiological IoT system for workers which is applicable for industrial site. This system contains various sensors which are able to communicate with each other. Each worker is provided with a wearable system which can monitor the oxygen and pulse rate. This concept uses mobile hotspot for internet connection and User Datagram Protocol (UDP) for communication purposes. Prior to workersmoving to the site, a rover equipped with a USB camera embedded with gas, temperature and pressure sensors monitors the environment. Depending on the condition, the workers are allowed. The monitored data is compared with current vital sensory values respective to working environmental data. It can guide the workers if any health issue happens and also can avoid unwanted death. If there exists any abnormal condition, the system alerts the workers.

The Internet of Things (IoT) involves linking computer-based technologies with industrial equipment or household appliances over a network to enable teleoperation, workflow management, and data collection through the use of sensors [1]. Users can receive real-time data from the IoT through the browser or mobile applications wherever they are [2]. Wireless Sensor Network(WSN) is one of the foundational technologies for IoT that mainly uses interdependent smart sensors to sense and monitor physiological factors. Currently an emerging technology called Compressed Sensing(CS) is intensively applied for effective information analysis and imposed on applications where gathering data is exorbitant [3]. In addition to healthcare applications, WSNs can also be used to monitor environmental factors like temperature, humidity, and gas for safety purposes. WSNs provide exceptional benefits for a variety of different activities [4]. IoT systems merge and create robust networks that offer several solutions for developing sensible PPE products for underground mining applications due to

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technological immaturity, accidents, and closed systems. Smart sensors in combination with connectivity solutions and data storage are enabling Personal Protective Equipment (PPE) to provide health protection and enhance safety. By using this solution, manufacturers can take concepts from the primary plan to development of prototype Bluetooth Low Energy, also called Bluetooth Smart, which is an advanced wireless technology allowing fast wireless connections and featuring drastically reduced power consumption [5][6].In the automation world, ZigBee plays a significant role as a cost-effective, power-efficient, and low-complexity networking technology. Each ZigBee network has a network coordinator that starts the mesh network and controls the operation of devices to and from the network [7]. Due to the imminent technologies, IoT devices using Lora WAN which can run for several years without any substitution. It contains simple network architecture, strategic designing which is effective in outdoor IoT applications [8]. In wired communication, there exists higher price and higher risk in underground mines especially during gas inflammation or disaster. On the other hand, wireless communication has a low-cost RF transmitter and receiver and doesn’t have any risky consequences [9].

Implementation of robots have been successful in complex environments. The components inside a robot help to assist in control and its movement and a communication system that enables effective data transmission by the camera and the sensors [10]. Alert system is implemented for all workers from different locations within the mining area and sends the alert to the control room. Applicable actions would be taken whenever there exists a dangerous situation [11]

The major contribution of this paper is addressed below

1. To propose a Health Monitoring System which includes the detection of oxygen level and the heart rate.
2. To present the Work Guidance System which includes the recognition of temperature, pressure and type of gas using IoT.

The organization of the paper is as follows. Section II describes the proposed system including a block diagram and a flow chart. Section III elucidates hardware implementation and section IV summarizes results and discussions.

II. Proposed System Methodology

The block diagram shown in Fig. 1 elucidates the health monitoring of mining workers and their safety in the mining field. The proposed system includes two nodes: one is named as the health monitoring node and other node is named as safety node. In the health monitoring node, a wearable device embedded with the MAX30102 sensor monitors the oxygen level in the blood and heart rate of the workers. An alert message “Worker Unhealthy” will be sent if the health condition of the worker is worsened. The safety node has a four-wheel rover setup along with a USB camera integrated with Raspberry Pi to transmit the live video of the mining field to ensure the condition of the environment is fine. The sensors embedded in the rover are used to monitor the level of temperature, gas, and pressure in the work field. All the monitored data will be transmitted and displayed by a local server in the control room.

The flowchart shown in Fig.2 illustrates the mechanism for the health monitoring and work guidance system for mining workers.

III. Hardware Implementation

A. Detailed description about the components used in this proposed system:

1) Raspberry Pi 4

The Raspberry Pi 4 Model B is a microcontroller commonly used in health nodes, where it is connected to sensors, cameras, motor drivers, and a four-wheel robot setup. This model boasts faster processors and enhanced multimedia performance compared to its predecessors, as well as more memory and improved connectivity options. End users can expect desktop-like performance from this microcontroller, which is comparable to entry-level x86 PC systems. Its high-performance quad-core processor can support dual displays at up to 4K resolution via micro-HDMI, and it can decode hardware video up to 4Kp60. Additionally, it comes equipped with 8GB of RAM, dual-band 2.4GHz/5.0GHz wireless LAN, Gigabit Ethernet, and USB 3.0 ports. The Raspberry Pi 4 Model B is powered via a USB port that delivers 5V(2A).

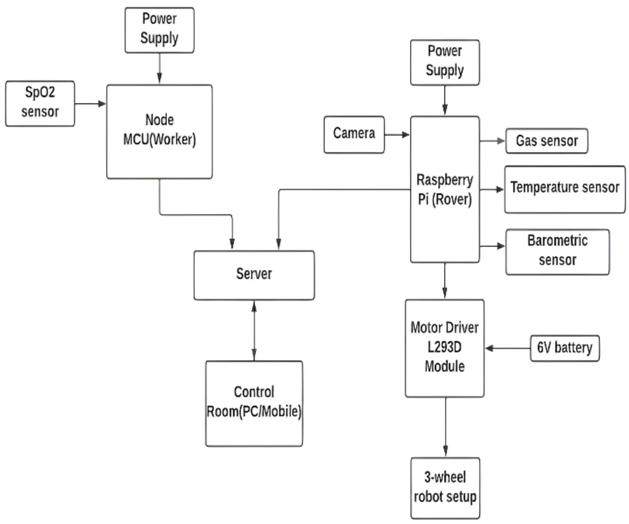

Fig. 1. Block Diagram of the proposed system

2) Power Supply: In order to operate Raspberry pi and Node MCU it is provided with 5v Dc power supply for Raspberry pi through USB port and 5v for Node MCU through USB type B.

3) USB camera: USB camera is used to monitor the work field from the mining control room. It has no built-in microprocessor and no non-volatile memory card, so it does not "remember" pictures because it is designed to capture images and send them right away to a computer. For this reason, webcams have USB cords that start at the back. By connecting the webcam to the computer, and then transferring the digital data taken by the webcam’s image

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sensor back to the computer, the data can be sent to the internet.

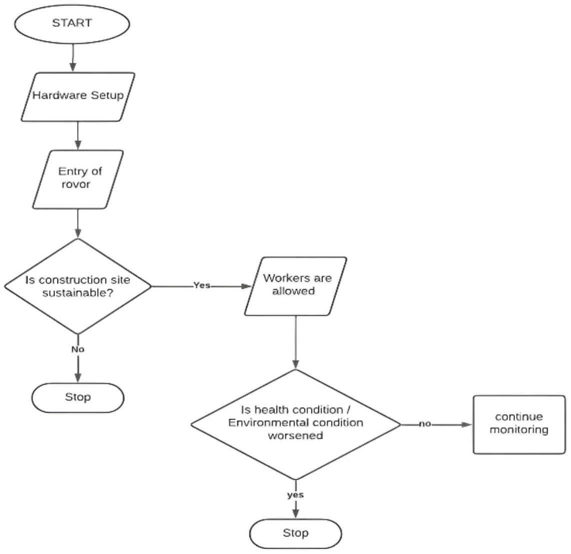

Fig. 2. Flow chart of the proposed system

4) MCP3008: The values sensed from MQ2 and MQ7 sensors are analog. To convert those values from analog to digital MCP 3008 is used. It is a 8-channel 10-bit ADC IC measures 8 different analog voltages with a 10-bit resolution for every channel. It measures analog voltages between 0 and 1023 and sends the measuring values to a microcontroller over SPI communication. Analog voltages are converted into digital values using the SAR method.

5) L293D motor driver: A Motor Driver regulates the speed and direction of the wheels connected with dc motors. Two motors at the same time. This motor driver is made with the L293D IC. It has 16 pins where 8 pins are dedicated for controlling the motor on all sides. There are two INPUT pins, two OUTPUT pins, and one ENABLE pin on each motor.

*6) Motor:*A device that transforms DC electrical energy into mechanical energy and enables the rover's wheels to move is known as a DC motor.

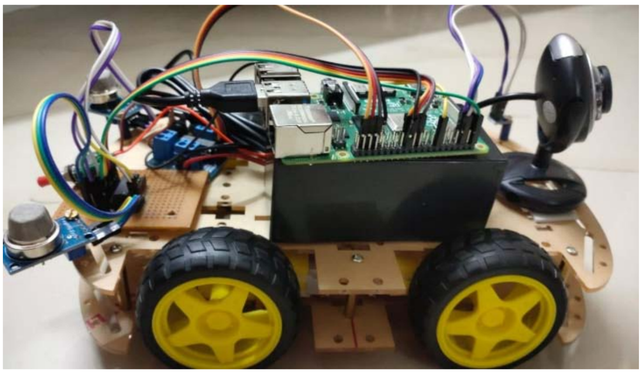

Fig. 3. Hardware setup for Safety Node

7) Battery: Battery is one of the best portable power supply. Since Lead -Acid battery is a rechargeable one and cheap. It is used as a backup power supply for the rover. Sealed lead acid battery provides better battery life.

8) MQ 2 Gas sensor: This gas sensor detects gases such as LPG, propane, methane, hydrogen, alcohol, smoke, and carbon monoxide in the air. It contains a substance which can alter the resistance as it comes in contact with the gases. This MQ2 sensor ranging from 300 - 10000 ppm. Sensors identify these gases by measuring voltage. Each gas has its unique voltages. By measuring the current discharge, it can measure the concentration of gas.

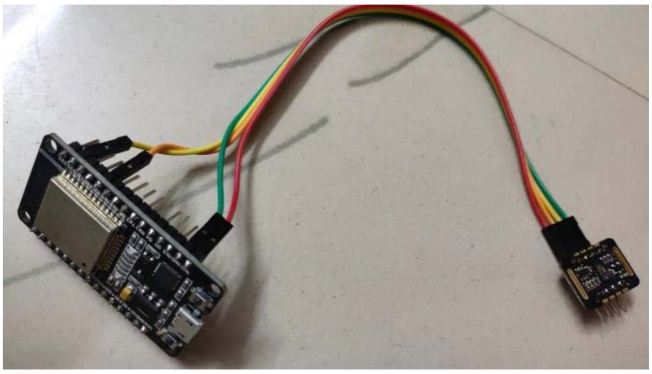

Fig. 4. Hardware setup for Health Monitoring Node

9) MQ 7 Gas Sensor: The sensor detects the carbon monoxide (CO) gas concentration in the air .The detecting range is from 10 to 500ppm.

10) BMP 180 Sensor: BMP180 is an atmospheric pressure sensor used to measure atmospheric pressure and temperature in the environment where it present and convert the findings into an electrical signal. This sensor works based on the weight of the air. The sensor measuring range is from 300 to1100 hpa.

11) Node MCU: Node MCU is used in the safety Node connected with MAX30102 sensor. It is an open-source plat- form that connects and transfers data to other connected devices. It is based on an ESP8266 microprocessor.

12) MAX30102 Sensor: This sensor measures pulse oxime- try and heart rate using analog signal processing and also includes a photodetector and two LED's .It is designed to ease the design-in process for mobile and wearable devices.

13) The complete Hardware Setup for Safety Node and Health Monitoring Node is shown in Figure. 3 and 4 respectively.

IV. Results and Discussion

A. *Safety Node*

A rover with USB Camera is made to invade the mining field, the movement of Rover could be controlled by using the keys present in the keyboard with the help of Motor Driver L293D Module. The forward and backward movement of the Rover is done by pressing up and down arrows respectively. By clicking the left and right arrow keys, the movement of Rover in left and right direction could be done as shown in Figure. 6. The movement is last for a particular period of time and the continuous pressing of

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keys could be implemented for its continuous movement. Then the rover starts sensing the level of temperature, pressure and presence of toxic gas in the environment and transmit the sensed value to the control room via mobile hotspot. Then the sensed values are displayed in the VNC viewer in the order of temperature, pressure, altitude, CO and CO_2.

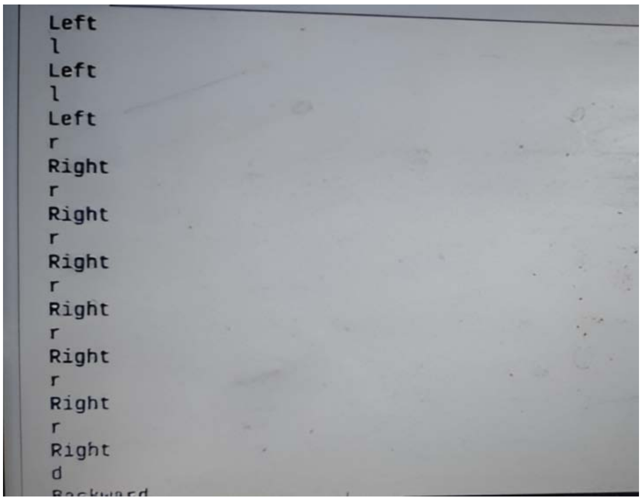

Fig. 6. Movement of Rover

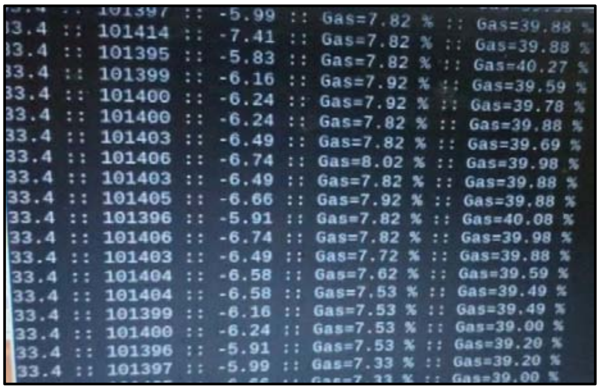

Fig. 7. Sensed data in normal condition

The normal threshold value of pressure is 101400 Pascals, for temperature it is 37°C inside the body and 28°C around the environment and 50% is the threshold amount for poisonous gases. If any of the received sensor value exceeds the threshold value then the alert message "High Pressure/High Temperature/High Toxic Gases" is displayed respectively next to the sensed values in VNC viewer as shown in Figure 8. The result is represented in the form of Temperature(in °C)::Pressure(in Pascals)::Altitude(in feet)::Amount of CO(in %)::Amount of CO2(in %).

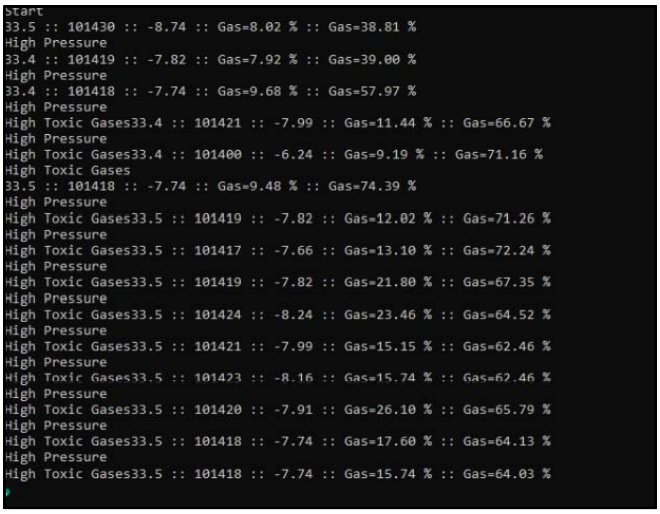

Fig. 8. Sensed data in abnormal condition

B. Health Monitoring Node

After verifying the data's transmitted by the rover, the workers are allowed to the mining field equipped with a wearable device. The wearable device is embedded with MAX30102 sensor continuously monitors the Spo2 level and heart rate. The threshold value of heart beat rate ranges from 60 to 100 bpm whereas the Spo2 level should be higher than 90 percentage. When the sensor value exceeds the threshold value, an alert message "Worker Unhealthy" will be displayed in the screen. If the device is not properly worn by the worker, an alert message "NO Finger" will be displayed as shown in Figure 9.

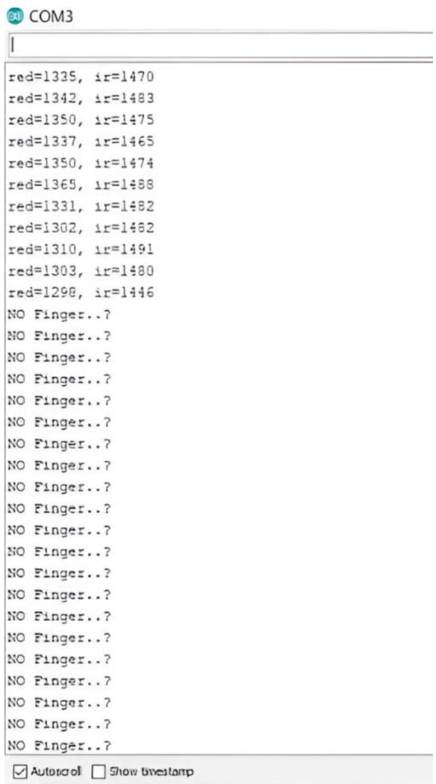

Fig. 9. Alert message for wearing the device imperfectly

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Fig. 10. Sensed Data in normal health condition

V. Conclusion

This paper aims to design an IoT based health monitoring and work guidance system for mining workers' welfare in order to monitor their health and safety. The proposed system continuously monitors the health condition of the workers and governs the environmental condition by using rover. With the help of data received from the health node and safety node in the control room, the worker's will be rescued if any of the conditions are abnormal in the mining field. The first component of worker safety in underground coal mining was addressed in this research. This project is not only for coal miners, but also for workers who perform subterranean work. In the future, the system could be equipped with a range of environmental and physiological sensors to meet the specific requirements of various work settings.Overall, expanding the server infrastructure and allocating distinct IP addresses to each server can be a wise investment for the project, allowing for more effective management of vast mining regions, better performance, improved security, and easier troubleshooting.

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