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Safety Wearable for Miners

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Abstract

INTRODUCTION: Mining is the process of extraction of valuable minerals, ores and other non-renewable resources from the Earth's surface. The mining industry is known for its hazardous and highly risky working environment.
OBJECTIVES: The mining industry is involved in the extraction of these geological materials, which is essential for the development of the country and its economy. However, this industry comes with its fair share of risks and dangers. Recent statistics show that around 100 miners fall victim to the harsh working conditions every year.
METHODS: Explosions due to Methane and coal dust followed by roof collapses, mine fires, gas outburst, blasting accidents, poisoning and suffocation are the major reasons out of these few of them causes deaths inside the mines.
RESULTS: Even though many precautions are suggested, and measures have been taken to improve the safety of the miners and to improve the work environment, but mines are still unpredictable, and accidents are also recorded then and there.
CONCLUSION: The existing safety technologies and measures have either failed to monitor multiple vital features that could lead to fatalities, or to provide adequate and appropriate rescue resources in time to help the miners in danger.

Keywords: Miners, Safety Measures, Sensors, Precautions, Internet of things

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1. Introduction

Mining is the extraction of valuable minerals, ores and other non-renewable resources from the Earth's surface. The mining industry is known for its hazardous and highly risky working environment. The mining industry is involved in the extraction of these geological materials, which is essential for the development of the country and its economy. India currently has 1,303 active mines and produces around 95 important minerals. As of 2020-21, India is the second largest coal mining industry in the world. The mining industry is known for its hazardous and highly risky working environment. Mines are always larger in size, and it starts to work with large number of workers in it. Providing safety and precautions for their workers becomes a major challenge for the employers. Working in mines is really a tough job, there may be sudden landslides, and hazardous gas exhausts which leads to unfortunate accidents in the mines. Rescue operation is another important task to carry out as soon as the incident happened. Miners' safety is mandatory to achieve the goal of the employers and to support the nation in turn. Therefore, a system has to be adapted to identify and minimize the risk factors. However, this industry comes with its fair share of risks and dangers. Recent statistics show that around 100 miners fall victim to the harsh working conditions every year. Safety wearable was important for the workers in construction environment and a wearable safety device was used to assure safety environment for the people working in this environment [1]. Not only in mines, in Construction environment safety is mandate and it helps to improve the productivity in the society without creating the issues in the construction field and the importance of wearable devices based on the survey over 16 years and bibliometric data based analysed for individuals working in construction environment [2].The existing safety technologies and measures have either failed to monitor

multiple vital features that could lead to fatalities, or to provide adequate and appropriate rescue resources in time to help the miners in danger. ESP8266 NODEMCU has been used as the computing device that interfaces the sensors that monitors the external temperature and humidity, body temperature, pulse and SpO2 levels and the concentration of Carbon Monoxide and Methane gas in mines [3]; deliver this continuous stream of data to the concerned supervisor via an application and alert them, as well as those present in the mines, if any emergency arises [4]. Hence, the combination of these sensors and the Wi-Fi module could result in rescue operations being held in a much faster manner, thus ensuring better safety protocols for the miners [5].

2. Literature Survey

Remotely controlled wireless vital sign monitoring system using microcontrollers on Arduino supported by Bluetooth technology was discussed [6]. It provides outputs with minimum error as ± 0.4 °C during temperature measurement and heart rate and compared the results with digital thermometer tests and records. Infrared (IR) Sensors and Liquid Crystal Display are used in this monitoring system, and it is connected to a mobile phone via Bluetooth. Therefore, authorities can visualize and control the same remotely. IoT based Coal mine safety was proposed to provide to safety precautions for the mine workers were addressed [7]. AVR controller was used to design a smart helmet for coal miners to provide safety for the workers and it monitor the level of gases in the mines and it alerts the surroundings as well as workers whenever needed[8].An integrated cardiorespiratory and sweat monitoring wearable was discussed [9].The wearable platform must do biochemical analysis, sense the physiology parameters along using various sensors and the recordings are observed then and there to monitor the health conditions of the workers. Body fluids as well as cardiorespiratory parameters are to be considered to perform overall analysis are discussed [10]. An advanced system is used to track the health issues of miners for various vital signs through wireless health monitoring system and it was tested in real-world environment to measure various parameters and metrics are evaluated [11]. A wearable embedded system and it is designed to send GPS location to a specific IP address and pulse sensors are used to update pulse rate of miners continuously under critical conditions. A smart wearable system to secure the life of miners and it senses health related parameters of the coal miners includes heart rate, flame, temperature, location as well as detects hazardous gases. The measured details are transmitted via Wi-Fi to a dynamic internet protocol to inform corresponding authorities [12]. A smart helmet with sensors is used to detect collision and hazardous gases and it adapts a Wi-Fi technology to transmit data to an authorized user for medications if needed. It alerts the surroundings through buzzer and communicated via Cloud computing. The vital signs are collected and processed through ESP32 Arduino with Wi-Fi module. It allows the authorities to locate the miner's location through GPS [13]. A fault detection and people recovery in under water is discussed using Hidden Markov model [14].

3. Proposed Model

The proposed safety wearable for miners model is shown in Figure 1 depicts the details of components and processes involved in the implementation of the safety wearable system. Here, the ESP8266 NODEMCU is interfaced with MQ-9 Gas sensor, MAX30100 Pulse Oximeter, LM34 Temperature Sensor and DHT11 Temperature and Humidity Sensor.

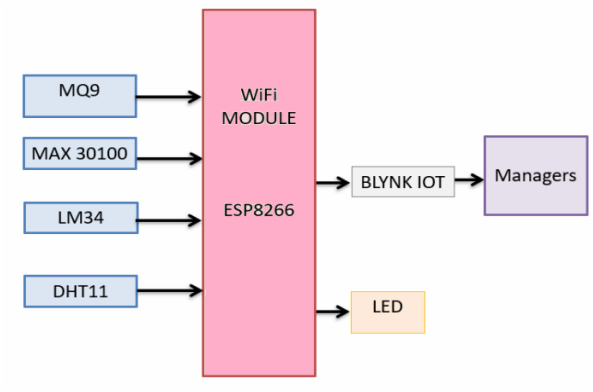

Figure 1. Safety Wearable for Miners – Proposed System Model

Sensors are used to check for any anomalies and alert the miners via LED's and buzzers. The monitored data is transmitted to the Higher Officials via BLYNK IoT app, which displays the continuously monitored data. This enables the Managers to act fast in case of emergencies, making it capable of saving lives much faster. Figure 2 shows the proposed system model which explains the above-mentioned process in a detailed manner.

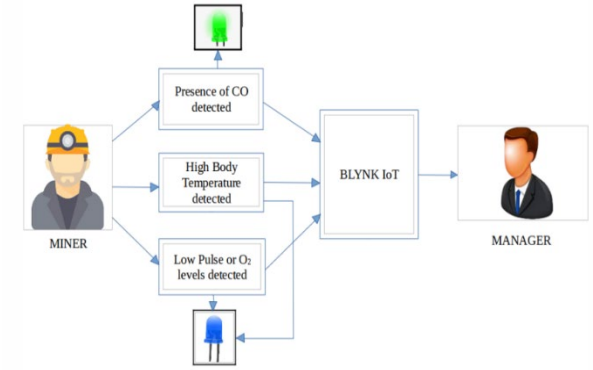

Figure 2. Flow diagram of the Proposed System Model

The NodeMCU is fed with IDE and required libraries are installed for the respective sensors. Figure. 3 discuss the steps involved in the working of the proposed system. Here, the sensors will first monitor and obtain the inputs of the mine surroundings and the miners working in the field. The NodeMCU will compare the current readings with that of the threshold values (as mentioned in code). If the readings go beyond the given threshold values, then the miners are made alert of the situation with the help of LEDs and buzzers, and this information is then relayed to the higher officials via the BLYNK IoT application, allowing them to take necessary actions.

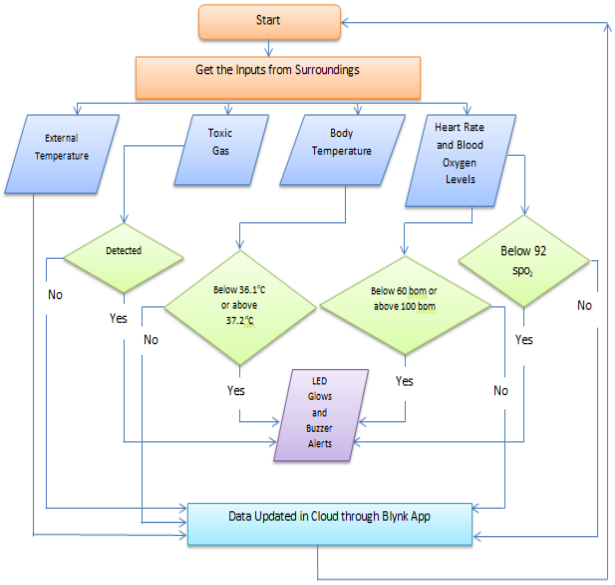

Figure 3. Workflow of the Proposed Model

The tolerable surrounding temperature in mines is around 32°C to 35°C. The DHT11 sensor continuously monitors the external temperature and notifies/ alerts the mining team if the working conditions are unsuitable for mining effectively. The human body temperature must average from 35°C to 37°C. Going above or below this threshold could result in feverish tendencies. The LM34 sensor monitors the body temperature and notifies the miners whether or not they would fall ill. Mines produce lots of toxic gasses, such as Carbon Monoxide which is dangerous even at low concentrations. The MQ9 sensor detects the presence of CO and CH4 and notifies the miners if the gas concentration is above the desired level. These data streams are uploaded to the BLYNK App regularly, allowing the higher officials to monitor the working conditions as well as the health of the miners, thus enabling them to make appropriate decisions at the right time.

4. Hardware Setup

ESP8266 NODEMCU: It is a cost-effective microcontroller with Wi-Fi used for a wide range of IoT based applications. It consists of System on Chip (SoC) with transmission protocol stacks that can be accessed via WiFi networks. Figure. 4. Visualizes the ESP8266 Microcontroller.

Figure 4. ESP8266 Microcontroller –Top View

The ESP8266 Node MCU is a development kit based on the ESP-12 series and features the SoC are mounted on it as seen in Figure 5. It has 128 KB RAM and 4MB flash memory. It comes with a Micro USB Jack that can be used to connect it with a PC. It operates at a clock frequency of 80Hz and a voltage converter to down convert 5V to 3.3V. The NodeMCU Development Board comes with 16 Digital I/O pins and 1 analog I/O pin along with 1 UART pin, 1 SPI pin and 1 I2C pin as well.

Figure 5. NodeMCU-Top View

The DHT11 Temperature and Humidity sensor has negative temperature coefficient (NTC) thermistor for sensing temperature with a capacitor for measuring surrounding humidity, as shown in Figure 6.

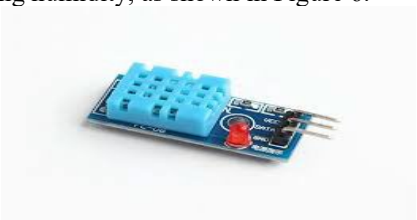

Figure 6. DHT11 Temperature and Humidity Sensor

The NTC and capacitor are connected to a PCB, which reads the digital value. The NTC would increase with fall in temperature and decrease with rise in temperature and

changed resistance is measured using PCB to calculate external temperature. The humidity sensor uses two electrodes having moisture holding substrate between them which measures the changes in humidity. LM34 Figure7 is a low voltage sensor which uses 5V of power. The IC has 3 pins - VCC, GND and an analog output pin (A0). The analog output is linearly proportional to the temperature in Fahrenheit. The IC senses internal body temperatures ranging from -55 to 150°C.

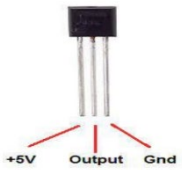

Figure 7. LM34 Temperature Sensor

The MQ-9 Gas sensor is shown in Figure 8 is part of the MQ Gas sensing series and is used for the detection of Carbon Monoxide (CO), Methane (CH4) and other flammable gasses. It can detect CO density from 10 ppm to 1000 ppm and flammable gasses density from 100 ppm to 10000 ppm. It detects gases in high and low temperature. If it detects low temperature (heated at 1.5V), then concentration of CO is above the required range. If it detects high temperature (heated at 5V), then concentration of flammable gasses is higher than the required range.

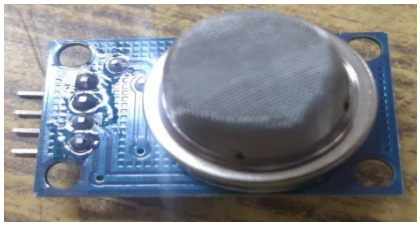

Figure 8. MQ9 Gas Sensor

MAX30100 checks the saturation of heart rate as well as the blood oxygen levels carried in our red blood cells. It consists of photo detector and low-noise pulse oximetry (SpO2) to monitor heart rate and it is shown in Figure 9. The MAX30100 works based on RED and IR LEDs by placing it in the finger to measure the number of lights reflected using a photo detector.

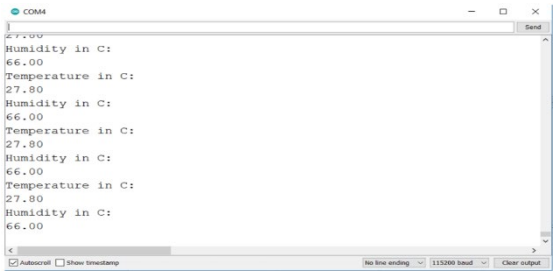

Figure 9. MAX30100 Pulse Oximeter and Heart Rate Sensor

Haemoglobin in our blood has a tendency to absorb more IR light, so higher the Haemoglobin content, more IR is absorbed and reflected, and this is measured by the photo detector and gives out the Heart rate reading. Pulse Oximetry readings depend on the variation in the RED and IR light absorbed by blood. Deoxygenated blood absorbs more RED light and Oxygenated blood will absorbs more IR light. SpO2 levels are measured using the ratio of RED and IR light received by the photo detector.

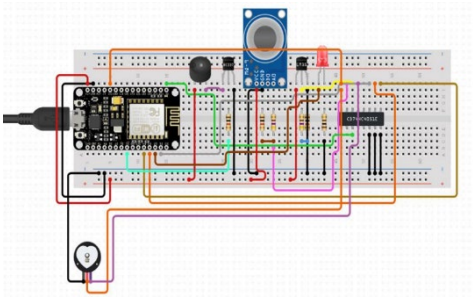

Figure 10. Circuit Diagram of the proposed system

Figure 10 depicts the circuit connections for interfacing the different sensors with the ESP8266 NodeMCU board. The communication is done via BLYNK app through internet. It is an IoT platform for iOS and Android smartphones and it will control the hardware remotely and displays sensor data, store data, visualize the results as well.

5. Results

DHT11 SENSOR: The output for the DHT11 Temperature and Humidity Sensor is shown in Figure 11 through Arduino IDE. The sensor continuously monitors the external temperature and humidity and displays the results in the Serial Monitor.

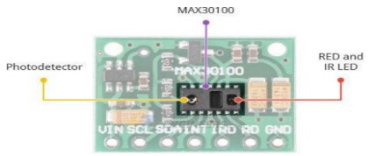

Figure 11. DHT11 Output in IDE

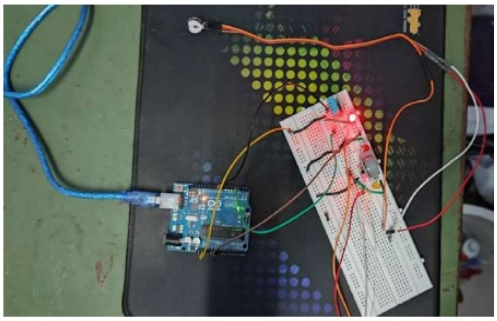

Figure 12. Hardware Output of DHT11

Hardware setup is illustrated in Figure 12. Whenever the temperature exceeds the threshold then it will notify the miner by turning on the LED and would send an Alert signal to the Higher Officials via the BLYNK application.

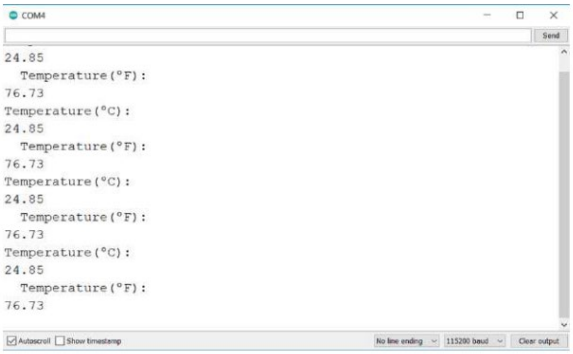

Figure 13. LM34 Temperature Sensor Output

LM34 Sensor output is depicted in Figure 13, and it indicates the temperature in both Celsius and Fahrenheit and the coding is done using Arduino IDE.

```
sensor_volt = 1.10
RS_ratio = 3.28
Rs/R0 = 10.26

sensor_volt = 1.10
RS_ratio = 3.27
Rs/R0 = 10.21

sensor_volt = 1.10
RS_ratio = 3.28
Rs/R0 = 10.26

sensor_volt = 1.10
RS_ratio = 3.27
Rs/R0 = 10.21

sensor_volt = 1.10
RS_ratio = 3.27
Rs/R0 = 10.21

sensor_volt = 1.10
RS_ratio = 3.27
Rs/R0 = 10.21
```

Figure 14. MQ-9 Sensor Output

MQ9 Sensor results are displayed in Figure14, and it is obtained by interfacing MQ-9 Gas sensor with ESP8266.Sensor voltage, RS_ ratio and RS/R0 ratio are calculated based on the measured gas level using MQ9.The RS/R0 ratio is used to measure the concentration level of the gases present in the mine and their sensitivities are compared in the graph shown in Figure 15

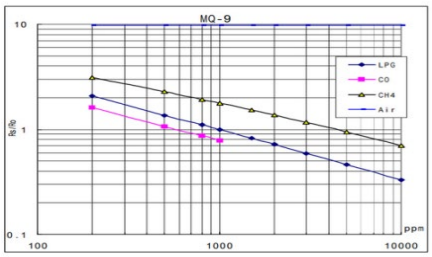

Figure 15. Sensitivity Characteristics

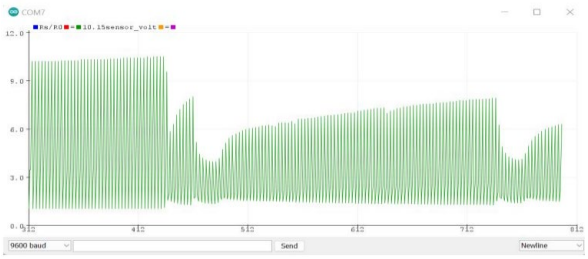

Figure 16. MQ-9 Output

Figure 16 illustrates the MQ9 output in graphical form in terms of RS/R0, Sensor Voltage and Gas levels. Figure17 depicts the output of MQ9 from the designed hardware through LEDs. LED glows when the concentration of Carbon Monoxide goes above the threshold level, i.e. the ratio RS/R0 becomes lesser than 7.

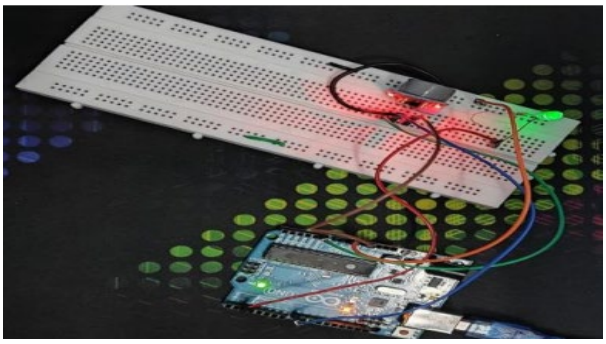

Figure 17. MQ-9 Sensor Real Time Output

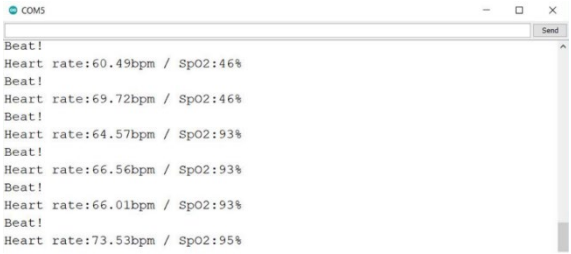

Figure 18. MAX30100 Sensor Output

MAX30100 sensor output is displayed in Figure 18. The heart rate and SpO2 levels are shown in terms of beat per minute (bpm) and percentage respectively. Results are obtained by interfacing MAX30100 with ESP8266.

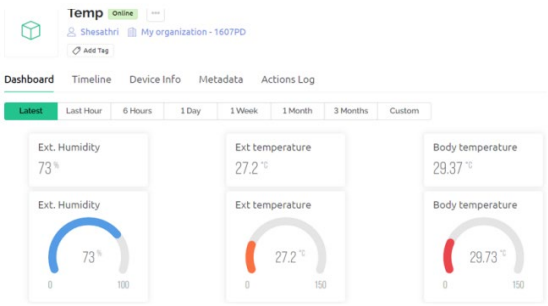

Figure 19. Results obtained from Blynk IoT

External humidity, External temperature and Body temperature are measured using BLYKK application used in IoT. The sensors so fare discussed have been interfaced with the ESP8266 NodeMCU and it has been connected to the BLYNK IoT application via Wi-Fi. Figure 19 indicates the readings obtained through the application using gauges in terms of percentage for humidity measurement and temperature in terms of Celsius.

6. Conclusion and Future Work

The proposed safety smart wearable system for miners is suitable to implement in underground mines to make them survive even after the critical circumstances. Heart rate, oxygen levels of the miners and presence of hazardous gases as well as humidity and temperature of both environment and miners are taken into consideration to do the real time analysis. This proposed system is suitable to measure the vital signs of the miners working in this environment. In addition to it, toxic gas levels are monitored to alert the workers under critical conditions. Continuous update on the surroundings and the miners' health is fed to the supervisor through wireless communication. The proposed system also collects data of several miners that are to be transmitted using Wi-Fi to the manager with the help of an alert systems and BLYNK application dashboard. This wearable is useful for miners under critical situations to rescue them at the earliest and to save their lives. In future, it can be extended to support other industries for various applications based on their requirement.

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