IoT Domain Analyst

IoT-Based Smart Helmet for Safety in mining

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Abstract

The project's main goal is to detect dangerous situations. Our main goal is to create a great smart helmet design that protects worker safety. We want to create a low-cost device that can detect air quality, a collision with an object on the head, and any other unavoidable event that may arise on the job. We've chosen to put in place a system that can be installed on the mine employees' helmets. Various sensors will be used in our proposed system. The device will detect mining conditions as well as worker health issues. Workers will be alerted by a buzzer on their helmet as well as an app. The model given in this project uses an application interface to recognize and show data, which is the next key component of this project. Because it is a small project, it can fit almost anyplace, giving it a wide range of applications and flexibility. Our project's major tagline is "Rescue with Flexibility." As a result, we anticipate that this project will serve as a guiding foundation for revolutionary transformation.

Keywords: *Machine Learning, Object Detection, Object Classification, Android, Calibration, Sensor Networks, Internet of Things, Stabilization, Biomedical Instruments*

Introduction

The difficulties faced by miners working underground are gas explosion, deficiency of light, etc. If any disaster occurs in mine and if miner gets injured, all the blame directly goes on supervisor. So there must be communication between miners, supervisor and control station. Therefore the purpose of the proposed system is to modify an existing mining safety. We aim to develop a low-cost device that will be able to sense the quality of air, crash of an object on the head and any unavoidable situation occurring in working sites.

Literature Review and Related Works

Roja et al. [1] proposed an IoT-based smart helmet consisting of six-units for the safety of miners. Their main idea is to detect harmful gases in the mining environment and also the removal of helmet by the miner and to send an alert to the supervisor. This is achieved by using IR sensors as helmet removal sensor, MQ7 as the gas sensor to detect the levels of harmful gases like LPG, CO, CO2

etc. and Arduino Uno as the Data Processing unit. A GSM modem is used to wirelessly transmit data from the mining industry to the server. Due to the remote environmental monitoring capability, a GSM-based network is preferred. On crossing the threshold value detected by the sensor, the Piezo buzzer is turned on which acts as the alerting unit and the results are displayed on the LCD. The monitoring system consists of ThingSpeak which allows the user to analyze and visualize uploaded data. This system, however, does not detect the miner's circulatory strain and heart rate, which are very useful parameters to detect and analyze unfavorable circumstances.

Eldemerdash et al. [2] improvised on the existing system to detect the levels of gases using the Smart Helmet by proposing an improved gas control, force detection and temperature and humidity monitoring system and developed a Graphical User Interface to alert the control room. A monitoring system was proposed that monitors the climate changes and updates the management with real time data. Both these systems were integrated and the power consumed by the helmet system was evaluated. The sensors used in this system are Temperature and humidity, IR, Pressure and Gas sensors. As Wi-Fi or Bluetooth protocols will not be a sufficient solution for underground systems, ZigBee is used for wireless communication owing to its robustness. LED display is used to show the status of the miner's conditions. A GSM module is used for output to send the message and Node Red is used for developing the GUI. GUI displays the data of humidity, temperature, amount of force on the helmet and gas monitoring system. Every sensed information has a triggering threshold on crossing which an alert is sent. The developed system was tested in Gua Tempurung located in Gopeng Perak state in Malaysia. A comparison of Idle and Sleep Mode with previous work done was stated. The power consumption of the system was evaluated which can be a very good factor to save energy. The power consumption during Transmission mode is 39 mA more than that in sleep mode.

Borkar et al. [3] suggested to design a system small enough to fit into the safety helmet and last long enough while running on battery power. In the proposed system, Raspberry pi is the heart of the system. The operation is based on this smart controller which collects all the real time sensor data automatically, and performs operations to give required output. When coded properly, it is possible to

display real time sensor values to the LCD, computer at base station as well as upload it on the web so anyone can see values anytime anywhere by using the internet. MQ2 sensor, which is sensitive to flammable gas and smoke, detects hazardous gases such as CO, SO2, NO2, and particulate matter and if it exceeds its limit raspberry pi uses IoT to send information to the base station and alert the miner through buzzer. The measurement of environmental humidity and temperature around the miner is done by DHT11, the operating voltage of which is 3 to 5 volts, while the max current used when measuring is 2.5mA. To determine successfully whether the helmet is on the miner's head an off-the-shelf IR sensor was used, and when removed an alert was sent. The measurement of light intensity inside the mines is also done using an LDR sensor. However, the system can further be improved by implementing node hopping and adding the sensors to detect collision and also add the devices to check the miner's heart rate and blood pressure.

Noorin et al. [4] developed a wearable device incorporating the various sensors, alerting mechanism and communication system to enhance the safety of the miner. The hardware comprises data collection, data processing and data communication sections. WSN technology is used for the data collection or measuring of the parameters. The collected data is processed using an Arduino Nano board and then the same is sent to NodeMCU via serial communication and the alerting unit. The sensors used in the proposed system are DHT11 for temperature and humidity monitoring, MQ4 for gas detection, SW420 for detecting collision. WSN technology is the core of this wearable device, which is a network of sensors, where each of the sensors has different parameters to sense yet perform together as a part of the system. Arduino is used for prototyping the device which uses a simpler version of C++. The data is then processed and made available to NodeMCU via serial communication using I2C protocol. After this the data in real time is updated to the cloud. ThingSpeak is used as the IoT platform, which employs MATLAB analytics for real- time data analysis. By using this model of helmet, the identification of each individual is possible, as separate channels are built at the IoT platform for every specific user ID. The system can however be improved by tracing the location of the person using a platform known as location of things, which works better in closed environments.

Bagali et al. [5] reviewed and analyzed different innovations utilized in mining and mishap discovery domains. Since there is an increment in accidents in mines and road mishaps, it is the need of the hour to analyze the situation and develop solutions accordingly. Technologies used in both mining helmets and motorcycle riders' helmets were studied and compared. It was found that using Wi-Fi technology, communication between different helmets was not good. Data logging mechanism and heart rate and blood pressure detection are absent in ZigBee wireless technology. Headlight technology is only applicable to motorcycle riders' helmets. GSM and GPS technology fail to detect alcohol. For the ZigBee and IR sensors technology, layout of visualization of software is still not completed and the IR sensor can be improved. It was also observed that ZigBee innovation is vastly utilized however this covers the restricted distance and acts like a Bluetooth. This cutoff points to 100m. Also, IR sensor and expert and slave strategy are not totally carried out.

Behr et al. [6] designed a smart helmet for miners to detect three hazardous events. Firstly, the level of hazardous gases was detected by using an electrochemical gas sensor as it has high accuracy and low power consumption. The threshold values of CO, SO2 and NO2 were 4 ppm, 0.2 ppm and 0.10 ppm respectively. On crossing the threshold value, an alert was successfully sent to the alerting unit of the helmet using the ZigBee transmitter module. The second unfavorable condition that was detected was helmet removal. Different approaches were considered and it was concluded that a helmet removal test can be successfully carried out using an off the-shelf IR distance sensor. The IR sensor was designed in such a way that it was constantly sending signals from one side of the helmet to the other and it successfully detected when the helmet was removed 10 cm away from the head. The third hazardous condition was collision or an impact on the miner's head which was done using an accelerometer. Head Injury Criteria (HIC) was calculated by the software and on exceeding a value of 1000, an alert was sent. However, the test also showed that the output of the accelerometer was inaccurately scaled and more accurate calibration of the device was needed. Along with that, a single axis of the accelerometer could only be measured every 12 ms. By increasing the processing speed of the system, the measurements of the accelerometer could be more accurate. Inculcating node hopping in the system would allow the supervisor of the mine to receive all the data. Additionally, heart rate and blood pressure measurement can be done to modify the helmet even more.

Ayush Dagar et el . [7] The main objective of this research is to design smart helmet system for mining industry application which would be monitored by the system on the grounds of hazardous events such as temperature, humidity, gas, removal helmet of the miner and obstacle damage to the helmet. System makes the use of atmega microcontroller based rf tracker circuitry in order to receive the various kinds of the data transmissions by worker's helmet nodes thereby mapping current location of the workers throughout the mining field. Tracking systems will be used to track and prevent the mining site from various hazardous events. To the contrary side it made the work of the workers working in the mining industries much easier with the technical advancements thereby giving each and every clue about the upcoming hazardous situations which can be faced by the workers during mining.

V. Jayasree et el. [8] To provide continuous monitoring of the workers and to prevent them from any health hazards during working, this system proposes a smart flexible helmet for the construction workers to provide security and rescue measures in case of any emergency conditions. The proposed system describes a smart inexpensive helmet for the construction workers made up of chromium embedded with Accelerometer and Gyroscope sensor. In order to provide continuous monitoring of the workers and to prevent them from any health hazards during working, this system proposes a smart flexible helmet for the construction workers to provide security and rescue measures in case of any emergency conditions. This system ensures safety for workers at the mining area but this helmet is not purposely provided for the safety of the workers. Through this smart helmet, the contractor can continuously monitor the entire workers involved in construction process and can also get notification about the workers' physical condition and can immediately save the workers from any serious issues in case of emergency.

Subhash Rathod et el. [9] In current days coal mining has been a totally risky interest which can bring about some of unfavorable consequences at the surroundings for instance in the course of mining operations methane, a regarded greenhouse fueloline, can be launched into the air. Keeping most of these components in thoughts they have designed a machine, i.e. clever helmet the use of ZigBee generation for tracking the dangerous gases, strange temperature situations

and the humidity degrees withinside the air. A clever mining helmet turned into advanced this is capable of discover 3 varieties of risky activities which include threat stage of risky gases, miner helmet eliminating, and collision or impact (miners are struck with the aid of using an object). The tool makes use of Gas sensors for detecting stage of poisonous gases within the mine. It additionally makes use of an Atmospheric Pressure sensor for detecting growth or lower in atmospheric strain that could bring about dangers for the mine worker. The tool makes use of Gas sensors for detecting degree of poisonous gases in the mine.

Hitha Kothakonda et el .[10] Coal miners are those who bring the coal on to the ground .so in underground their are many toxic gases are present, temperature and humidity values are different which causes suffocation for a person who is in underground. Smart helmet can sense the temperature ,humidity, toxic gas, oxygen levels and give the output in the form of buzzer and as in the form of vibration to their body so that they get alerted and can be protected . With the help of temperature sensor, humidity sensor, oxygen level sensor, gas sensor and an alert is given with the help of buzzer and a vibration sensor is used to which is attached to their neck so that they get vibrated when the limit of the sensor exceeds. Coal miners already wear a helmet so we are going to make this helmet in to the smart way where the coal miners will be alerted with the buzzer sound and vibration motor is going to vibrate. So, in this way we are going to protect the coal miner to some extent for this we are using 2 sensors DHT11 sensor and Gas sensor (MQ2 sensor) which is connected as inputs to Arduino uno and we are going to place a buzzer and a vibration motor as output to the Arduino and we are going to display the values on lcd display. the outputs that we are connecting here is a buzzer, vibration motor, led and an LCD display which is used to display the temperature and humidity values.

V.Srinath et el . [11] This helmet will help in maintaining the safety of worker and also operational ability of work. In this helmet there is GPS which will provide the location of the worker in case he is unable to move. Node MCU is used as a controller which is embedded with Wi-Fi drives so it can be used as long term communications. The device always connects to the internet so the controller of the workers always checks the data. Taking everything into account, we proposed a safety helmet which is used to avoid the accidents with a low-cost sensor. This

helmet will help in maintaining the safety of worker. This work suggests the safety helmet with number of sensors which will continuously monitor the worker health condition minute to minute and will store the data that is collected by the sensors to the cloud data base. The supervisors or the controllers can spectate the workers all the time. In this helmet there is GPS which will provide the location of the worker in case he is unable to move. The sensors provided in the helmet will trigger the alarm in case of hazardous conditions.

Kumar et al. [12] worked on the improvement of the already existing Smart mining helmet to ensure more safety of the mine workers. ZIGBEE technology is used to improve the helmet in order to ensure more safety. Here, it is proposed that every miner is given a unique tag which a reader identifies. Reader sends the details to a microcontroller and the microcontroller further send the data to PC. ZIGBEE transmitter is used to send the data to PC. It verifies the helmet and also it informs the microcontroller if the helmet is absent. Microcontroller the further sends an alert to the corresponding miner. To check the presence of the helmets, IR sensors are incorporated in the design. Gas sensors are used to detect hazardous gases in the nearby surroundings. Also, head injuries can be detected by using the MEMS sensors. And towards the end, all the data gathered from the sensors is posted in the PC via the ZIGBEE transceiver.

Bozdal et al. [13] worked on the design of the Smart lifesaving mining helmet by making it able to predict explosions and improve the communication of miners. The design is divided as communication system, sensory system, gate control and the GOC. GOC (Ground Operation Center) is the name of the main program which collects all the data from the gate control and the miners. All the temperature and the accelerometer data is collected by the sensory system and is further transmitted to the GOC using the Wi-Fi communication interface. The accelerometer data can be used to predict if someone has fainted as they'll be in a free-fall if they happen to faint. ADXL345 accelerometer is used. For communication system, underground wireless communication is set up. It can be further divided into two sub-categories which are PCS (primary communication systems) and the secondary communication system. PCS is used for regular communication between the miners and the ground workers. Secondary communication is used in the case of emergency which can propagate through the ground. The ad-hoc mesh network is

used in this design for wireless communication because it has a lot of additional features. In the Gate control system, the helmets are embedded with NFC tag which can be used to control the access gates so that no miner can enter without wearing the helmet. For the software part, a program is written in C# to build the GOC.

Tajane et al. [14] stated how accidents at mining sites can have a negative impacts which include loss of lives, shifting of livelihoods, etc. which are caused by occasional rock falls, explosions, fire, electrocution, etc. So, to avoid all this, they designed an intelligent sensing and warning system. For better communication, RF technology is used inside the mines. As the technology is advancing, the monitoring techniques are also becoming more and more advanced and sophisticated. Wireless sensor networks (WSNs) are now replacing wired communications. It is an ad-hoc, multi-hop and self-organizing network consisting large number of nodes which can monitor the whole situation. Because of these, there is no need of cable. Data is acquired with a higher accuracy and precision. Also, ZIGBEE based wireless mine supervising system is used in this design. It is cost effective which works on early waring intelligence. IOT is used to monitor the status of the worker. Mine ventilation system is also introduced in this design which helps in making ventilation changes easily based on data collected from the atmosphere in the mine.

Sujitha et al. [15] designed a mine safety system which consists different sensors along with an Arduino Uno microcontroller. The values gathered by the sensors are taken in by the Arduino uno and further it is stored to the cloud. A threshold value is set to judge the various parameters. If the parameters cross the threshold value, an alert is sent to the control room. Also, the design consists of THD11 (Temperature and Humidity sensor), MQ11 (Flame sensor), Gas sensor and the LDR sensor which monitor the physical parameters of mine unit which cannot be easily predicted. It also consists of a buzzer, LCD display, a Wi-Fi module and a GSM module. It is designed in such a way that it can also detect fall alarms by analyzing the fall and judging if it should send an alert or not. This also contains an automatic trigger which can only be activated if the miner is not able to push the button on the helmet. The results and statistics can be displayed via Thingspeak website.

Krishna et al. [16] proposed a design where sensors which can detect air quality for harmful gas detection, collision sensor, helmet removal sensor and ZIGBEE for communication. Their design which they have termed as Smart system architecture is divided into two parts, mainly transmitter part and the receiver part. The transmitter part further consists of 4 sensors mainly MQ2, DHT11, IR and Vibration sensor. It also consists of a power supply, Arduino uno board, LoRa communication transmission part, GSM and buzzer. Arduino, LoRa communication receiver part, power supply and laptop come under the receiver part. MQ2 is a gas sensor which is used to detect levels of poisonous gas. DHT11 sensor is used to detect the temperature and humidity. Vibration sensor is used to detect immediate changes in movements. To detect obstacles IR sensor is used which are interfaced with Arduino. A particular threshold value is set for these sensors and if any parameter crosses these values, alerts are sent to the mobile phone and the receiver module as well via GSM.

Methodology

In the system, a NodeMCU ESP8266 is used as the microcontroller. The sensors: ADXL, XD-58C, MQ7 are connected to it. The NodeMCU has a Wi-Fi module with which it is connected to the Thingspeak through which the sensors data will be recorded. These sensors and microcontroller are embedded on the miners' helmets. In coal mine use of personal protective equipment like helmet, shoes etc. are not proper and proper arrangements were not there to check if the person is wearing personal protective equipment or not. The proper supervision for worker wears the protective element is very important factor for consideration. The miners will go into the coal mines wearing these IoT embedded helmets which will sense the heartbeat, surrounding conditions, location etc. If the sensors detect a high heartbeat, or unfavorable conditions or a sudden fall, the alerting device will notify the supervisor and lights will be lit and so that other people around the miner will be alerted and an alert will be sent via mail of the foreman handling the workers and also to the base station via e-mail or some other way. All the data is received from helmet and transferred to the base station through IOT and display on PC. By using IOT module we will able to get mine's update anywhere anytime through

internet. The threshold values of the sensors can be manipulated as required by the mining company to keep their workers in a safe environment.

Technical Specification:

NodeMCU ESP8266:

- Low-cost Wi-Fi microchip
- Full TCP/IP stack and microcontroller capability
- Processor: L106 32-bit RISC microprocessor core
- 32 KiB instruction RAM
- 17 GPIO pins
- The Arduino IDE was used to program the sensors and the microcontroller. It has a C++based firmware and it can be programmed like any other Arduino using this IDE.

Accelerometer(ADXL):

- Supply voltage: 2.3–3.4 V
- Consumption: 3.9 mA max.
- Low power, low cost, and high-performance
- Operating temperature: -40 °C to +85 °C
- Accelerometer:
    - o Measuring ranges: ±2 g ±4 g ±8 g ±16 g
    - o Calibration tolerance: ±3%

Gas Sensor MQ7:

- Carbon Monoxide (CO) sensor
- Concentrations ranging from 20 to 2000ppm.
- High sensitivity
- Relative humidity 65%±5%
- Temperature: -20°C to 50°C
- Voltage: 5V±0.1

Heart Beat Sensor XD-58C :

- Power Supply Voltage:3V/5V

- Magnification: 330
- LED peak wavelength: 515nm
- Product Weight:15g
- Output type: analog

System Flow chart

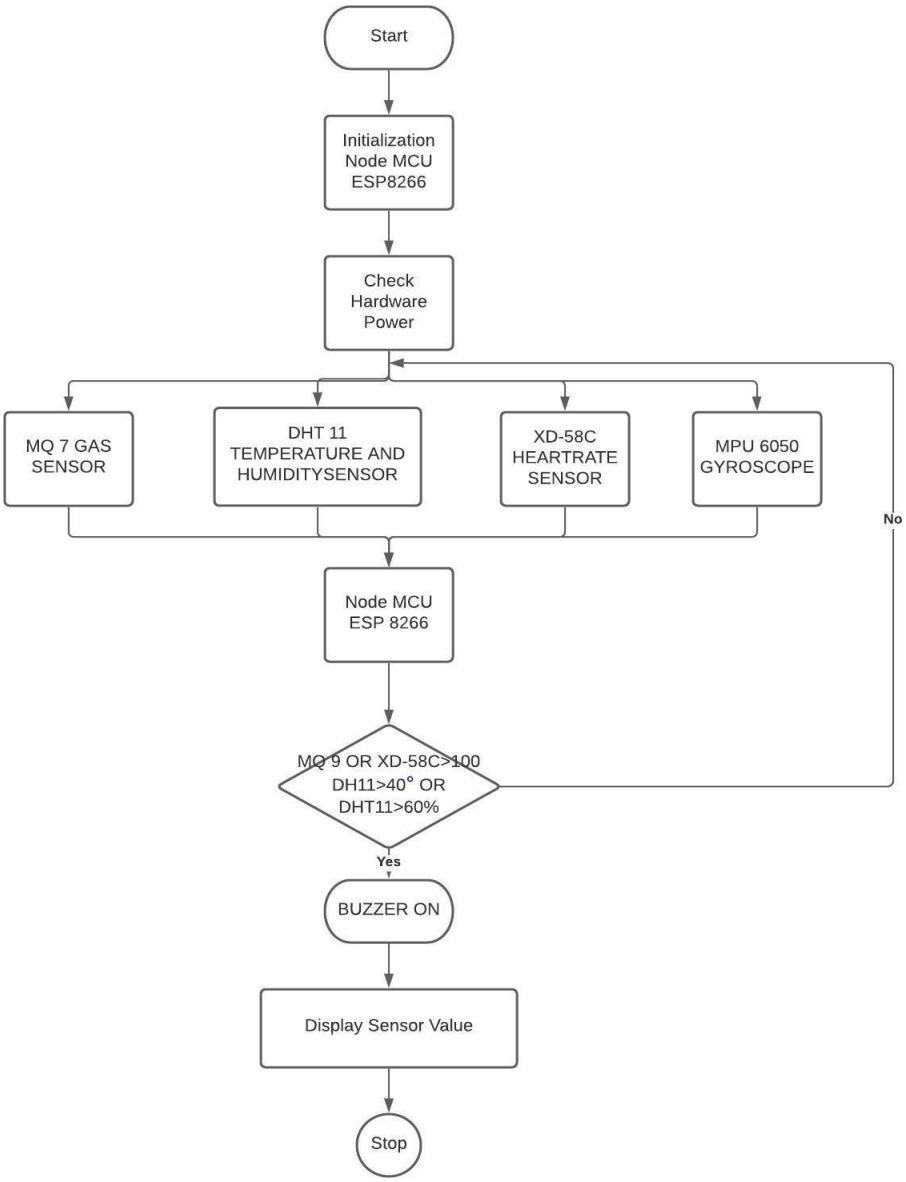


Figure 1: System Flow diagram of the Machine

Block Diagram

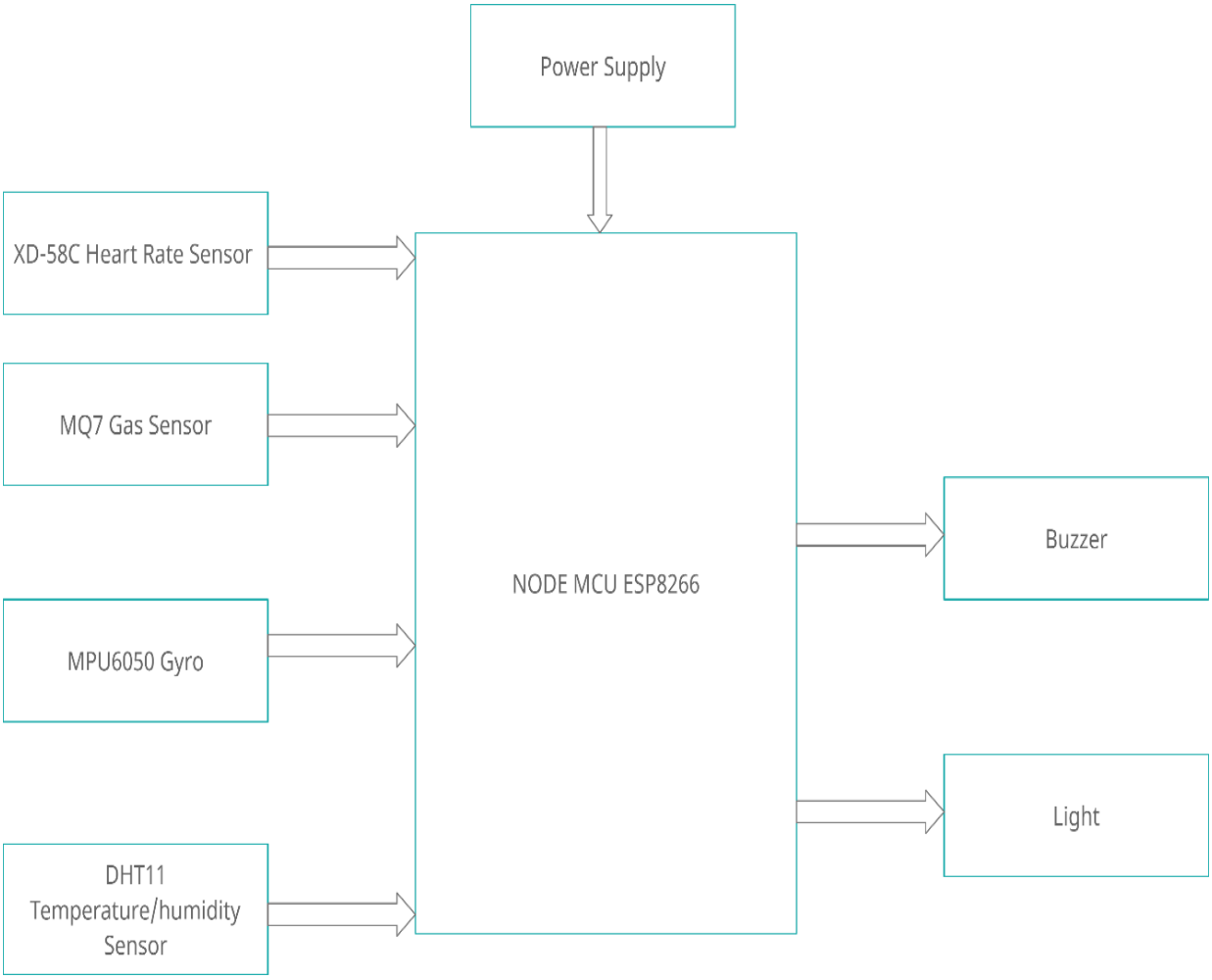


Figure 2: Block Diagram

The NodeMCU ESP8266 is the microcontroller to which all the sensors are connected. Twoof the sensors; heartbeat and gas, provide an output whereas accelerometer and temperature sensor provide digital outputs to the NodeMCU. the NodeMCU has only one A0 analog pin, so the heart beat sensor is connected to it . The accelerometer and gyroscope sensor uses the D1 and D2 pin of the NodeMCU as the SCL (Clock line) and SDA (Data Line) respectively. The temperature and humidity sensor uses the D3 pin. This entire system is planted on a helmet.

Pin Configuration

1. Gas Sensor (MQ7)

NodeMCU ESP8266	Gas Sensor MQ7
D4	D0
3.3V	VCC
G	GND

2. Pulse Sensor

NodeMCU ESP8266	Heartbeat Sensor XD-58C
3.3V	+
A0	S
G	-

3. Accelerometer (ADXL)

NodeMCU ESP8266	Accelerometerand Gyroscope MPU6050
5V(Arduino UNo)	VCC
G	GND
D1	Trigger Pin
D2	Echo pin

Difficulties Faced

We can only implement the model with the Wi-Fi module as of now. Implementing ZigBee and LoRa WAN is not possible hence the helmet is not very viable underground.

The model is not very compact hence it would be difficult to place it on a helmet. The design has to be more intricate.

Development Work for Future

We can work with the Bluetooth module on a smaller scale. On a larger scale, theproject can be shifted to a Wi-Fi module. The cost might increase by Rs.100.

Result and Analysis

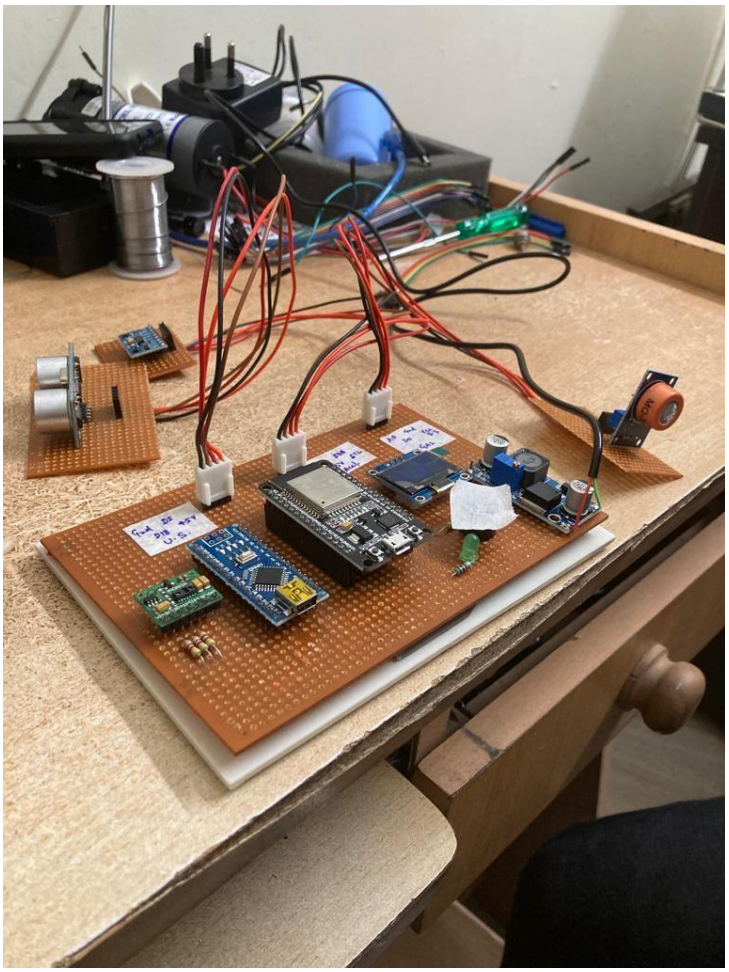


Figure 3: Hardware Setup

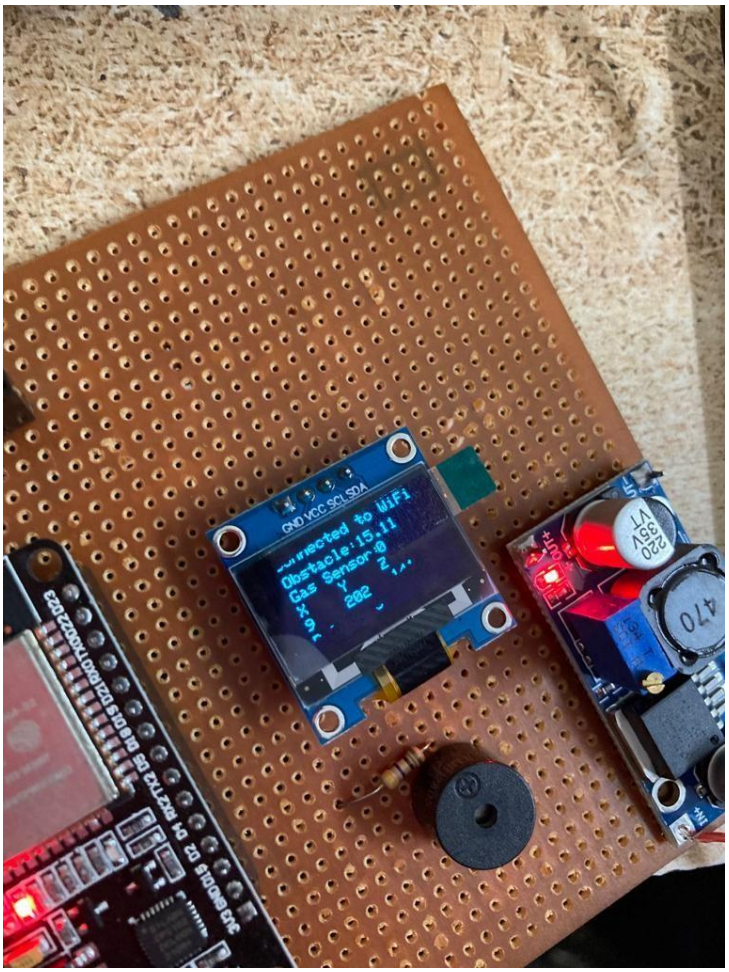


Figure 4: Smoke sensor value on LED

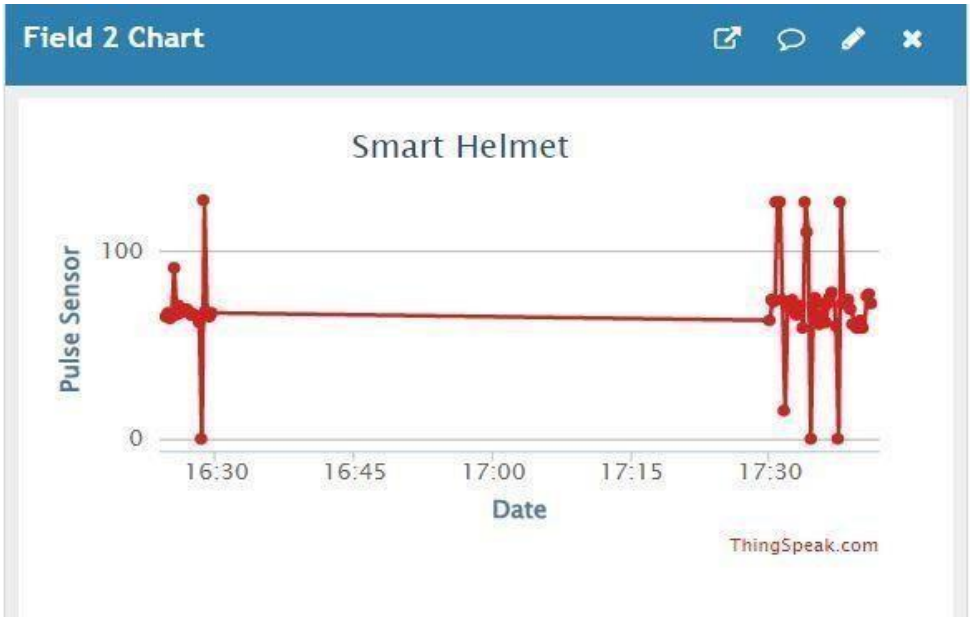
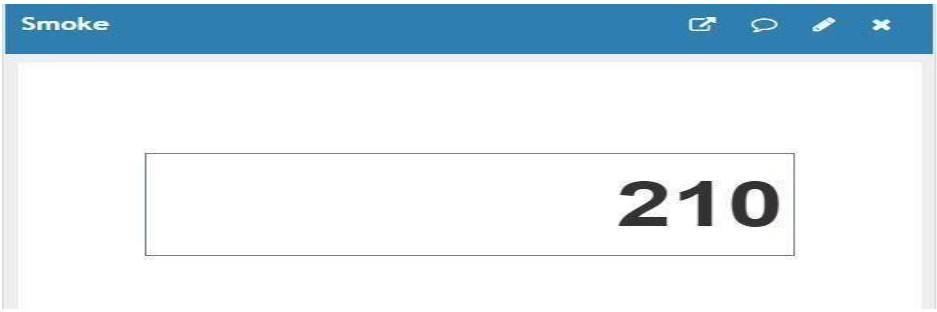


Figure 5: Pulse sensor graph

Figure 6: Smoke sensor graph



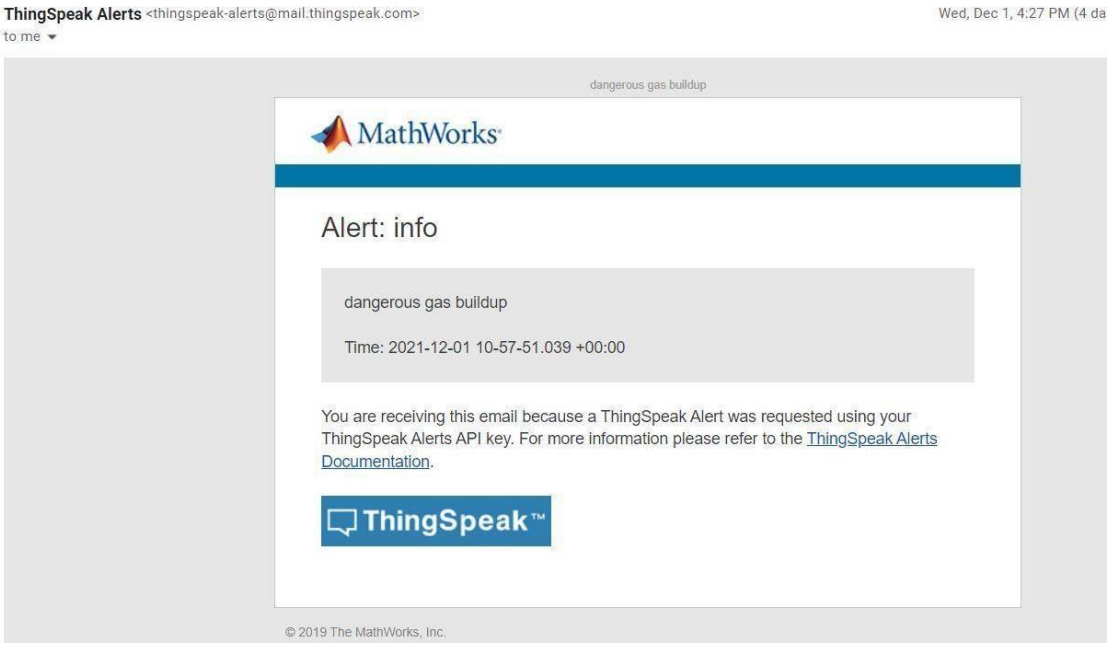


Figure 7: Smoke build alert

Conclusion

A mining helmet is developed that is able to detect different types of hazardous events such as, humidity condition of mines, then temperature and existence of combustible gases, the helmet removing by miner, and light intensity inside the mines.

Hence, a helmet was created for mine workers which would allow their supervisors to monitor their health conditions and environmental conditions and be alerted if any of the conditions exceed threshold value. Our expectation from this project is to successfully rescue workers from mines using the IOT based project which we have created.

We can work with the Bluetooth module on a smaller scale. On larger scale the projected can be shifted to a Wi-Fi module. The cost might increase by Rs.100.

However, the Wi-Fi module can be linked to the Blynk app and Arduino IoT Cloud platform, and it will make it more convenient to monitor.

Appendix

```
#include <Adafruit_ADXL345_U.h>

#include <PulseSensorPlayground.h>

#include <MQ7.h>

#include <ThingSpeak.h> #include <ESP8266WiFi.h>

#include <WifiClient.h>

#define BPM A0

const char *ssid= "XXXX";

const char *pass= "998XXXX";

const int trigPin=5;//d1
```

```
const int echopin =4;//d2
const int Smoke = 0;
const int LED =16;
WiFiClient client;
unsigned long myChannelNumber = 1524622;
const char * myWriteAPIKey = "LOYFQ6BJXXMPK1Z9";
float dist = 0.0;
float temp = 0.0;
float pulse_sensor=0.0;
float smoke_sensor=10.0;
void setup() {
pinMode(BPM,INPUT); //gas sensor
Serial.begin(115200);
WiFi.begin(ssid, pass);
while (WiFi.status() != WL_CONNECTED)
{
delay(500);
Serial.print(".");
}
Serial.println("");
Serial.println("WiFi connected");
Serial.println("IP address: "); Serial.println(WiFi.localIP());
ThingSpeak.begin(client);
pinMode(LED, OUTPUT); }
float get_distance(){
```

```
float duration,distance; digitalWrite(trigPin, LOW); delayMicroseconds(2); digitalWrite(trigPin, HIGH); delayMicroseconds(100); digitalWrite(trigPin, LOW); duration = pulseIn(echopin, HIGH); distance = (duration/2)/29.1; Serial.print("\n");
return distance;
}
void loop() {
dist=get_distance();
pulse_sensor=analogRead(BPM)/8;
Serial.print("BPM reading ");
Serial.print(pulse_sensor);
Serial.print("\n");
if (pulse_sensor <= 70) {
Serial.print("Dangerous for health\n");
digitalWrite(LED, HIGH);
Serial.print(LED);
}
else if (pulse_sensor <120||pulse_sensor> 70)
{ Serial.print("Health is fine\n");
digitalWrite(LED, LOW);
Serial.print(LED);
}
else if (pulse_sensor>120){
Serial.print("Dangerous for health\n");
digitalWrite(LED, HIGH); Serial.print(LED);
}
smoke_sensor= (digitalRead(Smoke)+210);
```

```
Serial.print("Smoke ");
Serial.print(smoke_sensor);
Serial.print("\n");
ThingSpeak.setField(1,LED);
ThingSpeak.setField(2,pulse_sensor);
ThingSpeak.setField(3,smoke_sensor);
delay(1000);
ThingSpeak.writeFields(myChannelNumber, myWriteAPIKey);
delay(1000*5);
}
```

/**********MATLAB ANALYSIS **********/

```
channelID = 1524622;
 alertApiKey ='TAK1CPX3C0NF08VJ1GZ3W';
% Set the address for the HTTTP call
alertUrl="https://api.thingspeak.com/alerts/send";
readAPIKey='BZVQUA8HJ278I48Q';
 options = weboptions("HeaderFields", ["ThingSpeak-Alerts-API-Key",
alertApiKey
 ]);
 alertSubject = sprintf("info");
 char alertBody;
%options = weboptions("HeaderFields", ["ThingSpeak-Alerts-API-Key",
alertApiKey ]);
distance=thingSpeakRead(channelID,'Fields',[1],'ReadKey', readAPIKey);
temp=thingSpeakRead(channelID,'Fields',[2],'ReadKey', readAPIKey);
gas=thingSpeakRead(channelID,'Fields',[3],'ReadKey', readAPIKey);
if(distance<5)
```

```
alertBody='full!';
elseif(temp>100)
alertBody='fire!';
elseif(gas>100)
alertBody='dangerous gas buildup';
end
try
webwrite(alertUrl , "body", alertBody, "subject", alertSubject, options);
catch someException
fprintf("Failed to send alert: %s\n", someException.message);
end
```

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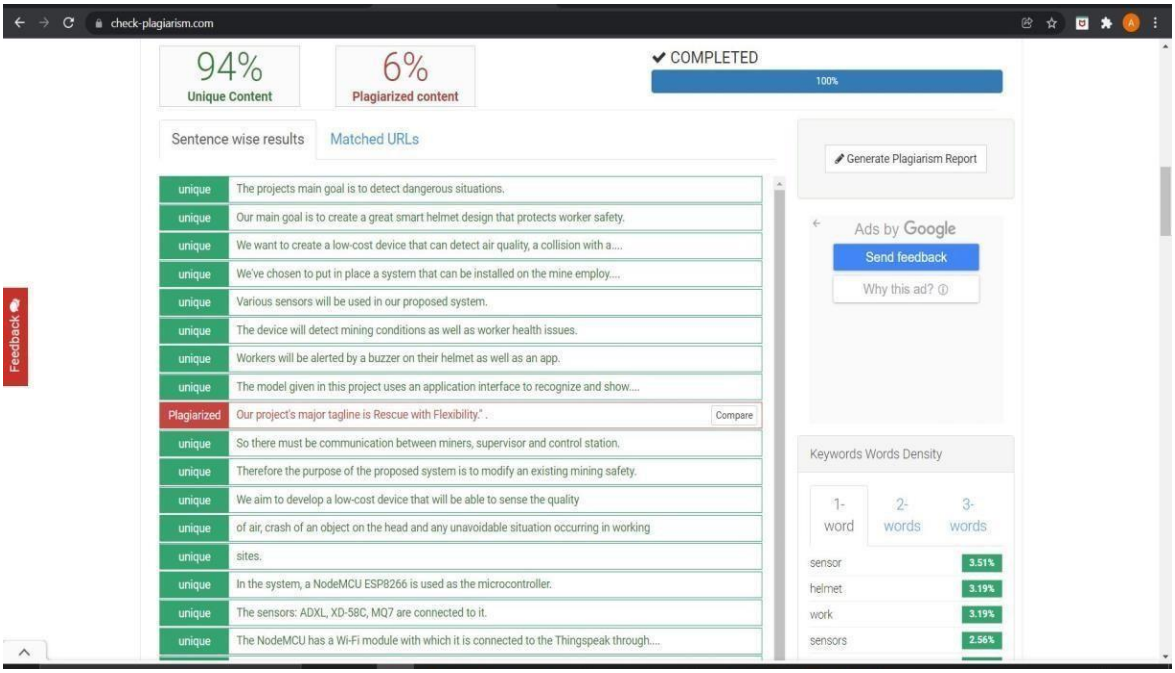

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