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MINING SAFETY AND HEALTH MONITORING SYSTEM

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Abstract: A miner's health and life are vulnerable to several critical issues, which include not only the working environment, but also the after effect of it. To increase productivity and reduce the cost of mining along with consideration of the safety of workers, an innovative approach is required. To monitor the concentration level of harmful gases, semiconductor gas sensors are used. Due to many reasons miner's falls and lose consciousness also proper treatment has not provided them at that time, so number of miners are died. To overcome this problem the system provides emergency alert to the supervisor if a person falls by any reason.

I. INTRODUCTION

A. Definition

Mining is the process of extracting useful materials from the earth. It is the extraction of valuable geological materials and minerals from the earth and other astronomical objects. Ores recovered by mining includes Metals, Coal, Oil shale, Gemstones, Limestones, Chalk, Rock salt, Potash, Gravel, and Clay. The safety issues of coal mines have gradually turned into a major concern for society and nation. Underground coal miners are exposed to a wide range of hazards including gas explosions, shifting rock, falls, and machinery and mobile equipment accidents. So, the miner safety is a very important factor to be considered.

B. Problem Statement

The purpose for the development and implementation of advanced technologies, safety protocols, and health monitoring systems to mitigate risks such as accidents, respiratory issues, and mental well-being and create a safer environment for mine workers.

C. Objectives

The main purpose was to provide an implementable design scenario for underground coal mines using wireless sensor networks (WSNs).

The main reason being that given the intricacies in the physical structure of a coal mine, only low power WSN nodes can produce accurate surveillance and accident detection data.

The work mainly concentrated on designing and simulating various alternate scenarios for a typical mine and comparing them based on the obtained results to arrive at a final design.

In the Era of embedded technology, the Lora protocols are used in more and more applications. Because of the rapid development of sensors, microcontrollers, and network technology, a reliable technological condition has been provided for our automatic real-time monitoring of coal mines.

The underground system collects temperature, humidity and methane values of coal mine through sensor nodes in the mine; it also collects the number of personnel inside the mine with the help of an IR sensor, and then transmits the data to information processing terminal based on ARM.

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II. SYSTEM DESIGN

A. Block Diagram

1. Receiver Section:

Fig. 1 Block Diagram of Monitoring Section

2. Sender Section:

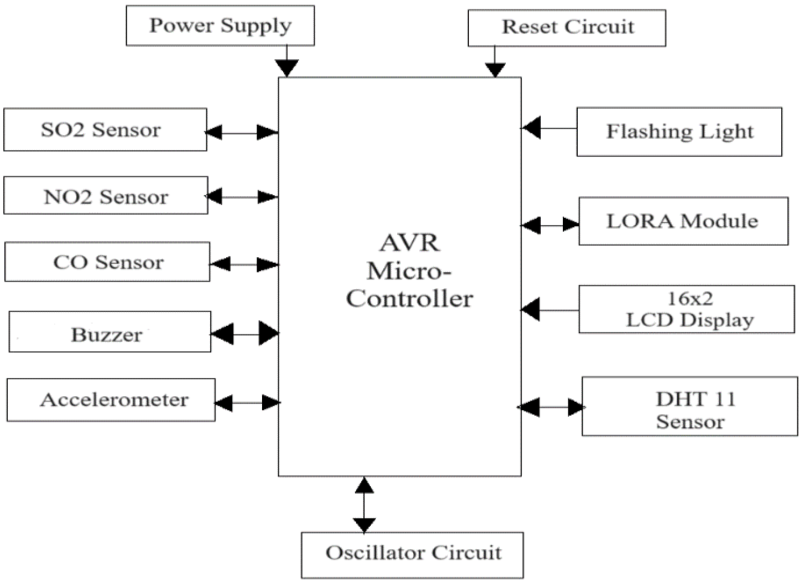

Fig. 2 Block Diagram of Mine Worker Section

Two sections are considered one to monitor the miner's health status and the other one is the total monitoring section. In the mine worker section, 2 smoke sensors are employed to monitor the different types of smoke level in the mine and the sensor measures values given to the microcontroller. If the smoke sensor values increase beyond the threshold range, then the microcontroller will give an alert to the person through buzzer and send the data to the monitoring section through the LoRaWAN module. The received data is uploaded to the webpage through IOT. In addition to that heartbeat and respiratory sensors are employed to monitor the health status of the mine workers.

The Data is also updated to a unique website through which the authorized person can access the data. The proposed system has Arduino UNO Mi- coprocessor, Smoke Sensors, Heartbeat Sensor, Respiratory Sensor, LoRaWAN networking protocol, IoT module, Buzzer, and an LCD display. y. The data from the respiratory sensor is updated on the IoT webpage. When the respiratory rate is above or below the threshold range of values then the buzzer gets turned ON. The air in mines contaminated by poisonous gases such as carbon monoxide, hydrogen sulphide, methane. Due to the minimal space, such gases do not continuously scatter. Hence, they loop within the mine environment.

The IoT supports sensing and control remotely across the current network structure. IoT board featured with SIM900 GPRS is employed in this system for exhibiting the data online. The Data is also updated to a unique website through which the authorized person can access the data. The proposed system has Arduino UNO Microprocessor, Smoke Sensors, Heartbeat Sensor, Respiratory Sensor, LoRaWAN networking protocol, IoT module, Buzzer, and an LCD display. Devices in the network are asynchronous and transmit the data once ready. Data transmitted by an end-node machine is received by multiple gateways, that transmit the data packets to a centralized network server. The information is then communicated to the application servers.

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B. Architectural Design

Arduino Based Helmet Module: Represents the Arduino-based helmet module, which includes sensors such as DHT11, IR, GPS, and Gas, along with a Node-MCU for Telegram intimation.

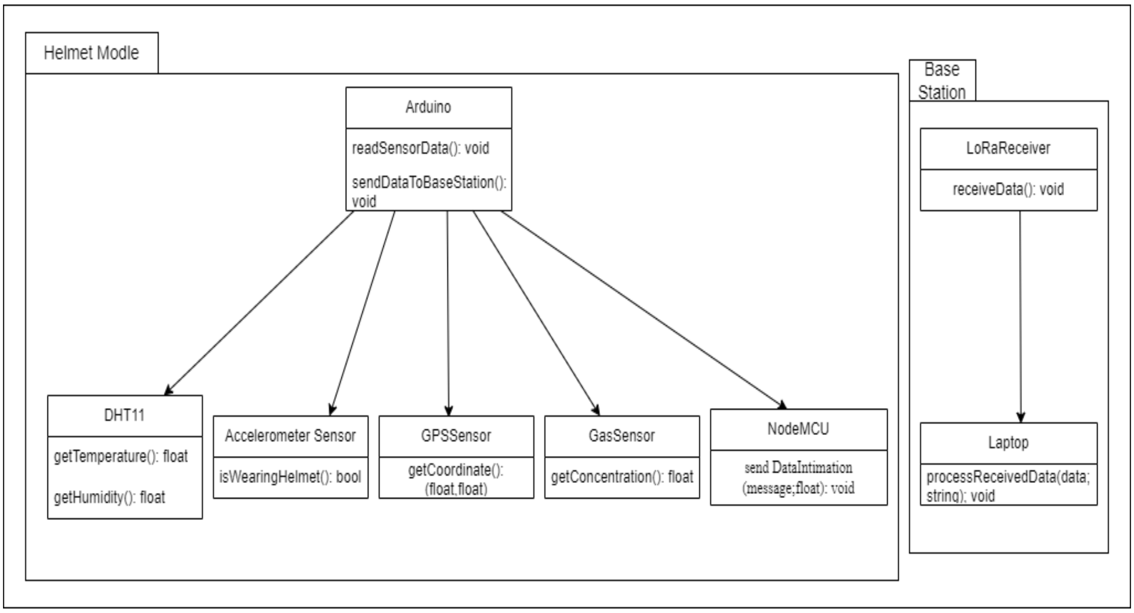
Receiver Module: Represents the receiver module, which includes a LoRa module for receiving data and a laptop for processing data.

Node MCU: Represents the Node-MCU module used for sending Telegram messages.

LoRa Module: Represents the LoRa module used for receiving data from Arduino-based helmet modules.

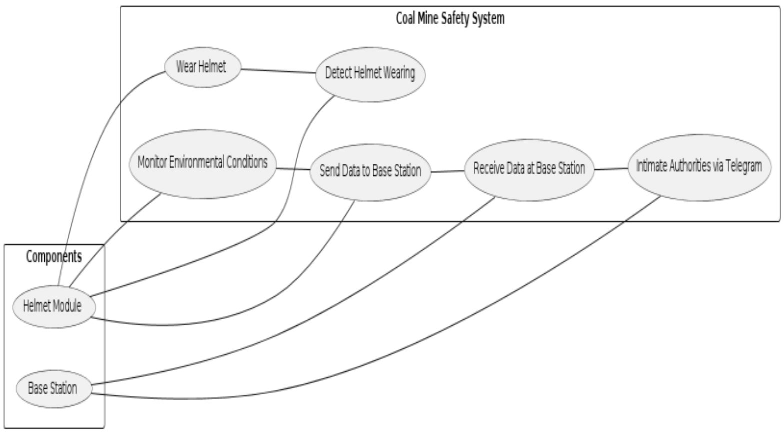
Laptop: Represents the laptop used for processing received data and performing further actions.

DHT11Sensor, IR-Sensor, GPS-Sensor, Gas-Sensor: Represent individual sensors integrated into the Arduino-based helmet module.



C. Use-Case Diagram

This UML use case diagram illustrates the interactions between the components of the coal mine safety system. The Arduino-based helmet module detects helmet wearing using IR sensors, monitors the environment using sensors such as DHT11, GPS, and gas sensors, and sends alerts via NodeMCU with Telegram integration. The base station receives data via LoRa, processes the received data, and handles alerts accordingly.



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III. METHODOLOGY

A. Components

1. Arduino:

Arduino/GenuinoUnois a microcontroller board based on the ATmega328P. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz quartz crystal, a USB connection, a power jack, an ICSP header and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with an AC-to-DC adapter or battery to get started. You can tinker with your UNO without worrying too much about doing something wrong, worst-case scenario you can replace the chip for a few dollars and start over again. "Uno" means one in Italian and was chosen to mark the release of Arduino Software (IDE) 1.0. The Uno board and version 1.0 of Arduino Software (IDE) were the reference versions of Arduino, now evolved to newer releases. The Uno board is the first in a series of USB Arduino boards, and the reference model for the Arduino platform; for an extensive list of current, past, or outdated boards see the Arduino index of boards.

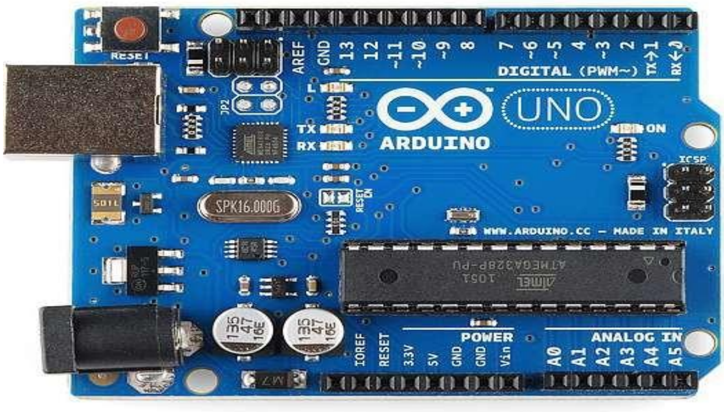

Fig.3 Arduino

2. LoRaWAN :

LoRaWAN means Long Range Wide Area Network, an open network protocol introduced by the LoRa alliance that enables the Media Access Control (MAC) layer for the network. The lower physical layer is termed as LoRa where the upper networking layers were deficient. LoRaWAN is advanced to define the upper layers of the network. LoRaWAN is a medium access control (MAC) layer protocol based on the cloud that primarily works as a network layer protocol for handling the interconnection between LPWAN gateways and end-node devices as a routing protocol. The LoRa physical layer supports the long-range communication link. LoRaWAN also governs the data rate, communicating frequencies, and electrical energy for all devices.

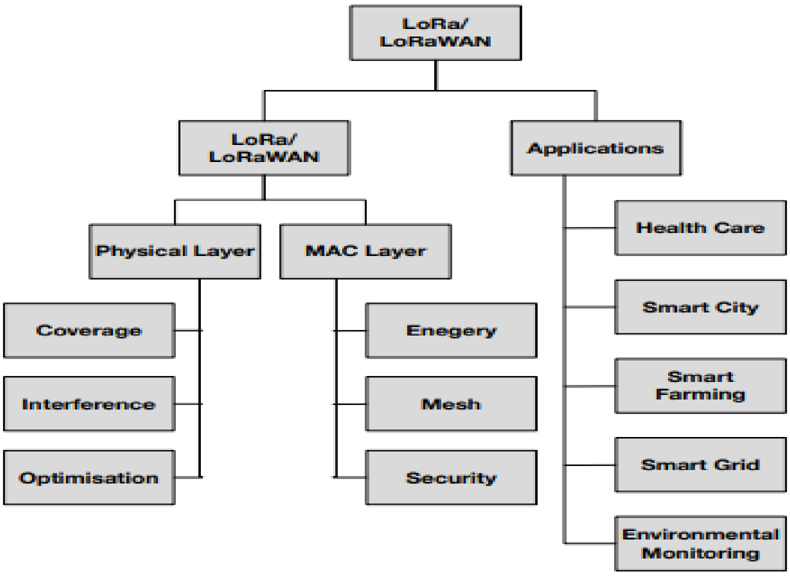

Fig.4 LoRaWAN Workflow with Application

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3. Gas sensors:

Gas Sensor Module Alarm Detection system is employed to detect and alert in case of gas hikes. It uses a simple circuit to convert the variation in conductivity of gas concentration with respect to the output signal. It is highly employed in home and industrial gas leakage alerting systems. They detect gases like Carbon Monoxide, Sulphur-di-Oxide, Nitrogen-di-Oxide gases.

Fig. 5 Gas sensor

4. DHT11 Sensor:

It is one of the DHTXX series of Humidity sensors. The other sensors in this series would be DHT22. Both these sensors are considered as Relative Humidity Sensor. Because they will check humidity and temperature. These sensors are cheap, small, and slow yet they are very common amongst hobbyists.

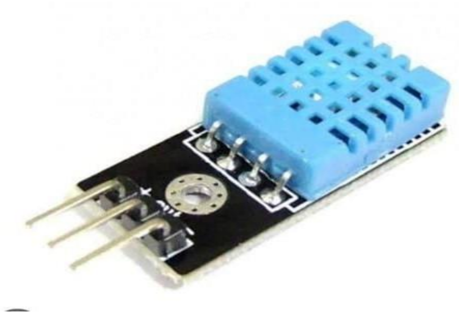

Fig. 6 DHT 11 sensor

5. Liquid Crystal Display:

Liquid crystals are substances that exhibit a phase of matter that has properties. Between those of a conventional liquid, and those of a solid crystal. For instance, a Liquid Crystal (LC) may flow like a liquid but have the molecules in the liquid arranged and/or Oriented in a crystal-like way.

Each pixel of an LCD typically consists of a layer of molecules aligned between two transparent electrodes, and two polarizing filters, the axes of transmission of which are (most of the cases) perpendicular to each other. The surfaces of the electrodes, which are in contact with the liquid crystal material, are treated to align the liquid crystal molecules in a particular direction. This treatment typically consists of a thin polymer layer that is unidirectional rubbed using, for example, a cloth. The direction of the liquid crystal alignment is then defined by the direction of rubbing. Electrodes are made of a transparent conductor called Indium Tin Oxide (ITO).

Fig. 7 Liquid Crystal Display (LCD)

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B. Methodology

- IOT Based Coal Mine Safety Monitoring project consists of two hardware modules, one transmitter and one receiver.
- The main controller in both the modules is an Arduino board. The transmitter module is installed inside the coal mine. The transmitter module contains the smoke sensor, temperature sensor and methane sensor.
- The transmitter module also has an LCD, all the sensor data is displayed on the LCD screen by the Arduino controller.
- The RF transmitter present on the transmitter module sends the sensor data to the receiver module.
- The receiver module also has an Arduino controller, LCD display, and an RF receiver. The RF receiver receives the sensor values from the RF transmitter on the transmitter module.
- The received sensor values are displayed on the LCD screen. The Arduino also sends the sensor data to the remote IOT server using the WiFi module every two minutes. If any of the sensor values exceeds a particular threshold level, the buzzer is turned on to notify the concerned personnel.
- The remote server has an IOT platform installed on it which displays the relevant data using the GUI which helps the users in monitoring and system control.

IV. TESTING

Testing is the process of evaluating a system or its component(s) with the intent to find whether it satisfies the specified requirements or not. Testing is executing a system in order to identify any gaps, errors, or missing requirements in contrary to the actual requirements.

Testing Principle:
Before applying methods to design effective test cases, a software engineer must understand the basic principle that guides software testing. All the tests should be traceable to customer requirements.

Testing Methods:
There are different methods that can be used for software testing. They are,

1. Black-Box Testing
The technique of testing without having any knowledge of the interior workings of the application is called black-box testing. The tester is oblivious to the system architecture and does not have access to the source code. Typically, while performing a black-box test, a tester will interact with the system's user interface by providing inputs and examining outputs without knowing how and where the inputs are worked upon.

2. White-Box Testing
White-box testing is the detailed investigation of internal logic and structure of the code. White-box testing is also called glass testing or open-box testing. In order to perform white-box testing on an application, a tester needs to know the internal workings of the code. The tester needs to have a look inside the source code and find out which unit/chunk of the code is behaving inappropriately.

Levels of Testing:
There are different levels during the process of testing. Levels of testing include different methodologies that can be used while conducting software testing. The main levels of software testing are:

Functional Testing:
This is a type of black box testing that is based on the specifications of the software that is to be tested. The application is tested by providing input and then the results are examined that need to conform to the functionality it was intended for. Functional testing of software is conducted on a complete, integrated system to evaluate the system's compliance with its specified requirements.

There are five steps that are involved while testing an application for functionality.

- The determination of the functionality that the intended application is meant to perform.
- The creation of test data based on the specifications of the application.
- The output based on the test data and the specifications of the application.
- The writing of test scenarios and the execution of test cases.
- The comparison of actual and expected results based on the executed test cases.

Non-functional Testing:

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This section is based upon testing an application from its non-functional attributes. Non-functional testing involves testing software from the requirements which are non-functional in nature but important such as performance, security, user interface, etc. Testing can be done in different levels of SDLC. Few of them are:

1. **Unit Testing**

Unit testing is a software development process in which the smallest testable parts of an application, called units, are individually and independently scrutinized for proper operation. Unit testing is often automated but it can also be done manually. The goal of unit testing is to isolate each part of the program and show that individual parts are correct in terms of requirements and functionality. Test cases and results are shown in the Tables.

Unit Testing Benefits

- Unit testing increases confidence in changing/ maintaining code.
- Codes are more reusable.
- Development is faster.
- The cost of fixing a defect detected during unit testing is lesser in comparison to that of defects detected at higher levels.
- Debugging is easy.
- Codes are more reliable.

2. **Integration Testing:**

Integration testing is a level of software testing where individual units are combined and tested as a group. The purpose of this level of testing is to expose faults in the interaction between integrated units. Test drivers and test stubs are used to assist in Integration Testing. Integration testing is defined as the testing of combined parts of an application to determine if they function correctly. It occurs after unit testing and before validation testing. Integration testing can be done in two ways: Bottom-up integration testing and Top-down integration testing.

a. Bottom-up Integration:

This testing begins with unit testing, followed by tests of progressively higher-level combinations of units called modules or builds.

b. Top-down Integration:

In this testing, the highest-level modules are tested first and progressively, lower-level modules are tested thereafter.
In a comprehensive software development environment, bottom-up testing is usually done first, followed by top-down testing. The process concludes with multiple tests of the complete application, preferably in scenarios designed to mimic actual situations. Table 8.3.2 shows the test cases for integration testing and their results.

3. **System testing:**

System testing of software or hardware is testing conducted on a complete, integrated system to evaluate the system's compliance with its specified requirements. System testing falls within the scope of black-box testing, and as such, should require no knowledge of the inner design of the code or logic. System testing is important because of the following reasons:

- System testing is the first step in the Software Development Life Cycle, where the application is tested.
- The application is tested thoroughly to verify that it meets the functional and technical specifications.
- The application is tested in an environment that is very close to the production environment where the application will be deployed.
- System testing enables us to test, verify, and validate both the business requirements as well as the application architecture.

V. RESULTS AND SNAPSHOTS

- The below given Snapshots show the Results that have been displayed at the LED display of the Hardware under different Circumstances.
- Each Value displayed is sensed by its respective sensors under different working place conditions.
- Fig.10.1. displays that a gas has been detected by the gas sensors in the working place.
- Fig. 10.2. displays an Emergency Message whenever a person press the emergency button.
- Fig. 10.3. displays that the Temperature of the working place has been detected and Fig. 10.4. displays the values of the detected Temperature as well as the Humidity in the working Place.
- Fig. 10.5. displays a Fall Message when a person gets fallen while working and Fig. 10.6. displays the coordinates of the person.

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Fig. 8 Gas Detected

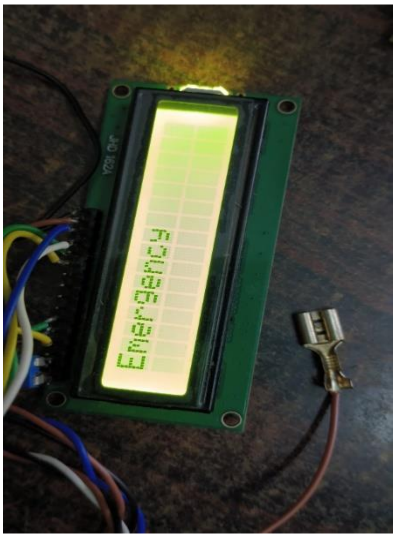

Fig. 9 Emergency

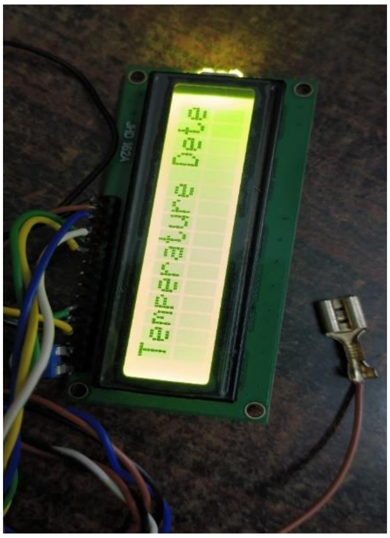

Fig. 10 Temperature Detected

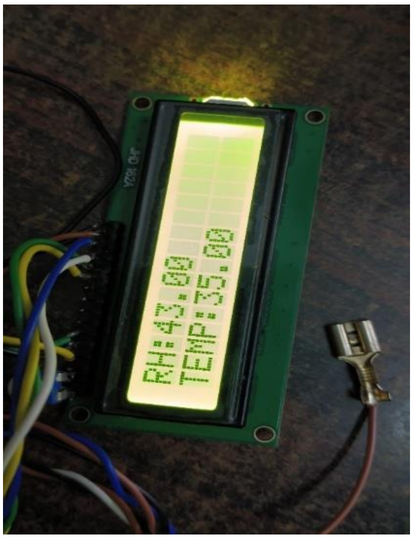

Fig. 11 Degree of Temperature and Humidity

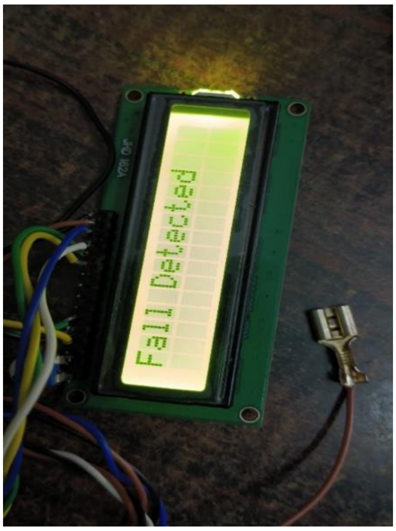

Fig. 12 Fall Detected

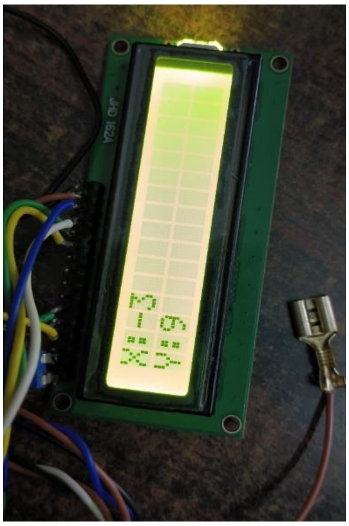

Fig. 13 Coordinates of the Person

- The below Snapshots determine the values obtained in the LCD Display has also been displayed at the Receiver end in the Monitor Section of the Computer.
- The gas values obtained will be displayed along with the temperature and humidity at which the sensor sensed.

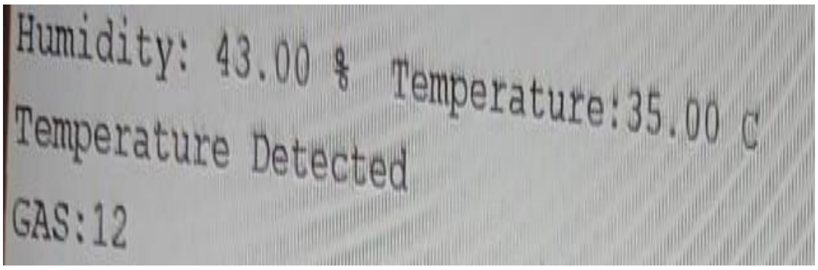

Fig. 14 Gas Values displayed at the Monitoring Section

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• Also, a person's Fall will be displayed along with the persons Coordinates as well as the values of the temperature and humidity of the place where the person is working.

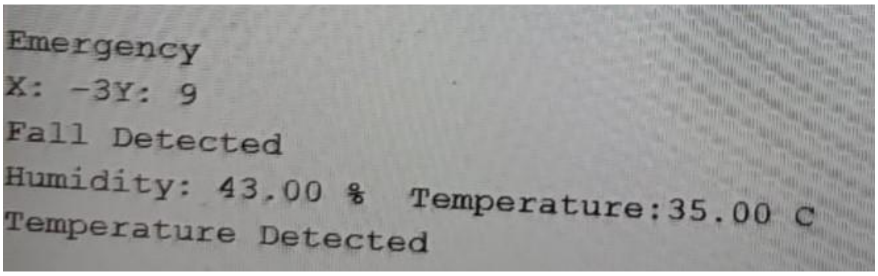

Fig. 15 Fall Message displayed at the Monitoring Section

VI. APPLICATIONS

• Reducing Accidents and Injuries: Implementation of safety projects can help identify and mitigate potential hazards in mining operations, leading to a reduction in accidents and injuries among miners.
• Health Monitoring: Incorporating health monitoring systems can ensure that miners are regularly checked for exposure to harmful substances, such as dust or gases, helping to prevent long-term health issues.
• Emergency Response Planning: Safety projects can include the development of robust emergency response plans and training programs. This ensures that miners are well-prepared to handle unforeseen events, such as cave-ins or chemical spills.
• Technological Innovations: Integration of advanced technologies like drones, sensors, and robotics can enhance safety measures. Drones can be used for surveillance, sensors can detect gas leaks, and robotics can be employed in hazardous environments.
• Training and Education: Safety projects can focus on creating comprehensive training programs for miners. This includes educating them about safety protocols, proper equipment usage, and emergency procedures.
• Real-time Monitoring: Installing real-time monitoring systems for environmental conditions, such as air quality and ground stability, ensures that miners are alerted promptly to any unsafe conditions.
• Communication Systems: Improved communication systems, including underground communication networks, can be part of safety projects. This ensures seamless communication between miners and surface personnel, enhancing overall safety.
• Behavioral Safety: Implementing programs that focus on changing and reinforcing positive safety behaviors among miners can significantly contribute to a safer work environment.
• Community and Environmental Impact: Safety projects can extend beyond the immediate mining operations to consider the impact on local communities and the environment, fostering a more sustainable and responsible approach.

VII. CONCLUSION

The Mine safety system is implemented using smoke sensors, respiratory sensors, heartbeat sensors for obtaining and health parameters environmental conditions. A smart alert system is implemented for the safety of mineworkers by alerting them at the right time to escape from the mining environment in case of any accidents.

This system constantly observes the mine and alerts the worker and the authorized person from the ground station by using LoRaWAN technology. The environment and health status of the mineworkers have continuously updated on the IoT web page.

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