

Smart Mining Helmet

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Abstract

The demand for coal as energy resource is always an important and significant part in our life. However, over the years many miners have lost their lives by facing accidents during the mining process due to lack of implementation of technology and monitoring systems. Now with the development of smart technology even the mining industry is adopting the technology for the safety of the miners. Hence in this paper, we propose to develop a smart mining helmet that is both safe and convenient for the miner to use, at the same time it monitors the environment surrounding the miner. At times of emergency, it alerts the miner along with the coworkers, thus helping them avoid accidents. The helmet is loaded with temperature and humidity sensors, smoke detectors, gyroscope sensors, and ultrasonic sensors along with algorithms to simultaneously operate these sensors and alert the miner using a liquid crystal display, sound module, and buzzer.

Keywords: Sensors, mining helmet, emergency detection, safety, industrial application

INTRODUCTION

The mining industry is a vital sector of the global economy, providing essential raw materials for a multitude of industries, from construction to electronics. In India, mining has historically been a significant contributor to the economy, with the country being rich in minerals such as coal, iron ore, manganese, bauxite, and more [1]. However, mining operations come with considerable risks, particularly concerning the health and safety of miners. Accidents in the mining industry are tragically frequent and can be catastrophic [2]. In India, notable accidents, such as the Chasnala mining disaster in 1975, where a coal mine explosion led to the flooding of the mine and the death of 375 miners [3], highlight the risks involved with mining activities. Although the number of accidents in the mining industry is decreasing over the years, accidents are still happening in the field of mining in significant numbers.

The hazards in mining are mainly due to the presence of toxic gases and the structural instability of mines. Common accidents involve cave-ins, gas explosions, and equipment malfunctions [4]. Moreover, miners are often exposed to harmful dust, leading to chronic respiratory diseases such as pneumoconiosis (black lung disease) [5]. The physical and psychological demands of mining also contribute to the high incidence of occupational injuries and illnesses. To mitigate these risks, the mining industry is increasingly turning to technology and developing systems to monitor the environments surrounding the miner [6]. However, it is impossible to move heavy monitoring equipment inside the mines, and it also becomes a tedious job for the miners to carry them around due to which miners often take off their safety instruments because it is too heavy, or uncomfortable to wear/use.

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Hence the aim is to design a smart mining helmet which is light to use, comfortable to wear, and at the

same time, provides maximum safety to the miner. The helmet can detect the toxicity in the environment, detect any obstructions overhead or falling objects from above and detect whether the miner is working without getting unconscious. Moreover, the helmet has an efficient alert system which should be effective in alerting the miner as well as coworkers in advance by making sounds and giving warning messages even when the loud mining equipment are running and its dark underground.

PROPOSED DESIGN

The smart mining helmet is designed in such a way that it provides the necessary safety to the miner without compromising the comfort and safety of the normal mining helmet. Sensors are used to monitor the miner and the environment surrounding the miner. Appropriate alert mechanism has also been incorporated in the system so that the miner, his colleagues and supervisors are also alerted in case of emergencies. A block diagram of the various modules in the proposed design is shown in Figure 1.

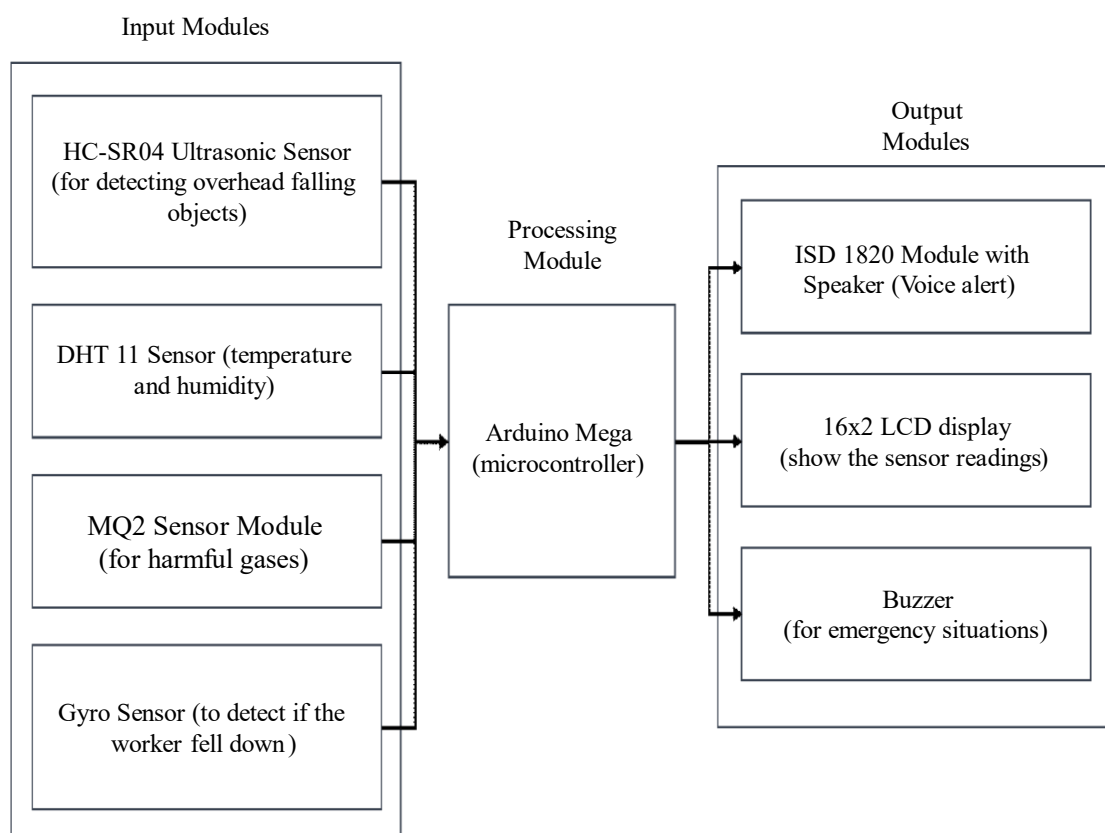


Figure 1. Block diagram of the modules of the smart mining helmet.

The whole system basically comprises three main modules, namely input module, processing module and output module, which are mounted onto the safety helmet. Input module consist of four sensors which monitor the environment surrounding the miner for any abnormality and upcoming danger. The sensors in the input module are DHT11 temperature and humidity sensor, MQ2 smoke sensor, gyro sensor, and a HC-SR04 ultrasonic sensor. The processing module consists of an Arduino mega board which processes the information collected and sends the necessary signal to the output module. The output module consists of a 16×2 LCD display, a buzzer and a ISD1820 module with an earphone attached to it.

MATERIALS AND METHODS

DHT11 is a low-cost humidity and temperature sensor which operates at 5 V and sends analog values to the microcontroller. It measures temperature in the range of 0°C to 50°C with $\pm 2^{\circ}\text{C}$ accuracy and

20% to 80% humidity readings with 5% accuracy [7]. In case the temperature and humidity rise above a threshold value, the buzzer is triggered. The output pin is connected to pin 6 of the Arduino board, VDD to 5 V and GND pin is connected.

The MQ2 smoke sensor is useful for gas leakage detection (home and industry). It is suitable for detecting H₂, liquified petroleum gas (LPG), CH₄, CO, alcohol, smoke, and propane. Due to its high sensitivity and fast response time, measurements can be taken immediately [8]. The sensitivity of the sensor can be varied by connecting a potentiometer but in this system it has been set to “50” by trial-and-error method. In case the sensor output goes above “50”, it is displayed in the 16 × 2 display and buzzer goes on. The output pin is connected to pin A0 of the Arduino board.

The gyro sensor used in this system is a LPY530AL which is a low-power two-axis micromachined gyroscope capable of measuring angular rate along pitch and yaw axes [9]. It operates at 3.3 V and sends values using an output port connected to pin A2 of the Arduino board. It is placed on top of the mining helmet in a way that the x axis aligns with the way where the user faces and y axis is perpendicular to it. According to the program, if there is any sudden and abnormal change in the ‘y’ values of the sensor, then it means that the miner has fallen, and thus the buzzer goes ON, alerting the other miners. The value in ‘x’ axis is not considered to detect the fall because it is unlikely for a miner to fall on his face, moreover the miner might need to bow/bend down during the mining process which will trigger a false alarm.

The HC-SR04 sensor is an ultrasonic sensor which is also placed on top of the mining helmet, to detect any falling objects overhead. Moreover, it can also prevent the head from hitting any overhead obstacles in case the miner needs to pass through narrow and low tunnels. This sensor works on 5 V and uses sonar to find out the distance of the object from the sensor. It provides an outstanding range of non-contact detection with high accuracy and stable readings. It includes two modules like ultrasonic transmitter and receiver. It has 4 pins, namely VCC, GND, TRIG, and ECHO. TRIG (connected to Pin 9) is an input pin, used to initialize measurement by transmitting ultrasonic waves by keeping this pin high for 10 μs. ECHO (connected to Pin 10) is an output pin, which goes high for a specific time period, and it will be equivalent to the duration of the wave to return to the sensor [10]. For this system the safe distance has been set to ‘50 cm’, if any object comes closer than the threshold, the output module sends an alert.

In the output module, 16 × 2 LCD display is used to update all the statistics that the sensors are monitoring and in case of emergencies, it displays the warning messages. It is placed in front of the helmet so that it can be easily read by the co-workers of the miners, and they can take the necessary actions. A piezoelectric buzzer with high-pitch sound is also used as an alarm to alert the miners in case of emergencies. It has been programmed in order to produce different sounds in case of different types of emergency situations and also depending on the severity of the emergency. Finally, an ISD 1820 module [11] is also connected to the Arduino board so that an earpiece can be connected to the system, through which the miner can be alerted about all the environment parameters. Earpiece is preferred over the buzzer because sound in an earpiece will be more audible compared to the buzzer during mining as heavy machineries will be operating simultaneously during the mining process. Figure 2 shows the connection of various components in the system.

RESULTS

Each module has been tested separately for their respective functions. After testing all, the modules were mounted on a helmet to detect the various parameters and react accordingly as shown in Table 1. All the functions performed as expected and the weight of the mining helmet is around 400 g excluding the power source. The power source can be a portable power bank connected to the helmet via a USB cable, it can be mounted on the helmet or else can be carried by the miner separately. Carrying the power bank separately will keep the helmet light weight, which will not hamper the miner while working (Figure 3).

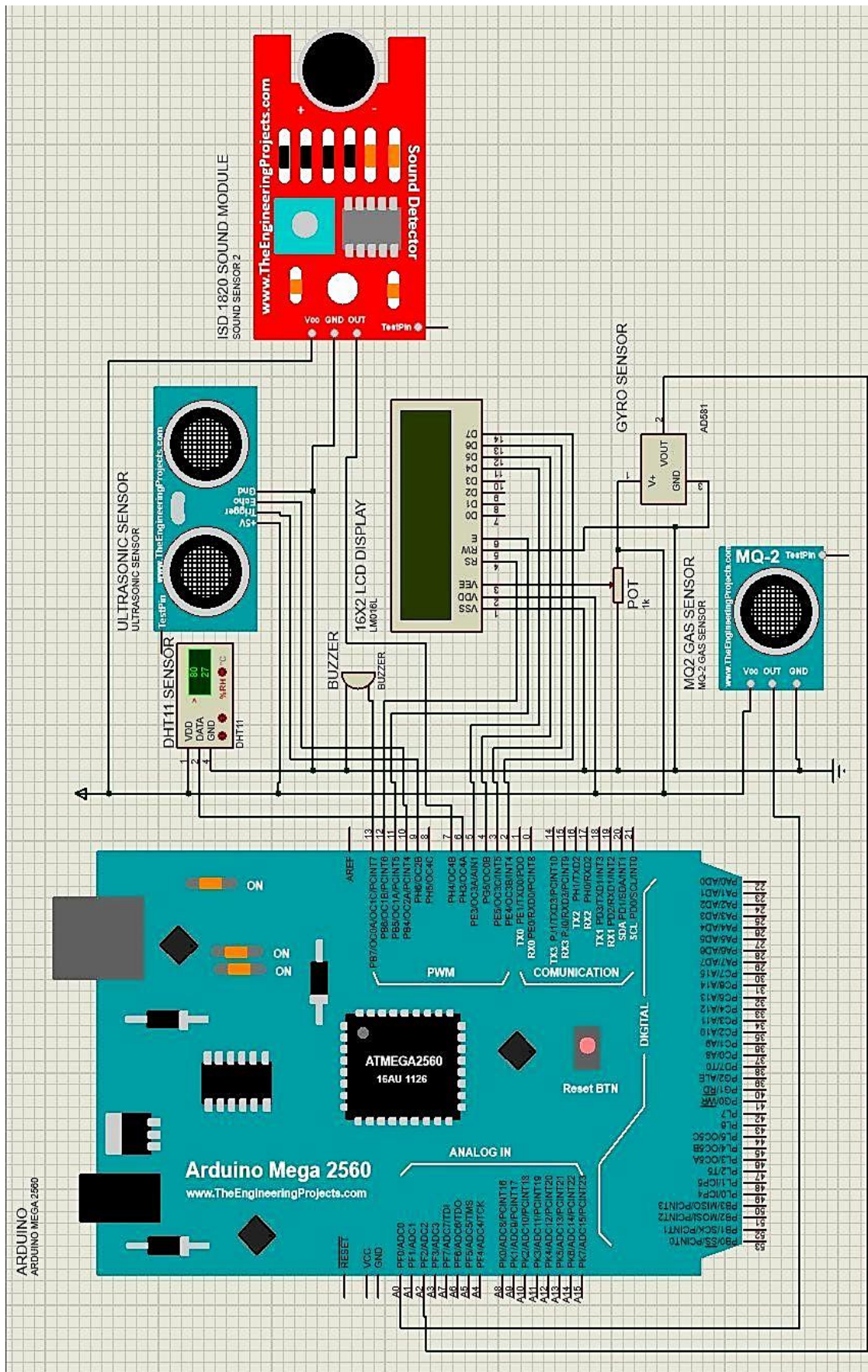


Figure 2. Circuit diagram of the system showing all the connection of the various components of the system.

Table 1. Various input modules along with their respective threshold parameter conditions and desired outputs.

Input Sensor	Threshold Parameter	Output
DHT 11 temperature and humidity sensor	For temperature above 45°C	Buzzer goes ON warning on LCD
MQ2 sensor module for harmful gases	For analog input above 50	Buzzer goes ON warning on LCD
HC-SR04 ultrasonic sensor	Any obstruction overhead closer than 50 cm	Warning message on earpiece, warning on LCD
Gyro sensor	Sudden change in the value of 'y-axis'	Buzzer goes ON (high pitched) Warning on LCD

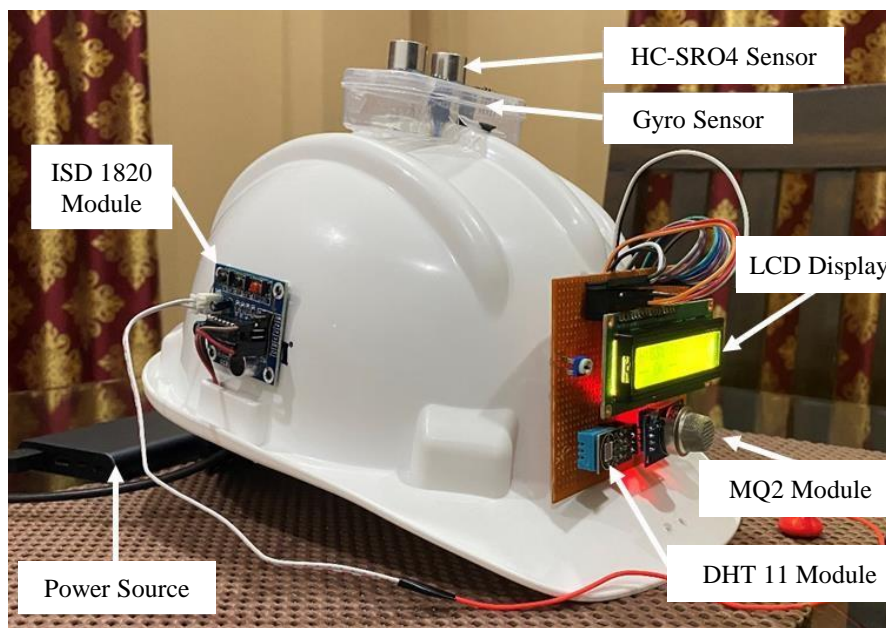


Figure 3. The smart mining helmet mounted with all the sensor modules and the alarm mechanism.

CONCLUSION

To conclude, it can be stated that in this project a smart mining helmet has been designed keeping in mind the safety of the miners and the convenience to use this helmet. It is lightweight and the sensors added very little extra weight to this helmet due to which a miner can easily use this helmet without any inconvenience. Internet of things (IoT) module can further be added to this helmet in order to remotely monitor the miner by a supervisor along with a GPS (global positioning system) tracker or a GSM (global system for mobile communications) kit, but then again it will lead to more weight of the mining helmet due to which it can be an inconvenience to use it. Finally, it can be stated that the system is reliable, made with simple and easily available components making this project very lightweight, portable, and compatible for use.

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