Mediterranean Journal of Basic and Applied Sciences (MJBAS)
Volume 7, Issue 2, Pages 48-55, April-June 2023

Smartguard: "An Intelligent Helmet for Enhanced Safety of Mining Work"

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DOI: https://doi.org/10.46382/MJBAS.2023.7207

Article Received: 21 March 2023 *Article Accepted: 28 April 2023* *Article Published: 19 May 2023*

ABSTRACT

The Internet of Things (IoT) has garnered significant attention due to its widespread adoption across various applications. This has led to increased focus on its design. The mining region represents a potential site where a cacophonous industrial setting could be present. The primary aim of this project is to develop and manufacture a smart helmet system that can be utilised in the mining sector. The designated system will persist in monitoring conditions that may pose a risk, such as temperature, humidity, gas levels, removal of a miner's helmet, and damage to the helmet caused by obstructions. The finalised design underwent refinement and validation through rigorous testing conducted within the confines of the Gua Tempurung cave located in Malaysia. The efficacy of the helmet system circuit under consideration was assessed and juxtaposed with prior research. The control room and helmet department were primarily designated for the programming and troubleshooting sections. The initial computation was utilised to determine the results.

Keywords: Smart helmet; Industrial application; Detection system; Wireless communication.

1. Introduction

Any modern nation's mining industry can be categorised as its most vital sector. It makes it easier to get rid of and find underground resources including coal, diamonds, gold, and iron. The phrase "Internet of Things" is a type of information and communication technology (ICT) that describes communications across wireless sensor networks (WSNs) [1]. This technique makes advantage of the well-known IEEE 802.14.5 protocol, which makes low-rate wide-area networks (LR-WAN) possible. The protocols are chosen based on the project application and requirements, and each has unique advantages and disadvantages [2].

Long transmission lengths are possible with the protocol designed for long-range wide-area networks (LR-WAN), which also uses a fixed data rate and little power. It also lowers the cost of manufacturing materials. IOT can be used in the majority of established applications, such as smart building management, smart parking systems, and smart energy monitoring systems [3]. Three methods: The wireless protocol, web-based model (things), and monitoring tools (Sensors) make up the IOT architecture.

1.1. System Overview

The present study utilised the constituent elements of the operating system of the intelligent helmet, which are as follows: The system comprises of a Gas Control mechanism, Force Detection module, Temperature and Humidity Monitoring unit, an LCD display, LED indicators, and a 9-volt power supply battery [4]. The integration of these systems is facilitated through the utilisation of the Internet of Things (IoT) platform Node-Red. The amalgamated systems transmit data at regular intervals of six seconds. The point of initialization for the central processing unit (CPU), microcontroller, and internet of things (IoT) platform. The decision is determined through the detection of infrared (IR) data. if it is low, the sensor will recognise the miner's head [5]. The signal is sent to Node-Red and/or Arduino for further analysis if the humidity level is more than or equal to 80%. Additionally, the temperature measurement will be updated on the LCD and transmitted to Node-Red [6]. The signal will be analysed using Node-Red, which will ring the bell in the control room and send an SMS to the rescue team.

2. Existing System

The most recent mining method makes sure that the helmets worn by miners are made to guard against a variety of hazards that may happen during excavation, improving their working safety [7].

Because the helmets can be cumbersome and difficult to wear while working, miners are occasionally spotted without them on their heads. To lessen the physical strain, they can decide to take them out for a little while. There isn't a helmet on the market right now that has the technology to examine and evaluate a worker's environment and then offer the best protection possible in light of that evaluation [8]. the creation of a smart helmet with decision-making capabilities.

(i) Ensuring the safety of miners during mining mishaps brought on by an increase in temperature, pressure, force;

(ii) To facilitate communication between the coal workers underground and the outside world;

(iii) To keep an eye on the conditions in the mines and notify the miners of any emergencies;

(iv) GPS is utilised to monitor the whereabouts of miners;

(v) The harmful gases' detection [9].

3. Proposed System

A helmet has been developed and implemented with optimal protective capabilities and a multitude of sensors for various forms of analysis and detection. Initially, gas sensors are employed to detect hazardous gases. When a hazardous gas is found, send an alert. A heartbeat level monitoring was assigned to the second dangerous occurrence. Falling item detection is done with the aid of an ultrasonic sensor. Unexpectedly dangerous situations, such temperature, are transmitted to the control station using wireless transmitters for constant observation.

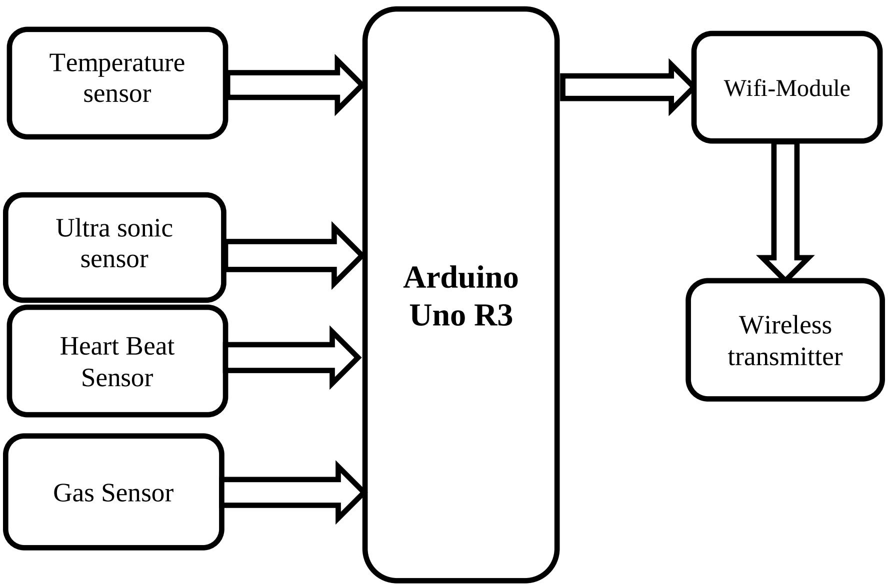

Figure 1. Block diagram of transmitter section

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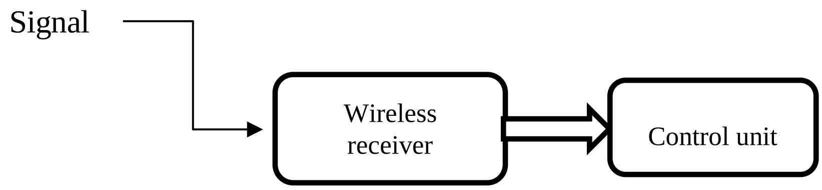

Figure 2. Block diagram of Receiver section

3.1. Working

The development of a safety helmet for coal mining workers that integrates an ultrasonic sensor, MQ3 sensor, temperature sensor, and heart rate sensor would enable the provision of real-time safety monitoring and warning systems for workers operating in a hazardous environment. The utilisation of an ultrasonic sensor is proposed for the purpose of identifying and detecting potential obstructions or hazards within the immediate proximity of the worker. These obstructions may include walls, equipment, or other objects that could potentially pose a threat to the worker's safety. The proposed method involves the emission of a high-frequency sound wave and subsequent measurement of the time elapsed for the wave to reflect back, thereby providing an estimate of the spatial separation between the sensor and the target object. The utilisation of MQ3 sensor is proposed for the detection of hazardous concentrations of methane gas, which is a prevalent risk factor in coal mining activities. The device is designed to detect and quantify the presence of methane gas in the surrounding atmosphere. In the event that the concentration of methane exceeds the permissible limit, the system will activate an alarm to alert the personnel to evacuate the premises immediately.

The utilisation of a temperature sensor is proposed for the purpose of monitoring the body temperature of workers as well as the ambient temperature of the surrounding environment. The aforementioned data would serve the purpose of assessing whether the labourer is susceptible to heatstroke or hypothermia. Additionally, it would notify the labourer or their superior in case any measures are required to avert any potential harm or ailment. The utilisation of a heart rate sensor is proposed to oversee the cardiovascular activity of the labourer and notify either the worker or the supervisor in the event that the heart rate surpasses a secure threshold. This observation may suggest that the employee is encountering stress, exhaustion, or other health concerns that could potentially affect their capacity to perform their duties in a secure manner. The various sensors would be linked to a centralised control unit situated within the helmet. The control unit of the Arduino would analyse the data obtained from the sensors and activate alerts in case of need. The helmet would be outfitted with a communication device, facilitating the worker's ability to communicate with their supervisor or emergency services in the event of an emergency.

4. Hardware Description

4.1 Arduino Uno

The Arduino UNO board is commonly acknowledged as a suitable point of initiation for novices who exhibit an interest in the fields of electronics and computer programming. For individuals who are inexperienced with the platform, it is advisable to commence with the UNO board as it is a comprehensive option for engaging in exploratory activities [10]. The microcontroller board, Arduino UNO, is primarily centred around the ATmega328P, which serves as its central component. The apparatus possesses a total of 14 digital input/output pins, out of which 6 have the ability to function as pulse-width modulation outputs. The device is equipped with six analogue inputs and a 16 MHz ceramic resonator, in addition to a USB port, power jack, ICSP header, and reset button.

The setup encompasses all the essential constituents required for the operation of the microcontroller. As per the reference provided [11], the device can be energized through two means: by linking it to a computer via a USB cable or by employing an AC-to-DC adapter or battery.

4.2. WIFI Module

Wireless Fidelity (Wi-Fi) modules, alternatively referred to as Wireless Local Area Network (WLAN) modules, are electronic constituents that are widely employed in various products to facilitate wireless internet connectivity [12]. The ESP8266 Wi-Fi module is a system-on-a-chip microchip primarily utilised for the creation of endpoint Internet of Things (IoT) applications. This device is commonly known as a self-contained wireless transceiver and is readily accessible at a relatively inexpensive cost. The purpose of this technology is to facilitate the connectivity of embedded system applications to the internet.

Wi-Fi modules or Wi-Fi microcontrollers are utilised for transmitting and receiving data through Wi-Fi technology. Furthermore, it is possible for them to receive and execute instructions through wireless local area network (WLAN) connectivity. Wi-Fi modules are utilised for facilitating communication among various devices. The prevalent application domain for these entities is the realm of the Internet of Things.

4.3. Ultrasonic Sensor

The ultrasonic sensor is a technological apparatus that utilises ultrasonic sound waves to ascertain the spatial separation between the sensor and a given object. The utilisation of a transducer in an ultrasonic sensor facilitates the emission and reception of ultrasonic waves, which in turn furnish information pertaining to the proximity of an object [13]. Ultrasonic transducers are typically utilised in air-coupled applications and function within the frequency spectrum of 30-500 kHz. The relationship between the level of attenuation and the frequency of ultrasonic waves is directly proportional, meaning that as the frequency of ultrasonic waves increases, the level of attenuation also increases.

Empirical evidence suggests that sensors operating at lower frequency ranges, specifically within the range of 30-80 kHz, demonstrate superior performance in detecting targets at longer distances. Conversely, sensors operating at higher frequency ranges are found to be more adept at detecting targets in close proximity.

4.4. Heart Beat Sensor

The measurement of heart rate can be accomplished through the utilisation of optical power variation, which occurs as a result of light scattering or absorption during its passage through the bloodstream, in response to changes in the heartbeat. These devices employ electrical sensing mechanisms to monitor an individual's heart rate [14]. Electrical activity is detected by means of a band that is placed around the chest. In order for the majority of these devices to function as intended, it is necessary for the band to be moistened or for a conductive gel to be applied to the areas where the sensors come into contact with the skin.

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4.5. Gas Sensor

Gas sensors, also referred to as gas detectors, are electronic instruments designed to detect and distinguish various types of gases. Gas sensors are frequently employed for the purpose of identifying hazardous or combustible gases and quantifying gas levels [15].

Gas sensors operate based on the fundamental concept of converting the gas adsorption impacts on the active material's surface into an observable signal, which is characterised by alterations in its electrical, optical, thermal, mechanical, magnetic (magnetization and spin), and piezoelectric properties.

4.6. Temperature Sensor

Temperature sensors are instruments utilised to identify and quantify thermal energy, encompassing both cold and heat. Temperature sensors are commonly employed in various aspects of everyday life, such as domestic water heating systems, thermometers, refrigeration units, and microwave ovens. Temperature sensors operate by generating electrical signals to deliver temperature measurements [16]. Sensors are typically constructed using a combination of two metallic elements, which are capable of producing an electrical voltage or resistance in response to changes in temperature. This is achieved by measuring the voltage that is generated across the diode terminals. With an increase in voltage, there is a corresponding increase in temperature.

4.7. Transmitter & Receiver

The NodeMCU V3 is a firmware and development kit that is open-source and serves a crucial function in the creation of an Internet of Things (IoT) product through the implementation of a limited number of script lines [17]. The board features several GPIO pins that facilitate the connection of external peripherals and support the generation of various serial communication protocols, including PWM, I2C, SPI, and UART. The firmware employs the Lua programming language. The firmware utilised in this project is founded on the eLua initiative and constructed through the implementation of the Espressif Non-OS Software Development Kit for the ESP8266 platform.

5. Software Description

5.1. Arduino IDE

The Arduino Software (IDE) [18] is equipped with an extensive array of functionalities, including a text editor that facilitates code composition, a message area that displays relevant information, a text console that enables communication, a toolbar for quick access to frequently used functions, and a set of menus for navigation through the software's settings and options. The Arduino IDE, which is commonly referred to as the Arduino Integrated Development Environment, serves as the principal software application employed for text editing in Arduino programming.

5.2. Embedded C

The utilisation of Embedded C programming is crucial in facilitating the execution of particular tasks by the processor. Electronic devices such as mobile phones, washing machines, and digital cameras are commonly utilised in daily life. All of these devices operate on microcontrollers that have been programmed using embedded C.

5.3. Proteus 8 Professional

The Proteus software is employed for electronic circuit simulation, design, and drafting. The invention is credited to Labcenter electronic. Proteus software enables the generation of planar circuit schematics. The software tools offered by Proteus are highly appropriate for the task of proficiently designing printed circuit boards (PCBs) and capturing schematics in a professional capacity.

6. Experimental Results

Thus, the system that was proposed has been successfully constructed and enables the central console to receive notifications in the event of emergency situations. The helmet device has been engineered to identify hazardous gases and temperature changes, and is equipped to notify the central monitoring station in the event of an abnormal situation. A voice communication system has been implemented to facilitate direct communication with miners in emergency situations. The Arduino Integrated Development Environment (IDE) software, which is installed on the central console, generates the visual representation. Data is transmitted wirelessly from the peripheral console to the central console.

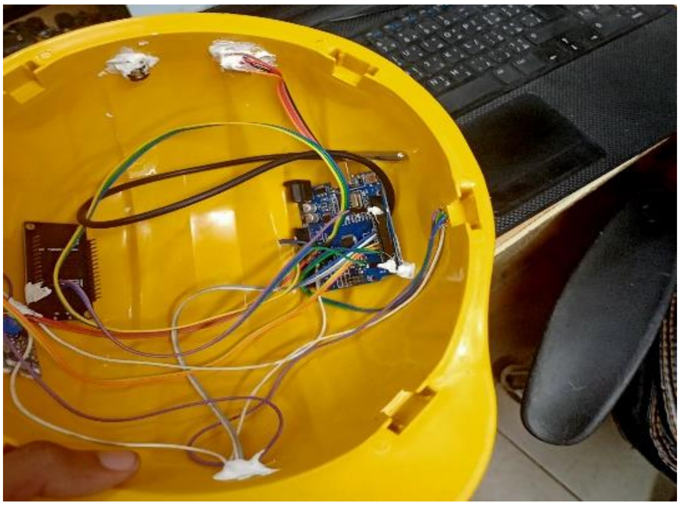

Figure 3. Transmitter section

Figure 4. Receiver section

7. Conclusion

The smart helmet was designed to make it easier to identify potentially dangerous occurrences, to keep track of the state of the surrounding environment, to transmit information to a central console for easy tracking (including GPS coordinates and sensor readings), and to deliver supplemental oxygen in the event that the wearer is exposed to potentially hazardous gases. The implementation of the Internet of Things (IoT) has the potential to make the system's expansion easier to accomplish. The creation of a database that is capable of maintaining ongoing tracking of sensor modules is a project that is within the realm of possibility.

Declarations

Source of Funding

This study did not receive any grant from funding agencies in the public or not-for-profit sectors.

Competing Interests Statement

Authors have declared no competing interests.

Consent for Publication

The authors declare that they consented to the publication of this study.

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