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***Research paper***

# IoT health monitoring system for preventing and controlling risk in confined space using microcontrollers

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**Abstract**

Healthcare monitoring is a field that caught many researchers from the computer science community in the last decade. In the literature, various levels of people have been considered when proposing a health monitoring system. However, some aspects are still not adequately tackled such as monitoring workers' health status within confined space where workers would be located in underground environment with less oxygen and a lot of dust. This paper proposes an IoT health monitor system for worker in confined places. The proposed system utilizes four types of microcontroller sensors including LM35 for measuring body temperature, heart beat rate sensor, blood pressure sensor and LPG gas sensor. All the aforementioned sensors are being connected via a GPS module in order to transmit the readings into a smartphone application. A simulation has been conducted to test the proposed sensors where competitive commercial measures have been used as a benchmark. Result of simulation showed that the sensors have fair accuracy that is near-identical to the benchmark.

***Keywords***: *Health Monitoring System; Internet-of-Things; Wireless Sensor Network; Micro-controller; Global Position System.*

## 1. Introduction

The growth of modern network technologies such as Wireless Sensor Networks (WSN) and Internet-of-Things (IoT) have significantly contributed toward improving wide range of tasks [1-4]. One of these tasks are the health monitoring. In fact, healthcare applications nowadays plays an essential role for tremendous people from different age and health levels [5, 6]. Assume a group of people with chronical diseases, presenting a healthcare monitoring system that can check up their medical situation would be a promising solution for early alarm which can save hundreds of lives[7-10].

Several research studies have addressed the health monitoring task using various techniques. For example, Bhatti et al. [11] presented a cost-effective and real-time health tele-monitoring system. The proposed system was intended to examine remote patient by employing wide range of Arduino sensors that have the ability to check up the medical situation of the patients and send such information to the hospital. Almarashdeh et al. [12] proposed a health monitoring system for elderly patients using WSN. The proposed system has been designed to collect information from elderly patients while they are staying at their homes where information such as body temperature, blood pressure and heart beat rate. Since elderly people are usually suffering from chronic diseases thus, the proposed system would offer a great opportunity for early warning. Gopi et al. [13] have proposed a health monitoring system based on IoT network where body temperature and heart rate are being checked using micro-controller Arduino. Using a Wi-Fi connection, the Arduino sensors will send the information through the IoT to the server to be stored for further processing tasks. Nowshin et al. [14] designed and implemented a health monitoring system based on various micro-controller in order to collect information regarding body temperature, heart beats and blood glucose level. The proposed system has been utilized based on the Global System for Mobile (GSM) where users can check their medical information through their smartphone. In terms of the micro-controller, Arduino Uno, buzzer, MQ2 gas, and LM35 sensors have been utilized to sense the required information. Suryanarayanan et al. [15] presented a novel system for health monitoring based on two types of sensors. The first type of sensor is intended to measure the medical situation parameters of the patient. While the second type aims to process the collected information from the first type. Using a pre-defined threshold values, the second type of sensors can detect abnormal cases in order to warn the patient.

As stated in the literature, various levels of people have been considered when proposing a health monitoring system. However, some aspects are still not adequately tackled such as monitoring workers' health status within confined space where workers would be located in underground environment with less oxygen and a lot of dust. Therefore, this paper proposes a health monitor system for workers in confined locations.

## 2. Research method

The complete schematic diagram design for the health monitoring wireless sensor node is shown in Figure 1.

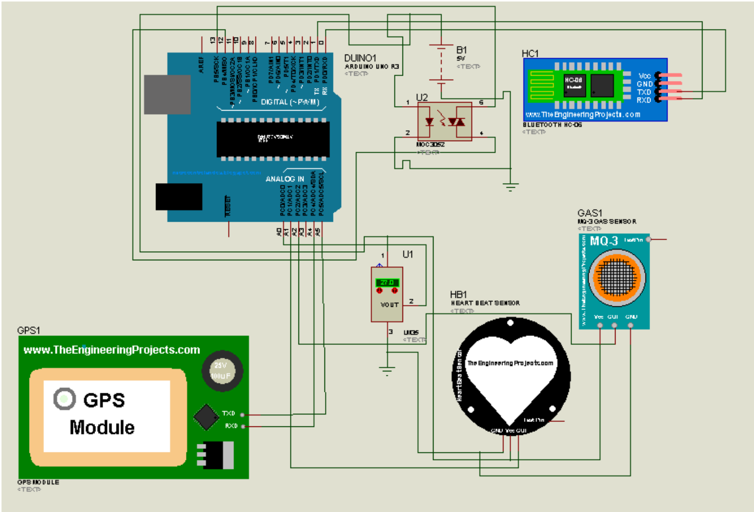


**Fig. 1:** The Circuit of the Proposed System.

As seen in the schematic diagram, the core component is the Arduino microcontroller (the component in blue colour on the left and on top of the GPS module). This Arduino microcontroller interface with sensors like heart beat rate sensor, temperature sensor, LPG gas sensor, blood pressure sensor and GPS module.

The important components present in the schematic diagram are:

1) Arduino Microcontroller
2) Heart beat rate sensor
3) LPG gas sensor
4) Temperature sensor
5) Blood pressure sensor
6) GPS module

The connection pins are summarize in Table 1. Other pins like pin 2 and 3 are connected to Wi-Fi module (ESP 8266).

**Table 1:** Pin Connection from Sensor to the Arduino Microcontroller

| Sensor pin | Arduino pin |
|---|---|
| Gas sensor output pin | A0 |
| Temperature sensor | A1 |
| Heart beat rate sensor | A2 |
| Blood pressure sensor | 13 |
| GPS | 4 |
| ESP8266 | 0 and 1 |

The in pins in Arduino microcontroller start with letter "A" indicates an analogue pins. Those pins label with number are digital pins. For example, in table 3.1, pin 0, 1, 4 and 13 are digital pins. All the pins in Arduino microcontroller can be programmed as input and output. In this circuit, all the pins start with letter "A" are programmed as input pins. Pin 1 and 2 are programmed as output pins and pin 8 is programmed as input pin. The rest of the pins available in the Arduino microcontroller are two Vcc pins, Vcc 5 V and Vcc 3.3 V and two ground pins. Vcc 5 V is used to power up the entire sensors whereas Vcc 3.3 V is not used. All the ground pins are used.

i) Programming design

The circuit shown in Figure 1 will be functioning if there is no programming downloaded into the Arduino microcontroller. This section shows the programming design for the Arduino microcontroller to read the sensor's signals, process the signals and send the signals to the ESP 8266 Wi-Fi module. The programming design in the form of flowchart is shown in Figure 2.

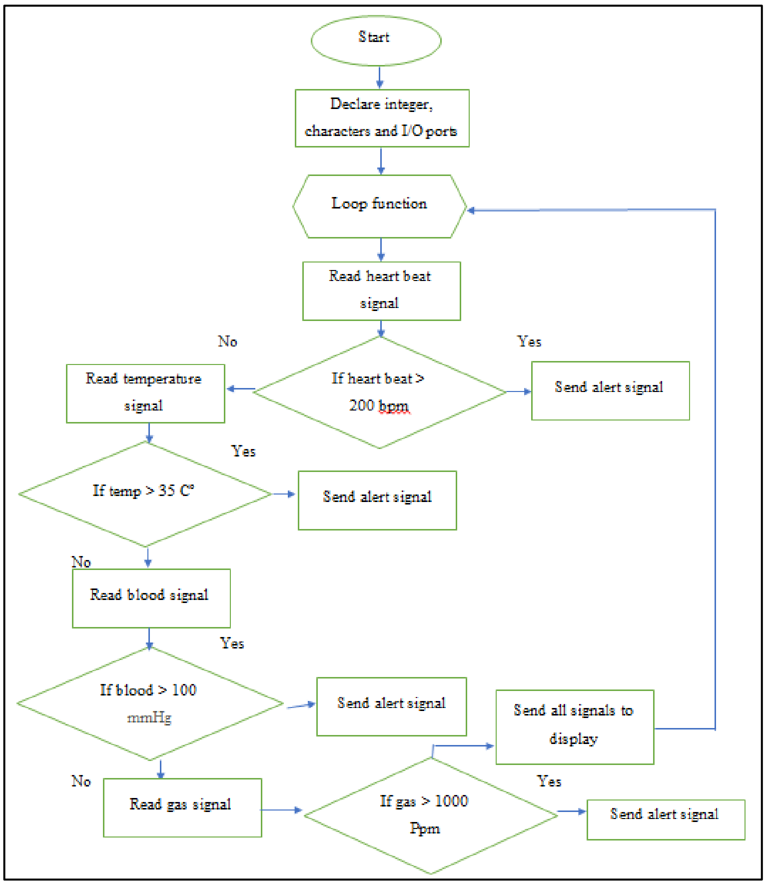


**Fig. 2:** Coding Flowchart.

As seen in the programming design, the system will read the sensor signals one by one. If the signal not related to the respective sensor, the program will pass to next level to read. However, if the sensor signals level is more than the programmed value (the programmed values are those standard values) for the sensors standard, then an alert signal will be send to the Wi-Fi module. From the programming, it is seen that there is no coding for the GPS. The GPS is works independently from the system. GPS will has its own protocol, thus the operation will be shown in next section.

ii) Arduino Micro-Controller

The Arduino microcontroller is a main component. The actual device used in the project is shown in Figure 3. Two important power ports are shown in the Arduino microcontroller. One is 12 V Vcc power port and second one is 5 V Vcc power port. This means that the microcontroller can be powered by 12 V and 5 V. For 12 V the jack port is used. For 5 V, the USB programming port is used.

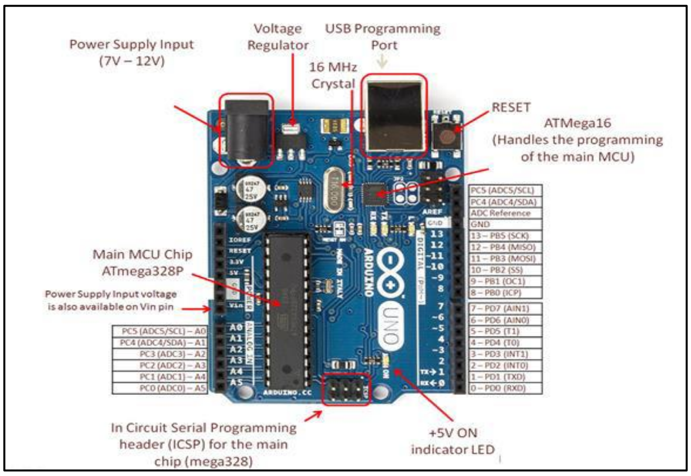


**Fig. 3:** Arduino UNO Pin Connections.

There are total 19 I/O pins. All pins can be programmed as input and output depending on the convenient of the user. The maximum current that the microcontroller can handle is 250 mA with maximum voltage of 5 V.

iii) Heart Beat Rate Sensor

Figure 4 shows the heart beat rate sensor used in the health monitoring system. The technical feature of this sensor is shown in Table 2.

**Fig. 4:** Heart Beat Rate Sensor.

**Table 2:** Technical Features of the Heart Beat Rate

| Parameter | Value |
|---|---|
| Voltage | 5v |
| Current | 50 mA |
| Types | Analogue |
| Sensitivity | 0.5 dB |
| Accuracy | ± 0.5% |

The heart beat rate sensor has three terminals. Two are for Vcc and ground connections and one is the signal output. The sensor detects the pulse rate from heart and then convert it into electrical pulse voltage. The amplitude of the voltage produces is the keep parameter to determine the heart rate. Equation used in the programming to program the voltage amplitude representing the heart beat rate is shown below:

$$\text{beat per minute} = \frac{\text{NumberOfBeatHeart}}{\text{StopTime} - \text{StartTime} \times 60} \quad (1)$$

iv) LPG Gas Sensor

Typical LPG gas sensor is shown in Figure 5. The unit of LPG Gas sensor is PPM. The values of gas sensor can be integer or decimals. Different gas will generate Different PPM values.

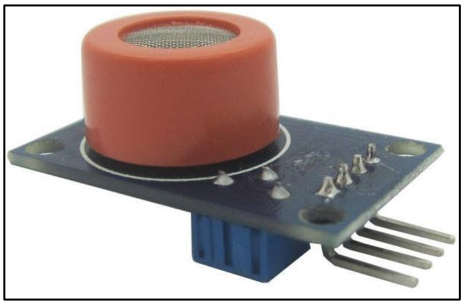

**Fig. 5:** LPG Gas Sensor.

Thus, when connecting the LPG gas sensor into the Arduino microcontroller and if use serial monitor to view the values, the following data will be observed:

1) Oxygen = 145 PPM
2) LPG = 555 PPM
3) Corban dioxide = 678 PPM

Table 3 shows the technical features of the LPG gas sensor.

**Table 3:** LPG Gas Sensor Technical Features

| Parameter | Value |
|---|---|
| Voltage | 5v |
| Current | 500 mA |
| Types | Analogue |
| Sensitivity | 0.1 dB |
| Accuracy | ± 0.1% |

v) Temperature Sensor

Temperature sensor used in this health monitoring system is LM 35. Typical sensor is shown in Figure 6.

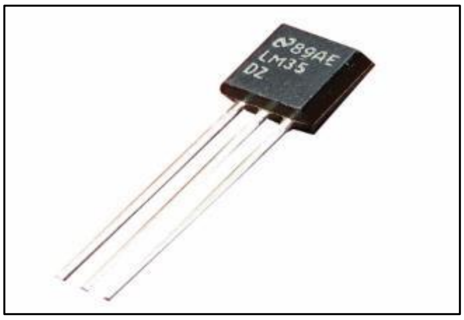


**Fig. 6:** LM35 Temperature Sensor.

Table 4 shows the technical features of the sensor.

**Table 4:** LM35 Sensor Technical Features

| Parameter | Value |
|---|---|
| Voltage | 5v |
| Current | 500 mA |
| Types | Analogue |
| Sensitivity | 0.1 dB |
| Accuracy | ± 0.1% |
| Voltage represent temperature | 0 – 5 v |

The equation in the programming to convert voltage reading into degree Celsius is:

$$\text{Temperature} = \text{ADC} \times 0.048 \quad (2)$$

Where ADC is the values present when the sensor is connected to the Arduino. ADC can be seen in serial monitor output in the Arduino C compiler.

vi) Blood Pressure Sensor

Photo transistor as shown in figure 7 generates an infrared sensor that can detects the blood pressure at the fingertip.

**Fig. 7:** Photo Transistor as Blood Pressure Sensor.

As the light penetrates through the fingertip, the blood density will block the light and hence the reflected light will get attenuated. The higher the light attenuated due to the density of blood, then the pressure of the blood will be high and vice versa. The technical feature of the photo transistor is shown in Table 5.

**Table 5:** LM35 Sensor Technical Features

| Parameter | Value |
|---|---|
| Voltage | 5v |
| Current | 50 mA |
| Types | Analogue or digital |
| Sensitivity | 0.45 dB |
| Accuracy | ± 0.1% |
| Voltage represent blood pressure | 0 – 5 v |

The unit of blood pressure is mmHg. In programming, the voltage representing the mmHg can be programmed as:

$$\text{mmHg} = (\text{Vmax} - \text{Vmin})/\text{ADC} * 0.2 \quad (3)$$

The mmHg can be displayed in LCD or in Apps or in pages.

vii) GPS Module

The GPS module used in this health monitoring system is shown in Figure 8. The module requires SIM card registered under valid communication provider. Table 6 shows the technical features of the GPS module.

**Table 6:** GPS Module Technical Features

| Parameter | Value |
|---|---|
| Voltage | 5v |
| Current | 200 mA |
| Types | digital |
| Sensitivity | 0.1 dB |
| Position upgrade | >15 minutes depends on location |
| Operation | Outdoor |

## 3. Results and analysis

This section presents the sensor testing before connect all of them into the Arduino microcontroller. It is important to test the individual sensor and ensure they are working and able to produce output signals. The sensors under testing are temperature sensor, heart rate sensor, gas sensor, blood pressure sensor and GPS.

First, the LM35 temperature sensor will be tested and compared with an actual Thermometer as shown in Table 7.

**Table 7:** LM35 Sensor Readings

| Time in minutes | LM35 temperature sensor reading in °C | Thermometer reading in °C | Accuracy (%) |
|---|---|---|---|
| 1 | 26 | 27 | 99 |
| 2 | 28 | 29 | 99 |
| 3 | 30 | 31 | 99 |
| 4 | 32 | 33 | 99 |
| 5 | 35 | 36 | 99 |
| 6 | 45 | 44 | 99 |
| 7 | 55 | 58 | 97 |

As shown in Table 7, it is notice that the temperature reading from the LM35 was very similar to the reading taken from the thermometer. This means that the temperature signals given by LM35 is very accurate.

On the other hand, the heart beat rate sensor will be tested by comparing it against an electronic stethoscope as shown in Table 8.

**Table 8:** Heart Beat Sensor Readings

| Time in minutes | Reading from heart rate sensor BMP | Stethoscope reading | Accuracy (%) |
|---|---|---|---|
| 1 | 85 | 86 | 99 |
| 2 | 0 | 0.01 | 99 |
| 3 | 85 | 87 | 99 |
| 4 | 0 | 0.01 | 99 |
| 5 | 85 | 86 | 99 |
| 6 | 0 | 0.01 | 99 |
| 7 | 85 | 88 | 97 |

As shown in Table 9, the heart rate produced stable BMP as a person was sit on the chair. This readings will increase and decrease based on the activities carried out by a person. In this experimental test, the range of BMP tested were within 85 to 86. There were also other results showing, which were very high when a person run or walk.

Third, the gas sensor will be tested by comparing it against a commercial type of gas tester as shown in Table 9.

**Table 9:** Gas Sensor Readings

| Time in minutes | Gas sensor reading in m3 | Gas sensor tester in m3 | Accuracy (%) |
|---|---|---|---|
| 1 | 1.2994 | 1.3 | 98 |
| 2 | 1.456 | 1.5 | 97 |
| 3 | 1.885 | 1.9 | 99 |
| 4 | 2.6798 | 2.4 | 96 |
| 5 | 2.884 | 3.1 | 93 |
| 6 | 3.4568 | 3.3 | 96 |
| 7 | 4.557 | 4.8 | 97 |

As shown in Table 9, gas under test is using the LPG gas from the lighter. A 5% of gas was free injected on the surface of the sensor and the readings was recorded in 7 minutes. It was notice the readings compare to both commercial one and the sensor type are quite closed to each other. This means the gas sensor is reliable and can be used to detect the LPG gas.

Finally, the blood pressure sensor will be compared against a commercial type as shown in Table 10.

**Table 10:** Blood Pressure Sensor Readings

| Time in minutes | Blood pressure sensor (mmHg) | Commercial blood pressure reading |
|---|---|---|
| 1 | 134 | 133 |
| 2 | 135 | 133 |
| 3 | 138 | 134 |
| 4 | 136 | 135 |
| 5 | 138 | 133 |
| 6 | 135 | 136 |
| 7 | 136 | 133 |

As shown in Table 10 the blood pressure for a person can be stable as long as that person is in normal condition. The blood pressure sensor was quite stable compare with the commercial readings.

Apart from the sensors, it is necessary to examine the GPS. The GPS should tested outside the building in order to get the satellite signal. Figure 8 shows the GPS module is connected to 12 V power supply and tested outside the building.


**Fig. 8:** GPS under Outdoor Test.

To test the GPS, a mobile phone is required. The phone has SMS where it will be send to GPS. The GPS process the signal, update the location and send the information back to the cell phone in the form of SMS message. The SMS message contents location information like longitude and latitude. Figure 9 shows the test results.

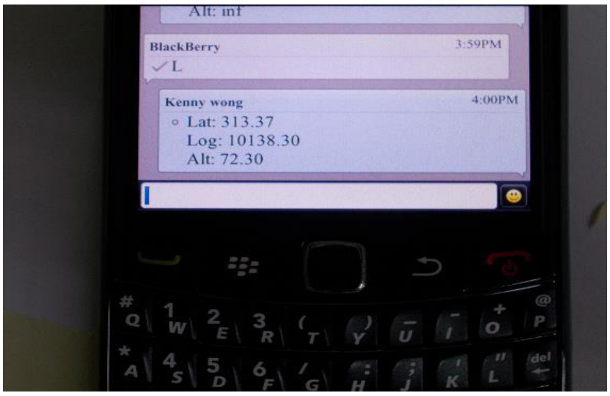


**Fig. 9:** The Return SMS Which Content Latitude and Longitude.

The results of readings will be displayed on the user's smartphone where Blynk application is being used. Figure 10 shows the health monitoring sensor signals.

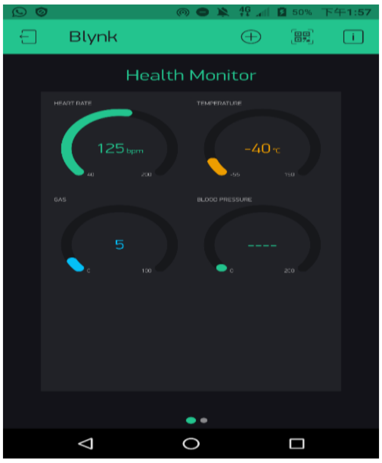


**Fig. 10:** Display Health Monitoring Parameters.

The sensor signals present in the Apps will be identical to the one present in the thingspeak.com. It is important to login to the Apps and ensure it is synchronize with the thingspeak.com. The Apps results are obtained from the microcontroller. All the sensors will give the alert signals as indicate in Figure 10. When the sensor detect something that is not in safe level, an alert signal will appear in the Apps. As seen in Figure 11, the colour of the indicator will turn into orange if the signals are out of safety level. The following shows the alert signals will appear in the Apps when:

1) Temperature > 37 °C
2) Gas > 1000 m3
3) Blood pressure > 300 mmHg
4) Heart beat rate > 200 bmp

Since the microcontroller gave reading approximately relative to the baseline devices. On the other hand, the system has been tested and gave precise results. Therefore, this study has successfully accomplished its goal in which a health monitoring system has been implemented.

## 4. Conclusion

This paper has presented a health monitor system for worker in confined places. The proposed system utilizes four types of sensors including LM35 for measuring body temperature, heart beat rate sensor, blood pressure sensor and LPG gas sensor. All the aforementioned sensors are being connected via a GPS module in order to transmit the readings into a smartphone application. Using Raspberry Pi microcontroller would be a potential for future researches.

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