IoT Based Patient Monitoring System using Sensors to Detect, Analyse and Monitor Two Primary Vital Signs

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Abstract. This paper presents the development of patient monitoring system for two primary vital signs of body temperature and respiratory rate. The monitoring system was implemented in IoT platform and designed using Arduino Mega 2560 and ESP8266 Wi-Fi Module. Two sensor’s modules used to determine each vital sign level, which each module use temperature sensors. The purposes of this project are to design patient monitoring system that can detect the vital signs level, analyse the level of vital signs according to the patient age, provide alert for abnormal condition and also displayed the results wirelessly through android apps. This project would minimize the work load for nurses in hospital and provide much convenient method in monitoring status of each vital signs for every patient in the ward. Conventional method which requires nurse to visit every patient to record vital signs measurement is time consuming. With this system, nurses can monitor the patient status through android apps installed into any android device. Nurses or doctors can also review the previous vital sign status by downloading the data from the cloud in the excel format. Comparison on the two vital signs level obtained from this system with standard measurement equipment or manual observation shown almost similar results.

1. Introduction
Hospital is a busy place with the doctors and nurses work hard to saves lives and improving patient’s health. Basically, the patients admitted to the hospital need to be monitored regularly by the nurse so that there are no worst circumstances occur to the patients. Sometimes there are too many patients need to be monitored by the nurses at a time. Nowadays, the nurses still need to go to the patient’s room one by one to monitor and update the current conditions of the patients. The state health director of Kuching, Datuk Dr Zulkifli Jantan, expressed his concern over the nurse to patient ratio. He said that the ratio of nurse to patient in 2015 was currently 1 nurse to 250 patients [1]. The ratio is too big and worrisome. A new system needs to be developed to make the nurse’s work become more efficient.

The vital signs are usually used as the important measurements to the patient’s body. There are 6 vital signs which are weight, height, blood pressure, pulse rate, body temperature and respiratory rate [2]. In this study, the focus will be on body temperature and respiratory rate. The standard mean body temperature is 37°C. There are 4 standards placed usually used to measure the body temperature by using thermometer which are in the mouth, anus, placed under armpit and lastly at ear canal. A person with temperature above mean body temperature is considered having a fever while if the body temperature below 35°C is considered hypothermia. The breathing rate or respiratory rate is the number a person breathing in a minute in a rest state. Table 1 shows the normal respiratory rate
according the range of age. The standard respiratory rate for an adult is at range of 12 to 20 breaths per minute. So, it is believed that it’s not normal to have breathing rate out of this range while resting. There are several circumstances that can affect the breathing rate such as an asthma, anxiety, congestive heart failure, lung disease and others.

| Group Age | Age        | Normal Respiratory Rate |
|-----------|------------|-------------------------|
| 1         | 1 year     | 30 to 40                |
| 2         | 2 – 5 years| 20 to 40                |
| 3         | 6 – 10 years | 15 to 25               |
| 4         | 11 - 18 years | 15 to 20              |
| 5         | 18 – 70 years | 12 to 20              |
| 6         | >70 years  | 15 to 20                |

There are a lot of studies about the patient monitoring systems including the respiratory rate and body temperature measurements [4],[5],[6],[7]. The purpose of patient monitoring system in this study is focused on measuring the respiratory rate (RR) and body temperature by using temperature sensors LM35 and MLX90614 while sending the data to the smartphone by using the ESP8266 as module wifi for the Arduino Mega 2560 microcontroller. Moreover, there is also a keypad for the nurses to enter the patients group age and LCD display to display several important data such as the group age, body temperature, respiratory rate and patient’s condition. Lastly, Blynk application is used as the IoT platform as android apps in the nurse’s smartphones.

2. Methodology

2.1. Overview of Patient Monitoring System

![Figure 1. Block Diagram for Patient Monitoring System.](image)

Figure 1 shows the block diagram of the patient monitoring system for respiratory rate and body temperature measurements. The inputs used are keypad and temperature sensors LM35 and MLX90614. Sensor MXL90614 used to detect the body temperature of patient, while two LM35 used
to determine the respiratory rate of the patient. The data then send to the Ardino Mega microcontroller for some calculation and send to the LCD display and smartphone as outputs. The data sent to the smartphones is supported by ESP8266 wifi module.

The flowchart in Figure 2 shows how the system works in order to calculate the RR of each patient. It is starting with the nurse inserted the range of age of the patients, then, the timer will start counting for 20 seconds (loop counter for 20). The temperature sensor 1 (TS1) and temperature sensor 2 (TS2) started to operate and the system will determine the temperature for patient breathing and room temperature. Both temperature values were then compared. If the difference is higher than 2℃, the counter for RR will increase by one. The process is continuously repeated until the 20 seconds is end. After that, the RR per min is obtained by multiplying the RR counter with three (in order to obtain the RR for 60 seconds or one minute). The program is then repeating for another cycle.

**Figure 2. Software Flowchart For Respiratory Rate Calculation.**
The patient monitoring systems is divided into several types for hardware designs which are inputs, controller and outputs which involving several important types such as analog temperature sensors, LM35, contactless infrared sensor MLX90614, keypad, Arduino Mega 2560, LCD display and ESP8266 module wi-fi. The flow of the system shown at Figure 3.

2.1.1. Input/ Sensors.
The inputs that has been used are temperature sensors and a keypad. Two Analog temperature type LM35 are used to detect temperature sensor and patient breathing temperature. A calculation is done to find the different value from the two data for 20 seconds. The other type of temperature sensor is digital non-contact infrared temperature sensor, MLX90614. The patient body temperature is measured by using MLX90614 through forehead. It can be seen in Figure 4 below. The nurse used the keypad to insert the group age of the patient. The inserted of group age is crucial since the normal breathing rate is unsimilar with different range of age.

With the help of keypad, the system can provide a precise measurement for normal breathing rate at different range and at the same time provide an accurate indicator or warning on abnormal condition of the patient. The group age can be seen in Table 1. The group age for age range between 11 until 18 years old is make same with higher than 70 years seems they have same value for range of respiratory rate.
2.1.2 Outputs.
One of the two outputs in this system is LCD display. It is used to display patient’s body temperature value, patient’s range of age and the value of breathing rate. Furthermore, LCD also displayed the patient’s condition which either “normal” or “abnormal” depending on the calculation done by the system from the input data. Since the LCD display has 4 rows, hence every part of data is displaying in each of the row. The other output is the graphical user interface (GUI) installed on the nurse’s smartphone (the GUI developed using Blynk application supported by ESP8266 wi-fi shield).

3. Results and Discussion
The experiment was tested on 13 peoples with different group ages as tabulated in Table 2. For every measurement, each person is tested for 5 repetitive times. Since not all the individuals have asthmatic or lung problems, so the 5 repetitive measurement subsequently used to determine the accuracy and precision of the patient monitoring system for normal person (in form of standard deviation calculation). Results of the experiment have been divided in two important sections which are results displaying on LCD display and results for GUI.

| Individual | Age | Group Age |
|------------|-----|-----------|
| A          | 23  | 5         |
| B          | 23  | 5         |
| C          | 21  | 5         |
| D          | 21  | 5         |
| E          | 17  | 4         |
| F          | 17  | 4         |
| G          | 17  | 4         |
| H          | 16  | 4         |
| I          | 10  | 3         |
| J          | 8   | 3         |
| K          | 8   | 3         |
| L          | 3   | 2         |
| M          | 4   | 2         |
3.1. LCD Display
The LCD used in this project has 4 rows, which displayed the body temperature of the patients, group age of patient at the second row, the calculation patient’s respiratory rate at the third row and the last row for the patient’s condition. The example of results shown in Figure 5(a) and (b).

![Figure 5. Example of Result for (a) normal condition patient (b) abnormal condition patient.](image)

Figure 5(a) shows an example of patient in a group age 4 with the range age is around 11 until 18 years old. Refering to Table 1, it is showed that, the standard respiratory rate per minute for that group age is between 15 to 20. Since the respiratory rate in Figure 5(a) is between the expected range, so the condition of patient is normal. While the respiratory rate of patient in Figure 5(b) is below the standard range hence it is abnormal.

3.2. Results in GUI (Blynk Platform)

![Figure 6. Display for Body Temperature and Respiratory Rate With Graph for (a) Patient’s Body Temperature (b) Patient’s Respiratory Rate.](image)

Blynk platform has been used to receive the data from the ESP8266 module. Blynk platform is a type of application on the smartphone for the nurse to monitor the patients from long distance. Figure 6 shows the GUI display and graph results from the Blynk platform displaying data received from the ESP8266. The body temperature of the patient is constantly around 37±5°C show that the patient’s body temperature is in good condition.
3.2.1 Comparison of body temperature measurement using temperature sensor (MLX90614) and non-contact infrared thermometer (FI01).

Body temperature of 13 individuals were taken using temperature sensor (MLX90614) and non-contact infrared thermometer (FI01) for 5 times in every 10 minutes. Comparison of average reading between MLX90614 sensor and FI01 thermometer for the 13 individuals can be seen in the graph shown in Figure 7. The reading recorded by FI01 is set as the expected measurement and the reading recorded by MLX90614 sensor is the output of the proposed system. Standard deviation for MLX90614 sensor also calculated to verify the accurateness of this proposed system. From Figure 7, different reading was observed between expected output and the output of the proposed system. However, the expected body temperature for only 4 individuals fall within the range of standard deviations.

![Graph showing average reading comparison between MLX90614 and FI01](image)

**Figure 7.** The Average Reading for Body Temperature in MLX90614 and Body Thermometer.

3.2.2. Comparison of body temperature between MLX90614 sensor with non-contact infrared thermometer (FI01) for asthmatic individuals.

The average body temperature reading measurements for three asthmatic individuals were recorded in Table 3. Even though three of these individuals have asthma, the reading measurement of body temperature does not affect the measurements since they do not have any fever. From the Table 3, it is shown that, the accuracy between the MLX90614 and thermometer is high which all of them are around 99%. Moreover, the Figure 8 shows that the graph between MLX90614 and body thermometer recorded close reading among each other.

**Table 3.** Body temperature comparison between MLX90641 and non-contact infrared thermometer (FI01) For Asthmatic Individuals.

| Patients | Body Temperature Measurements (°C) | Accuracy (100%) |
|----------|-----------------------------------|-----------------|
|          | MLX90614 | Non-contact Infrared Thermometer (FI01) |                |
| X        | 36.94    | 37.02                          | 99.78%          |
| Y        | 36.98    | 37.14                          | 99.57%          |
| Z        | 36.98    | 36.97                          | 99.97%          |
3.2.3. Comparison of Respiratory Rate Between Project Device and Manual Respiratory Rate Measurements.

Since, there is no actual device to measure the respiratory rate, the actual respiratory rate has been measured by observing the breathing of six individual for a minute. The experiment is repeated for five times for each individual. Then, the same experiment is repeated by using the project device, Patient Monitoring System for measuring respiratory rate.

The graphs comparison of average respiratory rate between two methods plotted in Figure 9 and Figure 10. The respiratory rates for each individual recorded different value between both methods. The highest different recorded for individual L and M which representing the group age 2 for kids around 2 to 5 years old. Besides, the individual of I, J and K recorded second highest different for the comparison, which these three individuals are from the group age 3 which represent child for age between 6 to 10 years old. The smallest different of respiratory recorded by group age 4 (individuals A, B, C, D) and 5 (individuals E, F, G, H) which is between 15 to 25 respiratory rate per minute. From the observation, the error of respiratory rate measurement for group age 3 which represent child is bigger than group age 4 and 5 which represent teenager and adults. However, the biggest error is recorded for group age 2 which is the group of age lower than group age 3. The hypothesis can be made is, the smaller the age of the individual, the bigger the different of comparison between using the project device and by observing the person breathing. There is high possibility this is because the breathing frequent of child is higher than teenager and adults while the temperature sensor, LM35 specification for rise time and fall time cannot keep up the breathing frequent of the child hence making the error become more obvious.
3.2.4. Comparison of respiratory rate between project device and manual respiratory rate measurements for asthmatic individuals.

Table 4 shows the comparison of average respiratory rate between the project device and conventional method. It can be seen the results between both methods is near each other. This is meant that the project device can be used to detect the breathing problems of the patients, but the accuracy of this device needs to be improved. The comparison of the two methods can be seen clearly by the graph plotted in Figure 10. The graph shows that the error bars (standard deviation) of the project device method is too big while the error bars for observing the person breathing is small.

Table 4. Results of respiratory rate for five consequence measurements for asthmatic individuals by using manual measurement.

| Individual | Respiratory Rate for Project Device (Breath per min) | Respiratory Rate for Observing Person Breathing (Breath per min) |
|------------|------------------------------------------------------|----------------------------------------------------------------|
| X          | 23.4                                                 | 22.4                                                            |
| Y          | 23.4                                                 | 21                                                              |
| Z          | 22.8                                                 | 22.2                                                            |
The body temperature MLX90614 can be say have an accurate reading results but the respiratory rate measurement does not provide a precision and accurate readings. This is because the sensor LM35 used to detect breathing of the person take some time to get actual results and have long time interval to decrease the temperature back. Hence, this problem has affected the reading of the respiratory rate to be accurate. The accurateness of the measurement can be increasing by replacing the LM35 sensor with other sensitive temperature sensor.

4. Conclusion
The IOT based patient monitoring system has been successfully developed. This system able to measure the body temperature and respiratory rate and the measured data sent wirelessly to android apps using IOT platform. This system is able to provide alert for any abnormal condition to the user/nurses through the android apps. The results of patient in LCD display does not have a lot of problems, while there is some instable result in the android apps where the internet issues play important role in the IOT implementation. The type of temperature sensor used to measure breathing temperature also plays crucial role in getting the accurate results for respiratory rate measurement. In future, high sensitivity sensor can be used to provide more accurate result.

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