Neonatal Health Monitoring System with IOT Application

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Abstract. The body temperature and heart rate are important parameters to monitor the neonatal situation. Neonatal need to be monitored closely in Neonatal Intensive Care Unit (NICU) to allow quick actions by physicians when any problems occur. The lack of systems that able to alert and indicates any warning condition of neonatal in NICU is one of the problems faced by most of the hospital. To reduce the complexity of the system at the NICU for monitoring the Neonatal condition from time to time, the health monitoring system using the Android app has been introduced. This system was introduced to improve the existing system to give alert and warning sign so that early precautions can be done. The project involves the LM35 temperature sensor and pulse sensor which is controlled by the Arduino Uno microcontroller with the help of instructions C / C ++, and Bluetooth networking system. This allows the user to monitor the baby's condition through applications that use Bluetooth networking system. Users must have the application that can be downloaded on Google Play. Furthermore, this system is not only applicable for the physicians but also for others to monitor the condition of Neonatal even though they are outside of the NICU. The neonatal condition can be checked by the LCD display.

1. Introduction
Each Neonatal Intensive Care Unit (NICU) has their own equipment for controlling neonatal health which is helpful in monitoring the neonatal health conditions [1]. One of the neonatal health controller equipment is the incubator where newborn baby will be placed and the temperature in the incubator will be adjusted according to the mother's body temperature around 36.5°C - 37.0°C [2]. Incubators are usually equipped with temperature sensors and humidity sensors [3]. The new baby incubator design has LCD monitors to display digital values such as body temperature values. This allows the nurse to observe the data from the LCD monitor without having to check the neonatal body temperature manually.

However, relying only on the temperature monitoring system is inadequate to indicate the neonatal health condition as the body temperature able to change rapidly [4]. Other signs like heart rate are also an important parameter for monitoring neonatal conditions [5]. The rate of heartbeat obtained will be used as a reference for nurses and doctors to identify the normal condition of the baby. According to Apgar score, the normal heart rate for neonatal between 80-120 per minute [6]. It is recommended
based on previous study that neonatal heart rate is one of the best ways to monitor neonatal condition [7][8]. It should be monitored continuously to avoid any serious conditions. Other than that, wireless system has been widely used in healthcare as it promotes convenience to the users in monitoring their health [9].

Therefore, the aim of this project to incorporate multiple sensory functions in a very small piece of garment, without making it uncomfortable for the infant. The developed sensory baby garment includes fully integrated sensors for the parameters respiration, heart rate, temperature and humidity, e.g. by sweating, for the continuous monitoring of infants [10]. It will allow early alert for potential life-threatening events as well as the recognition of the development or progression of diseases at an early stage. In this work, LM35 is placed in a baby's socks wrapped with cotton so that no irritation will occur. The pulse rate will be measured in the fingers by using optical sensors and displayed on the LCD. The transmitter sensor pair will be clipped to one of the subject's fingers. The moisture detection sensor is used for baby's urine detection. Moisture will be identified by installing two copper electrodes that will be placed under the cloth where the baby is sleeping. The flex sensor system is attached on the neonatal knee. The baby's movements are monitored by placing the accelerometer (ADXL335) correctly. It is placed in a baby's socks causing proper movement to be detected. With the help of a face-to-face GSM module, the system can send short message texts to specific parties required according to user's convenience [11][12]. Figure 1 below shows the reading of neonatal temperatures, urine detection and pulse rate.

![Figure 1](image1.png)

**Figure 1.** Sample readings of (a) LCD displaying infant temperature (b) LCD displaying infant urine detection condition (c) LCD displaying infant pulse rate value

2. Methodology

When the LM35 temperature sensor activated for 30 to 40 seconds, the sensors will detect the user's body temperature and results will be displayed on the LCD. The pulse sensor will detect heart rate and displayed on the Arduino monitor serial software. Data from the sensor will be transmitted through two signaling modes i.e. LCD and smartphone display over Bluetooth networks. LCDs can display data for three types of neonatal conditions i.e. normal value, alert and alert. Buzzer and LED will be activated if an abnormal sensor reading value is identified. Subsequently, the data obtained will be displayed via LCD display and smartphone using Bluetooth networks. Figure 2 and Figure 3 illustrate the block diagram and flow chart of the neonatal health monitoring system, respectively.

![Figure 2](image2.png)

**Figure 2.** The structure of the Neonatal Health Monitoring System
Figure 3. The flow system of Neonatal Health Monitoring System

2.1 Integrating flex sensor and HC-05 Bluetooth sensor for movement detection

Neonatal seizures with a variety of causes can be a life-threatening problem to infants [13]. Thus, a wearable flex sensor will be implemented in this project to calculate the movement of the knee in determining the early symptoms of seizure which is vigorous sudden bending movement of body parts. The data acquisition transmitted by Bluetooth is on real time graph and can be recorded for storage.
As shown in Figure 4, Arduino UNO was used for the microcontroller, flex sensor for the bending detection, HC-05 Bluetooth module to communicate from the Arduino to the devices, BlueSoleil Mini USB to create the Bluetooth connection and a power supply. Once the device is turned on, it will begin to process the data from the sensor every 3 seconds as the time being set initially. From the real time interface, the status of the neonatal condition can be monitored and the random bending movement will be notified. The data can be viewed through software interface of MATLAB Simulink and Bluetooth application in mobile phones.

2.2 Arduino Bluetooth Terminal Application
Android app used for this project can be downloaded on the Google Play Store as shown in figure 5. This app can display values up to 10 Sensors at the same time. To use this app, the required component is to load some code for the Arduino board, the Bluetooth Module (HC-05) wire connected to Arduino and the Android Device and Bluetooth-module pairs in System-Preferences. This application will establish a wireless serial Bluetooth connection between Arduino and smartphone.

3. Result and Discussion
Based on circuit in Figure 6, pulse sensor connected to the analogue input 0, grounding and 5V voltage of the Arduino microcontroller. Then, the LM35 temperature sensor to measure body temperature is connected to digital pin 8, grounding and 5V supply voltage. The LCD is connected to the PWM output from pins 2,3,4,5,11 and 12 Arduino microcontrollers to display results. A 10kΩ potentiometer is connected to the LCD to adjust the brightness of the LCD. The HC-05 Bluetooth module is used to transfer data to smartphones connected to 5V supply voltage, earthing, digital pin 0 and 1. Buzzer and LED are used as a warning alert and warning to users will be connected to the ground and power supply.
3.1 Results in Real Time

The data acquisition part of flex sensor can be seen in real time. After the data transmission by Bluetooth, the real time graph will display the results of the sensor. The real time interface was created using MATLAB Simulink software. It was equipped with the screen that displayed the value of the changing in angle and a scope screen viewing the real time graph simulation. The real time can be monitored and run according to the time which was being set at the beginning such as 3 seconds in this project. One of the early symptoms of seizure is a vigorous random bending movement within 2 to 3 seconds in neonatal stage. Therefore, the real time will simulate every 3 seconds and recorded data can be observed in the data storage part at the MATLAB Simulink interface. Caretaker will be alert by the changes in the real time graph whether it is an early detection of seizure or normal neonatal condition. Figure 7 shows the real time graph and the screen with sensor’s value.

Table 1. The difference in body temperature values for the tools developed using the oral and axillary methods and conventional standard tools.
Table 2. The difference in heart rate values uses the pulse the tools developed using the oral and axillary methods oximeter (Lotus-500) and pulse sensor for this system.

| Time (s) | Developed Tools (°C) Axillary | Developed Tools (°C) Oral | Conventional Standards (°C) |
|----------|-------------------------------|--------------------------|-----------------------------|
| 1        | 33.0                          | 35.6                     | 31.25                       |
| 2        | 33.5                          | 36.0                     | 35.16                       |
| 3        | 34.7                          | 36.0                     | 34.18                       |
| 4        | 34.8                          | 36.1                     | 33.19                       |
| 5        | 34.9                          | 36.1                     | 34.18                       |
| 6        | 35.0                          | 36.1                     | 33.13                       |
| 7        | 35.1                          | 36.1                     | 33.69                       |

3.2 Comparative between Conventional Standards and Developed Tools
The tool used is a type of digital thermometer (OMRON Model MC-246). The purpose of using this tool is to compare between the availability of digital thermometers and the LM35 temperature sensors in the neonatal health monitoring system. The reading value of the LM35 temperature sensor and conventional digital thermometer conventional standard (OMRON Model MC-246) was taken for 30 seconds and recorded in Table 1 while comparisons between the conventional standard pulse oximeter and the pulse sensor used was recorded in Table 2.

3.3 User Application
Neonatal conditions can be monitored by observing the LCD display which will show whether the body temperature and heart rate are normal, or any changes will be alert and lastly warning sign will be given as demonstrated in Figure 8. At the same time, the buzzer will produce a buzz sound to indicate the changes of neonatal conditions.

![Figure 8](image_url)
3.4 Android Application Test

Figure 9 shows the prototype consisting of Arduino UNO, LM35 temperature sensor, pulse sensor, flex sensor, HC-05 Bluetooth Module and LCD display. LCD Display will display data from temperature sensor and pulse sensor. Meanwhile, the real-time reading of flex sensor will be displayed on the monitor. After that, Bluetooth networks are enabled for Arduino microcontroller to connect with Android Apps. After the Bluetooth network is connected, the user will be able to monitor the same data on the LCD Display into the user's smartphone.

![Figure 9. The Neonatal Health Monitoring System](image)

4. Conclusion

The Neonatal Health Monitoring System is a tool that can measure, display and record human features such as body temperature, heart activity, pulse rate, respiratory rate and other health-related criteria. This work consists of a structural monitoring tool that helps patients or users to easily use this device to perform home health checking. Arduino UNO is programmed as a microcontroller for sensors which were the LM35 temperature sensor, pulse sensor and flex sensor to operate. For body temperature tests, the sensor had been tested on an individual. Based on body temperature results, the alert and warning signs working well. In addition, pulse rate and flexing tests have also been tested. Additionally, this project can also be used for adults. The implementation of this project can have a great impact on life because this monitoring system has been specially designed to alert and warning early sign so that drastic action can be taken if neonatal is in a dangerous condition.

Acknowledgement

The authors would like to thank the Research Management Center (RMC), UTHM and Ministry of Higher Education for sponsoring the research under Tier 1 Research Grants H192, CeDS and FKEE Universiti Tun Hussein Onn Malaysia

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