Remote monitoring of a premature infants incubator

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ABSTRACT

In this paper, the air temperature and humidity levels in the infant' incubator are monitored remotely by means of Arduino microcontroller with different sensors and an open source internet of things (IoT) applications. The system is connected to a network via a wireless fidelity (Wi-Fi) connection to be linked to an application on the smart phone or to the computer. The system is designed using Arduino microcontroller, DHT11/DHT22 sensor for measuring the body parameters, such as the temperature and the humidity, LCD monitor, ESP8266 WiFi modules, and NodeMCU-v3. The results have shown that real time updated medical records can be transferred to the medical staff utilizing ThingSpeak IoT applications.

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1. INTRODUCTION

Temperature and humidity are two of the most important aspects that need to be monitored to provide healthy environment for the infants [1]. Increasing or decreasing the body temperature for the infants might contribute in several health issues, for instance, hyperthermia in neonates can lead to increase in the oxygen requirements, dehydration and apnea [2]. In addition, as the temperature increase the air humidity increase. According to that, the temperature and humidity should be monitored continuously in infants' incubator to provide suitable environment and to maintain stable core temperature of the baby at 37 ^oC.

Health monitoring systems are important in modern technologies, the monitoring of health is achieved by using a set of sensors to read and transmit the biomedical signals such as the temperature [3]. Remote patient monitoring (RPM) is a technology used to remotely monitor the patients outside the patient room or conventional clinical setup [4]. Many baby monitoring systems are designed to provide the required observations to the newly born babies. In [5], a system that monitors several parameters such as, the temperature, pulse rate and other measurements has been proposed to remotely monitor and sends the measurements via a global system for mobile-communications (GSM) and sends alarm to the parents in the case of emergency. This system consists of an 8-bit PIC-18f4520 microcontroller, monitoring sensors, GSM interface unit, LCD screen and a buzzer.

A smart incubator system has been proposed in [6] that continuously monitors and sends the measurements to the cloud. The system consists of Arduino controller, several sensors, Wi-Fi connection, and cloud storing and processing system. A wireless smart sensor system has been proposed in [7] for infant incubator system to remotely monitor the infants utilizing different sensors, ZigBee wireless protocol and IEEE 1451 communication interface.

In [8], a temperature control system has been proposed to control the temperature of baby incubators utilizing temperature sensors and Arduino controller. The system sends an alert in the case of the change in the incubator temperature by means of IoT web system. A contactless radar based system has been proposed in [9] to monitor respiratory and heart rates of the infant patient. The antenna design was limited to the area of interest required to be measured. An advanced monitoring and control system has been used in [10] to control the temperature of the incubator and the body of the infant using several temperature sensors in addition to a humidity measuring sensor and Arduino controller. In [11], a proposed infant incubator monitoring system has been proposed that consists of a temperature, humidity and weight sensors that are connected via a long-range network to a central network to archive the medical data. Near-field communication interface has been used in this system which identifies the doctors, the progress of patients with the medications and entering new data to the records by the doctors.

Modern incubators contain local monitoring features including temperature and several other measurements [12-19]. The ability to send these measurements utilizing these instruments is limited and can be costly when the remote observation and control are involved. Designing and manufacturing low cost incubator with the feature of remote monitoring and controlling is vital especially with the growth in the communication technology and the internet revolution.

In this work, we designed an effective low-cost infant incubator with remote monitoring based IoT. An IoT is a concept that exploits the advantages of internet connectivity in a continuous manner with the possibility to share data, remote controlling, and several other features, while, ThingSpeak enables the creation of sensor logging applications [20-24]. According to that, the change in the temperature and humidity of infant incubator is possible to be observed through the IoT program of Arduino using ESP8266 wireless module.

2. METHODOLOGY

Figure 1 shows the block diagram of the temperature and humidity detector DHT11 for the incubator. The Arduino UNO as a microcontroller, liquid crystal display (LCD), ESP8266 WiFi module to transmit the temperature and humidity data remotely to the ThingSpeak, which is an open source IoT and application programming interface (API) to store and retrieve data from the sensors.

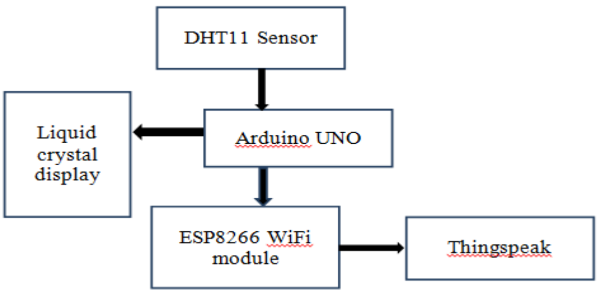

Figure 1. Block diagram of remote monitoring infant incubator

Figure 2 shows the block diagram of the temperature and humidity detector with the NodeMCU-v3, which is an open source IoT platform based on the ESP8266 Wi-Fi system on a chip. Compared to the Arduino Uno, the NodeMCU-v3 platform has more powerful processor than the Arduino's Atmega328, with 4 Mb flash memory and much more random-access memory (RAM). The advantages of using NodeMCU-v3 over the ESP8266 WiFi module with Arduino UNO is the ease of use and program with no connection problems that have been encountered with the latter module.

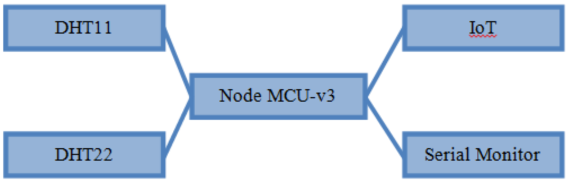

Figure 2. Block diagram of the temperature and humidity detector with NodeMCU-v3

In Figure 1, pin number 5 of the Arduino UNO receives the signal from DHT11 sensor and processes the received data and sends it to the WiFi ESP8266 module. This module is an independent system-on-chip (SOC) that provides WiFi access to the microcontroller utilizing transmission control protocol (TCP) / internet protocol (IP) scheme. In addition, this module has the ability to host an application and it can also deliver the WiFi networking functions from another application processor. The ESP8266 module has an AT command instructions pre-installed to control the modem. The measured data are sent to the ThingSpeak API and it displayed as a graph.

DHT11 sensor measures the humidity and the temperature with a relative range of 20-95 % for the humidity and 0-50 ºC for the temperature, respectively. The cost of this sensor is quite inexpensive with respect to its operating range that has accuracy of ±5% for the humidity and ± 2 ºC for the temperature. However, the new version DHT22 has more precision over a slightly larger range. Utilizing this method will provide an easy and precise way to monitor the incubator at any time and place with low cost using any available gadget and the account information of the ThingSpeak.

3. RESULTS AND DISCUSSION

The results of our experiments for the proposed monitoring system will be presented and discussed in this section. The temperature and humidity measured data are updated continuously and monitored utilizing the remote ThingSpeak IoT application.

Screen shot for the detected parameters on the serial monitor as shown in Figure 3. The DHT11 uses the exclusive digital-signal-acquisition technique and temperature and humidity sensing technology, which ensures high reliability and excellent long-term stability. The temperature and humidity of this sensor are recorded at different time instances inside the room for different temperature and humidity values. In Figure 4, the humidity has increased to 75 % when the temperature increased above 33.5 ºC, while it is reduced to 37 % when the temperature was below 32 ºC as shown in Table 1.

Figure 3. Screen shot for the detected parameters on the serial monitor

Figure 4. Temperature and humidity Vs time plot of the DHT11 sensor

Table 1. Measured Temperature and Humidity Inside the Room

Time	Temperature	Relative humidity
23.02	29 °C	40 %
23.04	34 °C	39 %
23.06	32 °C	37 %
23.08	32 °C	37 %

It is observed that, changing the location of the sensor inside the incubator gives different measurements. For instance, when placing the sensor at the left hand side above the incubator heater the temperature was 40 °C, while the temperature has reduced to 34 °C when placed on the center of the incubator as shown in Table 2, which is more realistic to be considered as optimum measuring point inside the incubator. Figure 5 shows the change in temperature and humidity by changing the location of the sensor and humidity with the presence of water in the incubator and in the absence of water. It is observed that the humidity level has increased to 22 % after placing the water inside the incubator after several seconds.

Table 2. Measured Temperatures Inside the Incubator using DHT11

Temperature of the left sensor	Time	Temperature of the centered sensor	Time
40 °c	13.05	34 °c	13.15
40.3 °c	13.10	34.4 °c	13.20

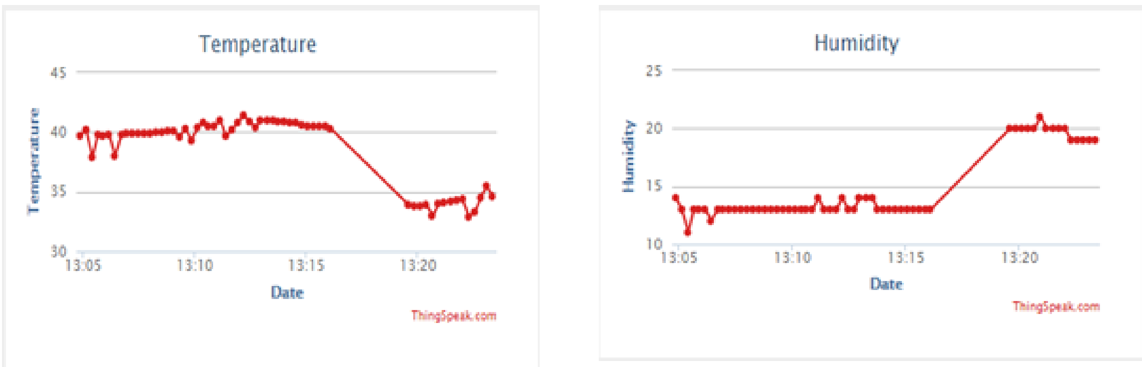

Figure 5. Temperature and humidity monitoring using DHT11 inside an incubator

Figure 6 shows the output of DHT22 that has been detected on IoT Thingspeak monitor. By switching the sensors from DHT11 to DHT22 during the interval 14.00 – 14.10, it is observed that both temperature and humidity measurements were zero. However, after that time the recorded measurement of the humidity was 50% while the temperature has increased above 25 °C. Real photos of the proposed remote incubator monitoring system as shown in Figure 7.

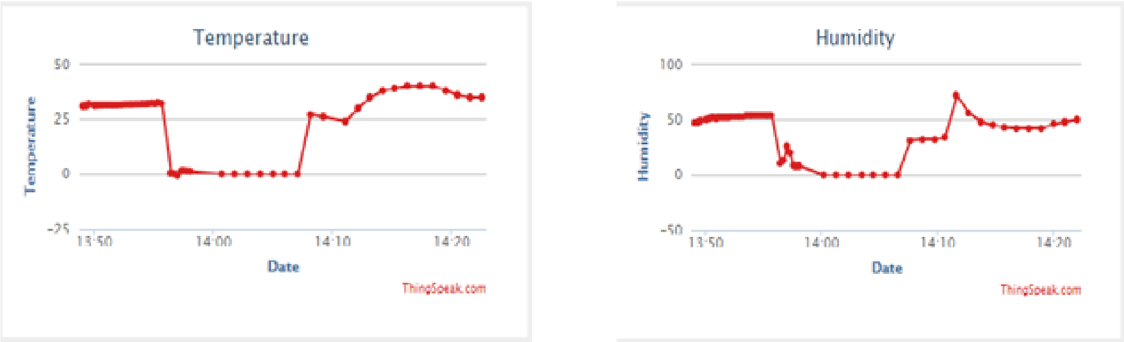

Figure 6. Temperature and humidity monitoring using DHT22 inside an incubator

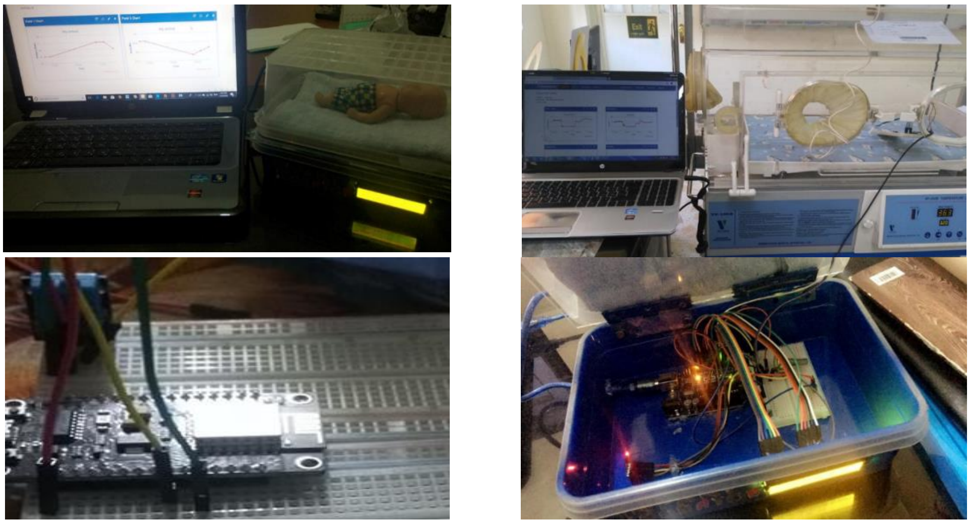

Figure 7. Real photos of the proposed remote incubator monitoring system

3.1. Error Calculations

Further investigations are performed to verify the results of this paper and to make sure that the transmitted measurements are accurate and reliable. In this section, we compared our measurements to the measurements of the built-in temperature sensor of the incubator. The relative error is measured using [25],

$$\text{relative error} = \frac{|\text{Experimental} - \text{Theoritical}\,|}{\text{Theoritical}}.$$

The output of the DHT11 was 34 °C at the time instance 13.15 sec, while the incubator temperature at that time was 35 °C, the relative error was 0.0285.
Similarly, the DHT22 measured temperature was 37 °C at time 14.15 sec, while the incubator temperature at that time was 37.2 °C, the relative error was 0.0053.

3.2. Technical Specifications

Technical specifications as shown in Table 3.

Table 3. Technical Specifications for the DHT11 and DHT22 Sensors

Item	Measurement range	Humidity accuracy	Temperature accuracy	Resolution
DHT11	20 – 90 % 0 – 50 °C	± 5 %	± 2 °C	1
DHT22	0-100%RH -40~80 °C	± 2%	± 0.5 °C	0.1

4. CONCLUSION

In conclusion, this paper proposed a remote monitoring system for the infant incubator utilizing Arduino microcontroller, DHT11 and DHT22 sensors with ESP8266 WiFi module and NodeMCU V3. It is observed that utilizing NodeMCU-v3 as a wireless module has facilitated the work and provided more accuracy than using the ESP8266 WiFi module. The proposed system has shown accurate and reliable temperature and humidity level measurements and transmitting via IoT module. The remote monitoring are achieved using smart mobiles or computers which provided low cost method for remote monitoring with very small tolerance compared to the incubator built-in sensors.

REFERENCES

[1] Donati, Marco, Francesca Cecchi, Filippo Bonaccorso, Marco Branciforte, Paolo Dario, and Nicola Vitiello. "A modular sensorized mat for monitoring infant posture." *Sensors* Vol 14, no. 1, pp. 510-531, 2014.
[2] Zhu, Zhihua, Tao Liu, Guangyi Li, Tong Li, and Yoshio Inoue. "Wearable sensor systems for infants". *Sensors* Vol 15, no. 2, pp.3721-3749, 2015.
[3] Lee, Won, Heenam Yoon, Chungmin Han, Kwang Joo, and Kwang Park. "Physiological signal monitoring bed for infants based on load-cell sensors." *Sensors* Vol.16, no. 3, 409, 2016.
[4] Ms. Nidhi Y. Agresara, Dr. Divyang D. Vyas, Prof. Bhavesh S. Bhensdadiya. "System for remote monitoring and control of baby incubator and warmer." *International Journal of Futuristic Trends in Engineering and Technology*. Vol. 3 (06), 2016.
[5] Savita P.Patil, Manisha R. Mhetre. "Intelligent baby monitoring system." *ITSI Transactions on Electrical and Electronics Engineering (ITSI-TEEE),* Vol. 2, no. 1, pp 11-16, 2014.
[6] D Sivamani, R Sagayaraj, R Jai Ganesh and A. Nazar Ali. "Smart incubator using internet of things." *International Journal for Modern Trends in Science and Technology,* Vol. 4, no. 9, pp 23-27, 2018.
[7] Wu, Guoguang, and Shangwen Chen. "*Design of wireless smart sensor module for infant incubator test*." In 2016 5th International Conference on Measurement, Instrumentation and Automation *(ICMIA 2016)*. Atlantis Press, 2016.
[8] M. Koli, P. Ladge, B. Prasad, R. Boria and P. N. J. Balur. "*Intelligent baby incubator."* 2018 Second International Conference on Electronics, Communication and Aerospace Technology (ICECA), *Coimbatore,* pp. 1036-1042, 2018.
[9] D. Schmiech, S. Muller and A. R. Diewald. "4-Channel I/Q-radar system for vital sign monitoring in a baby incubator." *2018 19th International Radar Symposium (IRS), Bonn,* pp. 1-9, 2018.
[10] M. Ali, M. Abdelwahab, S. Awadekreim and S. Abdalla. "Development of a monitoring and control system of infant incubator." *2018* International Conference on Computer, Control, Electrical, and Electronics Engineering (ICCCEEE), *Khartoum,* pp. 1-4, 2018.
[11] S. Sendra, P. Romero-Díaz, J. Navarro-Ortiz and J. Lloret. "*Smart infant incubator based on LoRa networks*." *2018* IEEE/ACS 15th International Conference on Computer Systems and Applications (AICCSA), Aqaba, pp. 1-6, 2018.
[12] Hall, Virginia, Eric Geise, and Nasser H. Kashou. "*The IncuLight: Solar-powered infant incubator*." In *IEEE* Global Humanitarian Technology Conference (GHTC 2014), pp. 223-226, 2014.
[13] Liu, Lichuan, Kevin Kuo, and Sen M. Kuo. "*Infant cry classification integrated ANC system for infant incubators*." In 2013 10th IEEE International Conference on Networking, Sensing and Control (ICNSC), pp. 383-387, 2013.
[14] Ali, Muslim, Murtada Abdelwahab, Sally Awadekreim, and Suliman Abdalla. "*Development of a monitoring and control system of infant incubator.*" In 2018 International Conference on Computer, Control, Electrical, and Electronics Engineering (ICCCEEE), pp. 1-4, 2018.
[15] Liu, Lichuan, Shruthi Gujjula, and Sen M. Kuo. "*Multi-channel real time active noise control system for infant incubators*." In 2009 Annual International Conference of the IEEE Engineering in Medicine and Biology Society, pp. 935-938, 2009.
[16] Asmidar, Nor, Natasha Binti, Mohd Fudzi, and Nurmiza Binti. *"Development of infant incubator for clinic in the rural area of Malaysia."* In 2016 IEEE EMBS Conference on Biomedical Engineering and Sciences (IECBES), pp. 331-334, 2016.
[17] Liu, Lichuan, and Sen M. Kuo. *"Wireless communication integrated active noise control system for infant incubators."* In *2013 IEEE* International Conference on Acoustics, Speech and Signal Processing, pp. 375-378, 2013.
[18] Liu, Lichuan, Shruthi Gujjula, Priya Thanigai, and Sen M. Kuo. "Still in womb: intrauterine acoustic embedded active noise control for infant incubators." *Advances in acoustics and vibration*, 2008.
[19] Bouattoura, Djaaffar, Pierre Villon, and Gilbert Farges. "Dynamic programming approach for newborn's incubator humidity control." *IEEE Transactions on Biomedical engineering* Vol. 45, no. 1, 48-55, 1998.
[20] Yuehong, Y. I. N., Yan Zeng, Xing Chen, and Yuanjie Fan. "The internet of things in healthcare: An overview." *Journal of Industrial Information Integration* Vol. 1, pp. 3-13, 2016.
[21] Nur Azaliah Abu Bakar, Wan Makhtariah Wan Ramli, and Noor Hafizah Hassan. "The internet of things in healthcare: an overview, challenges and model plan for security risks management process." *Indonesian Journal of Electrical Engineering and Computer Science (IJEECS)*, Vol. 15, no. 1, pp. 414-420, 2019.

[22] Huzein Fahmi Hawari, Aideed Ahmad Zainal, and Mohammad Radzi Ahmad. "Development of real time internet of things (IoT) based air quality monitoring system." *Indonesian Journal of Electrical Engineering and Computer Science (IJEECS)* Vol. 13, no. 3, pp. 1039-1047, 2019.
[23] Firdaus Hashim et. al. "Implementation of embedded real-time monitoring temperature and humidity system." *Indonesian Journal of Electrical Engineering and Computer Science (IJEECS)* Vol. 16, no. 1, pp. 184-190, 2019.
[24] H. B. Chi et. al. "Internet of things (IoT) based i-v curve tracer for photovoltaic monitoring systems." *Indonesian Journal of Electrical Engineering and Computer Science (IJEECS)* Vol. 13, no. 3, pp. 1022-1030, 2019.
[25] Bennett, Jeffrey O., William L. Briggs, and Anthony Badalamenti. "*Using and understanding mathematics: A quantitative reasoning approach*." Reading, MA: Pearson Addison Wesley, 2008.

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