Arduino Based Infant Monitoring System

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Abstract. This paper proposes a system for monitoring infant in an incubator and records the relevant data into a computer. The data recorded by the system can be further referred by the neonatal intensive care unit (NICU) personnel for diagnostic or research purposes. The study focuses on designing the monitoring system that consists of an incubator equipped with humidity sensor to measure the humidity level, and a pulse sensor that can be attached on an infant placed inside the incubator to monitor infant’s heart pulse. The measurement results which are the pulse rate and humidity level are sent to the PC via Arduino microcontroller. The advantage of this system will be that in the future, it may also enable doctors to closely monitor the infant condition through local area network and internet. This work is aimed as an example of an application that contributes towards remote tele-health monitoring system.

1. Introduction

Preterm birth, more commonly known as premature birth, is the birth of a baby less than thirty seven week gestational age, or less than two kilogram weight. Premature birth may cause babies to have less time to develop in the womb, which in turn expose them to complicated medical problems. For example, most premature babies have respiratory problems due to the lung not reaching its maturity stage. In addition, most babies also have trouble maintaining body temperature. In hospital procedure, premature babies will be monitored in the incubator and placed in the neonatal intensive care unit (NICU). However, incubators in rural hospitals do not have the ability to provide pediatricians with real-time monitoring.

The incubator system in all hospital’s NICU currently require nurses and doctors to monitor infants manually all the time. However, these hospital personnel are also required to do other work at the same time. Thus, motivated by this problem, this project is designed to help them monitor the baby in incubator more efficiently. In this project, a monitoring system which utilizes humidity sensor and pulse rate sensor is developed to measure the humidity in incubator, and baby’s heartbeat respectively. The data collected from the sensors can be viewed on a personal computer (PC) and an alarm system
will also alert NICU personnel if the data readings reach to certain level that can harm babies. The aim of this project is to provide an effective system for increasing NICU personnel’s productivity and efficiency at work.

This paper is organized as follows. Section 2 outlines the literature review related to various designs of incubator for infants. The proposed infant incubator system and experimental methods are discussed in section 3 and 4, respectively. The experimental results and discussion are described in section 5. Finally, a brief conclusion is given in section 6.

2. Literature Review
There are many designs of incubator for infants in the literatures. In recent work, Dive and Kulkarni designed an incubator that can monitor and detect the light inside the incubator, and also audio or voice of the baby [1]. The proposed incubator system can notify doctor and nurse about the baby's condition, as when the baby cries, the alarm will be triggered and the alarm will stop or deactivated only if someone turned it off. The advantage of the work is it helps doctors and nurses to monitor the baby's condition continuously. For future improvement, they recommended adding parameters such as monitoring of heart pulse and humidity. Costa et al. [2] developed a newborn incubator that can check the conditions of the incubator environment by utilizing a humidity control system. They concluded that the control of humidity could contribute to the thermos-neutral of the environment, thus improving the premature newborns’ quality of life. There are also several infant incubator designs that implement temperature control system [3-4]. However, following caregiving, infant and incubator temperature differed significantly over time by incubator control mode (air mode control or skin temperature mode control) [5]. Therefore, it is necessary to consider the temperature effects of caregiving when developing incubators. There are several others unresolved issues in developing infant incubators such as exposure to high noise levels in NICU, incubator’s surrounding light environment and electromagnetic fields (EMFs) impact on infant health to name a few [6].

3. The Proposed Infant Incubator System
In this work, an Arduino Uno microcontroller is used to process the data from sensors. Arduino Uno is a microcontroller board with ATmega328. It has 14 input pin of digital output 6 wherein the input pin can be used as PWM outputs and 6 analog input pin, 16 MHz crystal oscillator, a USB, power jack, ICSP header, and a reset button. This work also utilizes a unit of SN-PULSE pulse rate sensor. It is a plug-and-play heart sensor that can detect the pulse per minute for premature babies continuously. Figure 1 shows the image of a SN-PULSE pulse sensor. The proposed incubator utilizes a humidity sensor to detect humidity in the incubator. Figure 2 shows the image of a SN-model-MOD HMD humidity sensor to measure humidity. The proposed incubator is also equipped with an LCD display to show the humidity inside the incubator. Furthermore, humidity and pulse rate data are processed by
the Arduino and sent to the PC for continuous monitoring. Figure 3 shows the flow chart of the infant monitoring system.

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START

Humidity level and infant’s heart rate are measured

Data collected from sensor show on pc

Alarm system will turn ON if the data readings reach near danger level

STOP
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Figure 3. Flow chart of the infant monitoring system

4. Experimental Methods

As explained in the previous section, the proposed infant incubator is consists of a monitoring system which utilizes humidity sensor and pulse rate sensor to measure the humidity in incubator, and baby’s heartbeat respectively. Thus, the experimental methods are focused on these two parameters to show the usefulness of the sensors.

First, sensing the heartbeat of a baby is a little bit different compared to adult. Based on the work done by Kattwinkel et al. [7], to measure heart rate of a baby, a pulse oximeter should be placed on the right hand or wrist of the infant to obtain heart rate measurement. So, in this work, instead of using a pulse oximeter, a pulse rate sensor is placed on the right hand or wrist of an infant to measure baby’s pulse rate continuously. Table 1 shows the normal pulse rate for infants and children. In this experiment, the sensor readings were taken from babies from three categories only based on Table 1, which are newborn (0 ~ 3 months), infants (3 ~ 6 months) and infants (6 ~ 12 months).

Then, humidity readings in the incubator were taken continuously by placing the humidity sensor inside the incubator. The experiment was carried out in air-conditioned rooms, which has riskier moisture condition. This is because the moisture in the air-conditioning is lower compared to normal rooms. Moreover, the humidity sensor is also tested with extremely hot condition (by placing the sensor near a fire source) and extremely cold condition (by placing the sensor in a container full of ice cubes) for the reliability test. Regarding the information for preparation of incubators, for infants less than 37 weeks gestational age and/or less than 2 kg body weight must be placed in the incubator that can provide humidification within 24-48 hours of life [8]. Humidity values for gestational age infants less than 37 weeks are in the range between 64% to 94%.
Table 1. Normal pulse rate for infants and children.

| Age                     | Pulse Rate Range (BPM) |
|-------------------------|------------------------|
| Newborn baby (0 ~ 3 months) | 100 ~ 150             |
| Infants (3 ~ 6 months)  | 90 ~ 120               |
| Infants (6 ~ 12 months) | 80 ~ 120               |
| Children (1 ~ 10 year)  | 70 ~ 130               |
| Children 10 years old and above | 60 ~ 100             |

5. Experimental Results and Discussion

As explained in the previous section, the proposed infant incubator is consists of a monitoring system. In this section, the experimental results of the sensors utilized in this work are described.

5.1. Pulse Rate Sensor Experiment Result

Prior to the experiment, first, a pulse rate sensor is attached on the right hand or wrist of an infant to obtain heart rate measurement. The sensor must then be left for a minute to get a proper reading. The collected data were divided into three sections according to baby’s age. Table 2 shows the result of infant’s pulse rate compared to results from the work done by Fleming et al. [9] (benchmark). As shown in the table, the sensor shows results within the range of the benchmark results. These results demonstrate the usefulness of the chosen pulse rate sensor for the proposed infant monitoring system. Figure 4 shows the pulse rate of an infant shown in real-time developed using Processing software.

Table 2. Result of infant’s pulse rate.

| Age                   | Infants | Results (BPM) |
|-----------------------|---------|---------------|
| 0 ~ 3 Months          |         |               |
| (Results of BPM in Fleming et al. (2011): 100 ~ 150) | Infants 1 | 132           |
|                       | Infants 2 | 143           |
|                       | Infants 3 | 127           |
| 3 ~ 6 Months          |         |               |
| (Results of BPM in Fleming et al. (2011): 90 ~ 120) | Infants 4 | 93            |
|                       | Infants 5 | 107           |
|                       | Infants 6 | 112           |
| 6 ~ 12 Months         |         |               |
| (Results of BPM in Fleming et al. (2011): 80 ~ 120) | Infants 7 | 97            |
|                       | Infants 8 | 93            |
|                       | Infants 9 | 111           |

Figure 4. Software displaying the pulse rate of an infant.
5.2. Humidity Sensor Experiment Result
A SN-HMD-MOD humidity sensor is used in this project. The sensor has a fast response time and low power consumption which is suitable for medical applications. When the sensor is placed inside the incubator, it will detect the moisture around it. The data is transferred to the Arduino and then processed to be sent to a PC for further analysis. An LCD also will show the current humidity inside the incubator.

The proposed infant monitoring system will have an alarm system that can detect both parameters are nearing safety level threshold, and then, alert caregivers about this situation is also essential to prevent harmful situation. Unfortunately, at the current stage, the alarm system is still under development. However, the plan for the alarm system to work is to use the humidity level as alarm input. The sensor will work to ensure that the humidity incubators are always in the range of 64% ~ 94%. If the reading exceeds the upper and lower limits of this range, an LED will turn OFF, while a buzzer will be turned ON to alert the NICU personnel as shown in Table 3. Figure 5 shows the circuit for the hardware prototype of the proposed Arduino based infant monitoring system.

Table 3. Expected results for the alarm system based on incubator’s humidity level.

| RANGE                | 65% and below | 64% - 94%   | 95% and above |
|----------------------|----------------|-------------|---------------|
| RESULT               | DANGER         | IDEAL       | DANGER        |
|                      | - LED OFF      | - LED ON    | - LED OFF     |
|                      | - BUZZER ON    | - BUZZER OFF| - BUZZER ON   |

Figure 5. Circuit for the hardware prototype.

6. Conclusion
In conclusion, the objective of this project has been successfully achieved in which the pulse rate sensor can detect the infant’s pulse rate for three levels of ages, from 0 to 3 months, 3 to 6 months and lastly 6 to 12 months. For validation purposes, the results are compared with the results of previous work which show that the results. Meanwhile, the humidity sensor can also detect the moisture in the incubator and an alarm system will be developed which can alert the doctors and nurses if the moisture level falls in danger situation. Thus, it is hoped that this could help doctors and nurses in monitoring premature infants in hospital. Furthermore, they can also provide fast response if the infants in danger conditions. In order to further improve the project in the future, the data from both sensors will be sent via the internet to a laptop or mobile phone. This can help the doctors and nurses to monitor the infants.
conditions anywhere at all time. Most doctors in the hospital have very tight schedule and cannot always be in the NICU. They also have responsibilities to other patients at the same time. With this transmission of data via the Internet, caregivers will be able to monitor infant environment condition and health situation from a laptop or mobile phone with much ease.

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References
[1] Dive, K. and Kulkarni, G. (2013). Design of Embedded Device for Incubator for the Monitoring of Infants. Int. Journal of Advanced Research in Computer Science and Software Engineering, Vol. 3, Issue 1, pp. 541-546.
[2] Costa, J. L., et al. (2009). Humidity control system in newborn incubator. Proceedings of the XIX Ime-ko World Congress Fundamental and Applied Metrology, pp. 1760-1764.
[3] Oternalora, A. S., Molano, C. A. Q. and Tovar, O. M. L. (2013). Design and implementation of a prototype for neonatal intensive care incubator with fuzzy controller. ARPN Journal of Engineering and Applied Sciences. 8(8):677-686. A reference Parekh, D. (2010). Designing heart rate, blood pressure and body temperature sensors for mobile on-call system. Bachelor Degree Thesis. McMaster University.
[4] Tisa, T., A., Nisha, Z., A. and Kiber, M., A. (2012). Design of an Enhanced Temperature Control System for Neonatal Incubator. Bangladesh Journal of Medical Physics. 5(1): 53-62.
[5] Thomas, K., A. (2003). Preterm Infant Thermal Responses to Caregiving Differ by Incubator Control Mode. J. Perinatol. 23(8): 640-645.
[6] Antonucci, R., et al. (2010) The infant incubator in the neonatal intensive care unit: unresolved issues and future developments. Journal of Perinatal Medicine. 37(6): 587-98.
[7] Kattwinkel, J., et al. (2010). Part 15: neonatal resuscitation. 2010 American Heart Association Guide-lines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. 122: 909-919.
[8] Agren, J., Sjörs, G. and Sedin, G. (2006). Ambient Humidity Influences the Rate of Skin Barrier Matu-ration in Extremely Preterm Infants. J Pediatr. 148(5):613-7.
[9] Fleming, S., et al., (2011). Normal ranges of heart rate and respiratory rate in children from birth to 18 years of age: a systematic review of observational studies. The Lancet. 377(9770): 1011-1018.