Evolution in Electrical and Electronic Engineering Vol. 1 No. 1 (2020) 153 - 160

EEEE

Homepage: http://penerbit.uthm.edu.my/proceeding/index.php/eeee
e-ISSN : 2756-8458

Development of Infant Telemonitoring System

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DOI: https://doi.org/10.30880/eeee.2020.01.01.018
Received 06 August 2020; Accepted 06 September 2020; Available online 30 October 2020

Abstract: Infants are commonly well exposed to illness in challenging environment as they are in the early stage of developing their own antibody. Thus, this study is carried out to develop an effective telemonitoring system with accessible data using the 'Internet of Things (IoT)'. This system is anticipated to help parents monitoring their children throughout the day. Both heart rate and temperature of an infant were measured in real time using the appropriate sensors. Then, sensor circuits sent those data to the microcontroller, Arduino Maker NANO. There are LEDs on the microcontroller to indicate both the infant temperature and heart rate levels. Those data also transferred to the data cloud through the system. ThingSpeak app is used in this system for data storage and could be displayed to end users. An advantage of storing data in cloud is that the users could acquire them in real-time. The system also includes a wearable device in form of wrist band. Results suggest that the targeted data could be obtained in real time within the preset duration, and simultaneously pushed to the cloud to be stored. The wearable device of this system also strapped comfortably to infants. In conclusion, the developed system could be used to monitor the infant condition since it is capable of providing real time data. In addition, the data stream is secured in cloud storage and could be viewed as in-demand.

Keywords: Infant Monitoring, Telemonitoring, IOT

1. Introduction

A newborn is an infant who is only hours, days, or up to one month old. In medical contexts, newborn or neonate refers to an infant in the first 28 days after birth [1]. Previous studies showed that seizures are often the first sign of neurological disease in the newborn. However, their clinical manifestation is often subtle, which tends to hinder their diagnosis at the earliest possible time [2]. There are medications available to prevent seizures but they come with associated risk [3]. Vital signs such as heart rate, respiration rate, blood pressure, and temperature is essential to help parents identify the problem early in an infant [4].

Previous work on infant telemonitoring include wearable electro-dermal activity (EDA) that is paired with accelerometry (ACM) biosensor [5] or respiration sensor [6]. It is reported that this system could provide an ambulatory seizure alarm and improve the quality of life of patients with uncontrolled tonic-clonic seizures. In addition, the data could be streamed in eight hours continuously. Another work

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is developing hand held system with live images of the patients can be delivered on-demand [7]. Systems that acquiring newborn electroencephalogram (EEG) signal also have been reported [8] – [10]. This approach provides good prediction results as the model can compensate for the EEG variance for infants.

2. Methodology

This section will present the methodology used to develop the proposed infant telemonitoring system. The first subsection presents the overall block diagram of the system, followed by the flow chart of process mechanism and finally the details of each mechanism.

2.1 Block diagram

The proposed system is formed by two inputs, which are temperature and heart rate, and outputs go to monitor, LED and in form of data storage. The heart rate sensor measures heart rate and the temperature sensor will detect the temperature of an infant. The sensor circuits will send analog data to Arduino Maker NANO. The Arduino will convert the analog data into digital data. The Arduino will process its coding to interpret the data it is receiving and show it at the serial monitor. Then, the LEDs on the Arduino will turn ON based on three conditions which are low, moderate, and high. There are twelve LEDs on the Arduino that indicate the range of heart rate levels. For normal condition, temperature is below than 38° Celsius. The data will begin to transfer through the ESP 01 as the Wi-Fi module. Thing-speak will receive the data and start its process. The data will be kept in the ThingSpeak storage. Figure 1 shows the block diagram for the whole infant telemonitoring system.

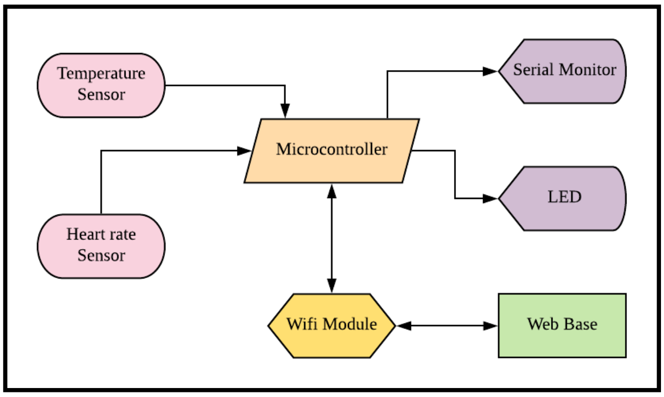


Figure 1: Block diagram of the proposed system

2.2 Flow chart

The flow of the system is shown in Figure 2. The process starts by reading the infant's body temperature and heart rate. Next, the LED will be turned on according to the range of heart rate that determines the condition of the infant. Finally, the data obtained will be sent to the ThingSpeak.

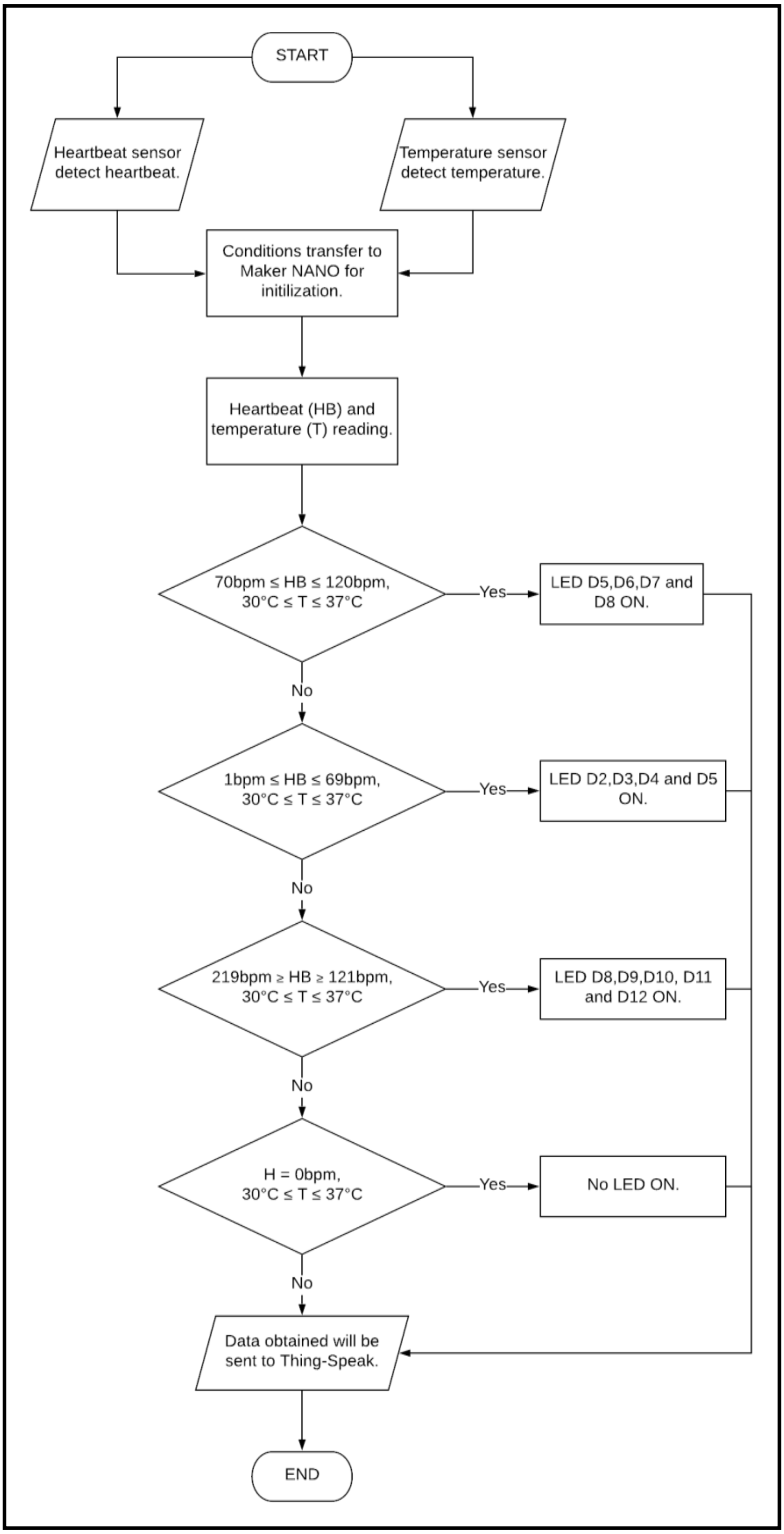
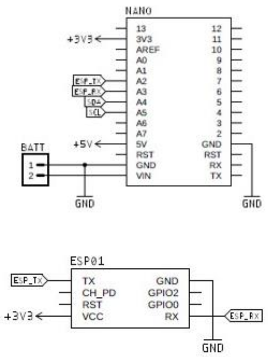


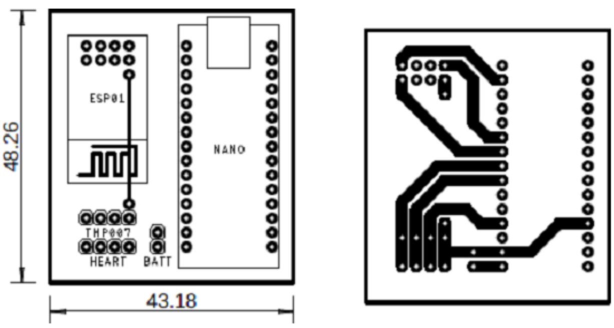
Figure 2: Flow chart of the temperature and heart rate monitoring

2.3 System design and development

2.3.1 Printed circuit board (PCB) design

Designing of PCB is the initial step to form the final layout of circuit of this system. Figure 3(a) shows the PCB design and followed by the PCB printout using Proteus software shown in Figure 3(b).



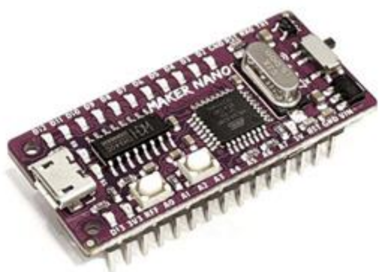


(a) (b)

Figure 3: (a) PCB design (b) Printout of PCB

2.3.2 Circuit components

Arduino Maker Nano board, shown in Figure 4(a) is used as the microcontroller in this study to receive signals from the sensors and deliver the correct data to the desired program. The heart rate sensor used in this study is Grove - Finger-clip as illustrated in Figure 4(b). It works when a fingertip is touched into the sensor, it is illuminated by the IR light coming from the LED. The photodetector diode receives the transmitted light through the tissue on the other side. More or less light is transmitted depending on the electrolyte produced by the heart. Consequently, the transmitted light intensity varies with the pulsing of the blood with the heartbeat. Temperature sensor used in the system is TMP007, shown in Figure 4(c) which is a simple sensor to record the infant temperature. Finally, as shown in Figure 4(d), ESP8266 ESP-01 is used as the Wi-Fi module that provides access to a Wi-Fi network for the microcontrollers. It is also a self-contained SOC with an integrated TCP / IP protocol stack.



(a)

(b)

(c)

(d)

Figure 4: Circuit components: (a) microcontroller (b) heart rate sensor (c) temperature sensor (d) WiFi module

2.3.3 Experiment method

The first experiment is to investigate output from the infant. It is to determine whether the system is reliable to take their physiological data and give responses according to system features. The sensors are attached to the infant's finger to get the reading. The hardware is designed purposely suitable to be used for infants where it is designed as a wristband. The procedure is done by taking a reading of their heart rate and temperature while the infant is sleep and play. Figure 5(a) shows the wristband on the infant for data recording.

The second experiment is to measure physiological data of four adults to examine the sensor data reliability and the system capability to store data in cloud as shown in Figure 5 (b). Temperature and heart rate data are taken at the initial experiment. Then participants are required to complete cardiovascular exercise, which are jump rope and stair climbing, in two minutes and measurement is taken immediately after exercise completion. Then, participants need to relax and cooling down their bodies for two minutes and another measurement is taken.

(a) (b)

Figure 5: Experiment on (a) infant (b) adult

3. Results and Discussion

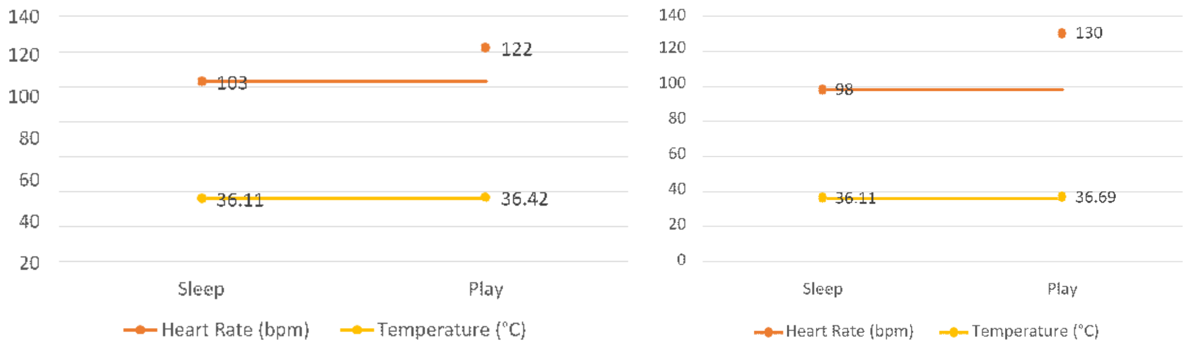
3.1 Physiological signals of infant

Based on the result shown in Table 4.1, during sleeping, the lowest heart rate recorded was 98 bpm and the highest was 103 bpm. In contrast, during playing, the lowest was 122 bpm and the highest 130 bpm. In general, the younger the child, the higher the heart rate. This is due to they have smaller heart chamber and lower volume than adult. This results in a low stroke volume and they compensate by having high maximal heart rates.

For temperature reading, there was no obvious change seen in both situations. Other than that, normal body temperature does not vary as much by age. During sleeping, the highest was 36.11° C and the lowest was 36.10° C. During awake, the highest was 36.69° C and the lowest was 36.42° C. No activity can raise their temperature, thus no obvious changes can be seen. Figure 6(a) shows the graph for sensor reading for the youngest infant and Figure 6(b) shows sensor reading for the oldest infant.

Table 1: Data of experiment 1

Participant No.	Age (Month)	Situation			
		Sleep		Play	
		Heart rate (bpm)	Temperature (°C)	Heart rate (bpm)	Temperature (°C)
1	17	103	36.11	122	36.42
2	26	98	36.11	130	36.69
3	20	98	36.10	124	36.52



(a) (b)

Figure 6: Data of (a) the youngest infant (b) the oldest infant

3.2 Physiological signals of adult and system responses

Based on results shown in Table 2, there were huge differences in heart rate between three situations. However, no obvious changes in finger temperature can be observed. From the experiment, the heart rate mostly increased about 140 bpm to 148 bpm, and the average reading after two minutes exercise was 130 bpm. A normal resting heart rate for an adult ranges from 60 to 100 beats a minute. By doing an activity that stimulates the cardiovascular system, heart rate keeps increasing. Then, it slowly decreases back to normal when the participants rest. The lowest recorded result after two minutes exercise was 98 bpm. The activeness while doing cardiovascular activities influenced the result.

For temperature data, there were no obvious changes can be recorded since the activity period was short. For every situation, the temperature mostly increases by about 3°C. The highest temperature was 37.13°C during cardiovascular activity and the lowest is 34.72°C taken during initial reading.

Table 2: Data of experiment 2

Participant No.	Age	Gender	Initial		Cardio Exercise		Relax	
			Heart rate (bpm)	T (°C)	Heart rate (bpm)	T (°C)	Heart rate (bpm)	T (°C)
1	23	F	74	34.82	99	36.30	84	35.00
2	19	F	84	34.90	148	37.13	118	36.28
3	19	M	89	34.72	147	37.02	118	36.21
4	23	M	65	34.91	127	37.00	120	36.00

F: Female M: Male bpm: Beat per Minutes °C: Degree Celsius

3.2 Data storage in cloud

The final part in the infant telemonitoring system is to store all data from the Arduino Maker Nano to the Thing-Speak via ESP8266-01. Figure 7 shows the data display on ThingSpeak which are two graphs that represent heart rate and temperature data in real-time. Besides display on ThingSpeak, it can also display the data in ThingView for smartphones users as shown in Figure 8.

Figure 7: Data displayed on thingspeak

Figure 8: Data displayed on thingview

4. Conclusion

Overall, the proposed infant telemonitoring was able to measure, record and store the heart beat and temperature data as expected. Although there were no erratic data present during the experiment, it is anticipated that the system could the data measurement very well. Besides, the telemonitoring system also able to store those data onto online cloud successfully.

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