EVOLUTION IN ELECTRICAL AND ELECTRONIC ENGINEERING
e-ISSN: 2756-8458

EEEE

Vol. 5 No. 1 (2024) 10-17
https://publisher.uthm.edu.my/periodicals/index.php/eeee

Internet of Things (IoT) Based Neonatal Incubator for Heart Rate Monitoring and Caregiver Motion Detection

Mastura Abdullah[1], Audrey Huong Kah Ching[1]*

[1] *Department of Electronic Engineering, Faculty of Electrical and Electronic Engineering Universiti Tun Hussein Onn Malaysia (UTHM), Parit Raja, 86400, MALAYSIA*

*Corresponding Author: audrey@uthm.edu.my
DOI: https://doi.org/10.30880/eeee.2024.05.01.002

Article Info

Received: 17 January 2024
Accepted: 13 February 2024
Available online: 30 April 2024

Keywords

IoT, Health Monitoring System, Infant Incubator, Motion Detection

Abstract

The IoT-based health monitoring system has transformed healthcare by enabling seamless real-time tracking of vital health parameters. Using affordable and low-power sensors, it gathers and transmits crucial data on heart rate and oxygen to healthcare providers for analysis. The systems diverse sensors perform well under various conditions, recording BPM readings of 60-100 at rest and 40-60 during occlusion, along with SpO2 values of 95%-100% at rest and 85%-95% during occlusion. Motion detection functionally successfully identifies objects ir caregivers within its proximity. This integration in infant health monitoring signifies a significant advancement with implications for future innovations in neonatal care. The wireless connectivity via Blynk enables remote monitoring with immediate alerts for healthcare providers. Through performance evaluation guarantees measurement reliability, secure data transmission, and algorithmic provide actionable insight.

1. Introduction

Manual processes introduce human error; they are labor intensive, have limited real-time access, delayed interventions and are intrusive for traditional infant health monitoring. Delayed recognition of any health change due to manual and intermittent nature makes contributions towards overall neonatal care outcome. Non-invasive monitoring of infants' sleep is necessary as intrusive monitoring disrupts infants' sleep [1]. Due to increasing demands for neonatal care, healthcare providers are faced with scalability challenges that exacerbate workloads. Integration of fragmented data impedes comprehensive understanding of infant's health. Predictive healthcare is impossible with traditional systems; hence, healthcare becomes reactive. Advancement, however, requires addressing these challenges, and IoT seeks to provide the non-intrusive real-time all-inclusive solutions for better neonatal care.

Healthcare has been the first among industries that were transformed by Internet-of-Things (IoT). IoT provides the necessary means for real-time data gathering through wearable sensors, hence continuously advancing patient care in health monitoring systems [2]. The use of a real-time monitoring solution gives a better view of the health status of infants. This helps in fast response for emergencies but also aids in the early detection of minor changes that could signal health problem [3]. Focusing on improved incubator infant monitoring is consistent with the aim of more effective neonatal care, and better results [4].

This helps to improve precision as well as early detection of anomalies. IoT facilities remote patient monitoring, thus enhancing timely access and interventions. The integration of IoT allows for personalized medicine, which is a more proactive and customized manner of delivering better healthcare solutions.

IoT in healthcare has significantly enhanced patient care, particularly in infant health monitoring overcome limitations of traditional systems. Real-time data collections with seamless connectivity enables non-invasive neonatal care, integrating advanced sensor technologies and artificial intelligence for improved outcomes. The use of IoT allows for remote monitoring and early detection of critical medical complications, supporting timely interventions.

For real-time monitoring of vital parameters such as heart rate level, IoT-based health monitoring systems in infant incubators deploys various sensors. Real-time data analysis using smart algorithms enables detection of patterns as well as aberrations [5], secure access point allow remote access for physicians on-the-go. This integration is very effective and enables real-time alerts for critical changes that facilities quick interventions and minimize chances of negative outcomes. Continuous tracking periodic maintenance, repair and calibration, quality control, and compliance check of the industry-specific standards of these sensors are essential [6] because constants monitoring can help prevent the unusual accidents and deaths that occur in an incubator due to improper monitoring [7].

Healthcare providers are relived of the burden of data collection and analysis as this is automated, which results in more resources spent on interpretation and decision making. In general, IoT-based in infant incubator makes a total difference in neonatal care with a dynamic, joined up and responsive health monitoring approach, which is shown I other sections by specific case studies and research.

2. Methodology

The hardware configuration in Fig.1 involved integrating the Durian Uno (microcontroller), an Arduino-based single-board computer system, into the system for an infant incubator, equipped with pulse sensor for heart rate and accelerometer for motion detection. The Durian Uno, processed and analyzed collected data using its onboard capabilities and transmitted health-related data to cloud platforms wirelessly, enabling remote monitoring and analysis. The MAX30100 was utilized for non-invase, continuous heart rate monitoring, enabling early detection of deviations from normal vital signs and while FC-51 IR sensor detected the presence or vicinity of objects or individuals, enhancing context-awareness in health monitoring. This device is equipped with built-seamless integration for online transmission data to the Blynk cloud server and rapid monitoring system focusing on heart rate and movement detection in a neonatal incubator, with consideration for potential limitations to ensure a thorough understanding of the systems capabilities and constraints.

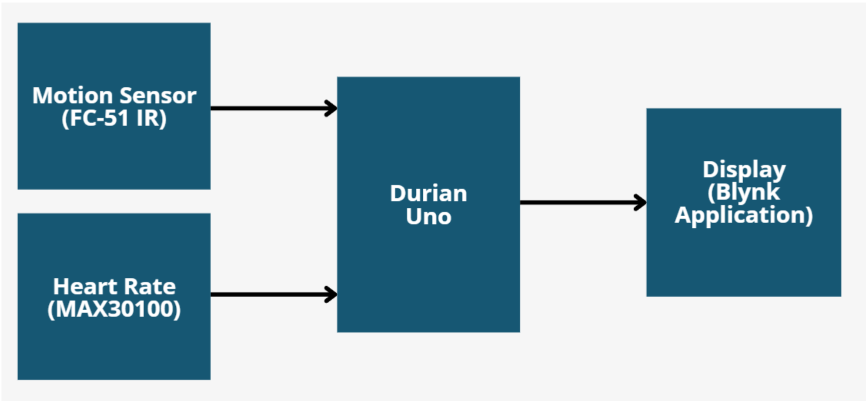


Fig. 1 *System implementation of health monitoring system infant incubator*

Fig. 2 shows the steps process for IoT-based health monitoring system. The process begins by reading the sensor values of interconnected devices, e.g. heart rates and motion sensors, within this health monitoring system flow. The system first then checks whether the value of the sensor exceeds a predefined threshold, representing an important level. A notification shall be sent to the healthcare professional or neonatal nurse on Blynk when this threshold has been exceeded.

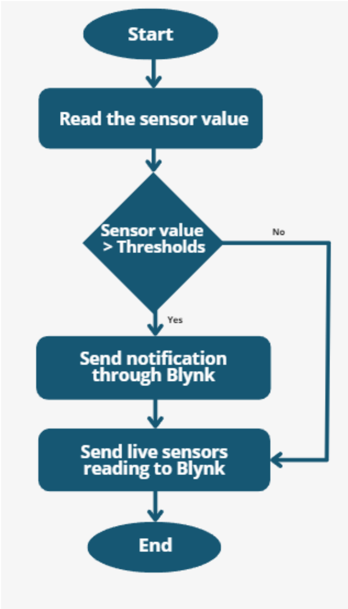


Fig. 2 *Flowchart of the system*

Measuring the accuracy and dependability of the heart rate (BPM and SpO2) monitoring device requires a thorough an analysis regarding how it performs under various conditions, specifically during at rest and when occluded that shows in Fig.3. The individual's heart rate is monitored while at rest condition in order to create a reference measurement. The test then moves on to occlusion conditions, in which the blood vessel will be blocked using raffia rope tied to the forearm to block blood flow into the blood vessels in ulnar artery. This simulates situations in which obstructions such as cuff-induced occlusion occurs. Heart rate readings will be compared with baseline measure and the systems reaction to variations in blood perfusion during occlusion is attentively observed. The systems accuracy, and response value are evaluated in both resting and occlusion scenarios.

Fig. 3 *Performs under condition to collect data during at rest and occlusion*

Based on Fig.4, detailed analysis of the motion sensor sensitivity system's performance within specific ranges is part of the centimeter-level detection performance analysis. The starting point is to clearly define the targeted application requirements and the essential distances for efficient monitoring. The system is calibrated in a controlled test setup so that measurements for sensitivity and range match the testing goals.

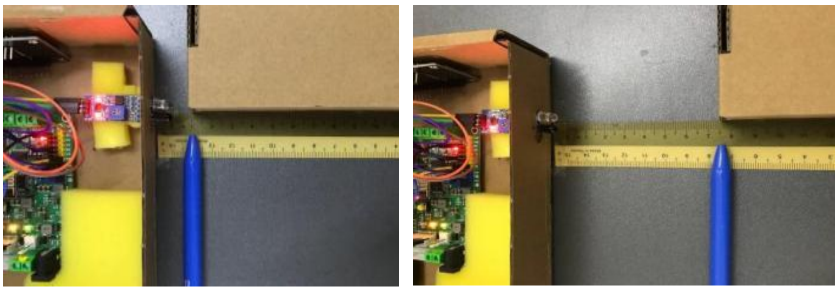
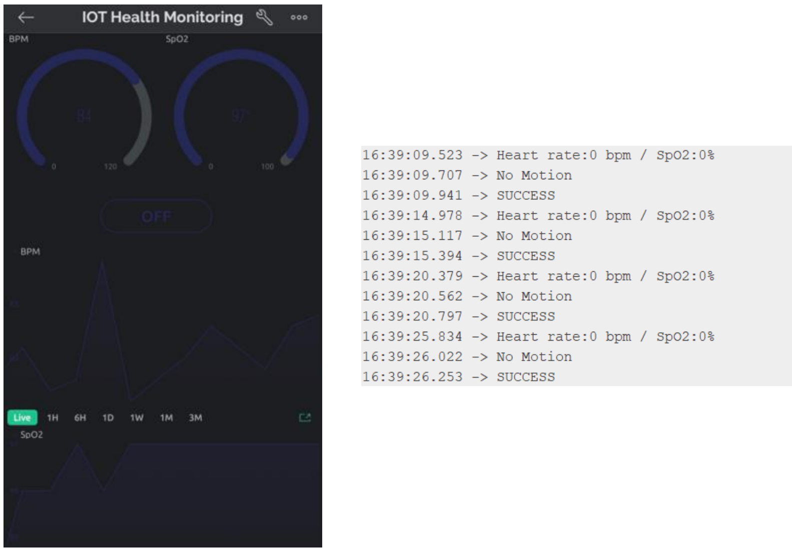


Fig. 4 *Testing equipment for sensitivity motion*

3. Result and Discussion

By concentrating on the results of the system's performance and the knowledge discovered through a thorough analysis. With a complete setup and testing procedure that uses the Arduino IDE and the Blynk application to properly guide users through configuration procedures. The system's performance is evaluated through actual testing, with a focus on criteria such as precision. The system's dependability in different physiological states is demonstrated by results obtained under occlusion and resting situations. The calculations of the mean and standard deviation reveal statistical insights that depict the variability and central tendency of heart rate readings.

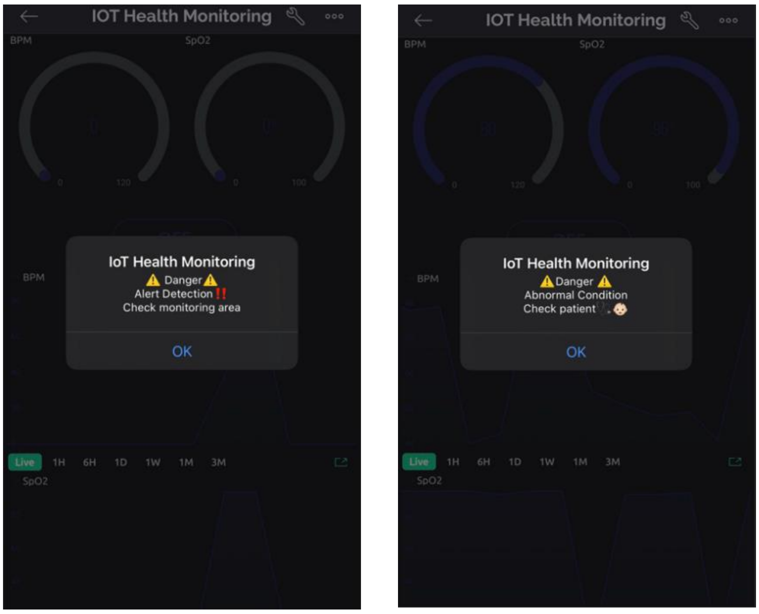
The setup and testing stages of the Arduino IDE and Blynk app entail a few crucial steps. The main purpose of the Arduino code is to generate an easily comprehensible and informative serial monitor output, as seen in Fig.5. In order to assist with configuration and testing, it provides real-time status updates, sensor readings, and diagnostic data. Simultaneously, to provide a consistent user experience, the Blynk application interface is meticulously developed with widgets that mimic the data displayed on the serial monitor. The real-time data visualisation provided by the Blynk applications enhances testing by providing users with a comprehensive grasp of patterns and anomalies.



(a) **(b)**

Fig. 5 *(a) Blynk application on mobile; (b) Serial monitor of Arduino IDE*

Blynk's real-time alerts, exemplified in Fig.6, promptly notify users of any deviations in an infant's pulse rate (BPM) or movements within the incubator. This immediate alert system allows for swift actions during emergencies, enhancing the safety and well-being of infants. Users can customize Blynk notifications, specifying unique motion and heart rate threshold tailored to each infant's needs. The remote monitoring capability facilities continuous communication for healthcare providers without direct physical contact with incubator. Integrating Blynk alerts in these settings improves the efficiency of healthcare monitoring, enabling more proactive and intensive care nursing for infants.



(a) (b)

Fig. 6 *Notification Alert received through Blynk application (a) Motion detection alert; (b) Abnormal condition alert*

Based on Table 1 and Table2, measuring the accuracy and dependability of a heart rate (BPM and SpO2) monitoring device requires a thorough analysis regarding how it performs under various conditions, specifically during at rest and when occluded. The individual's heart rate is monitored while they are at rest in order to create a reference measurement. The test then moves on to occlusion situations, in which the blood vessel will be blocked using a raffia rope tied to the forearm to block blood flow into the blood vessels in the ulnar artery.

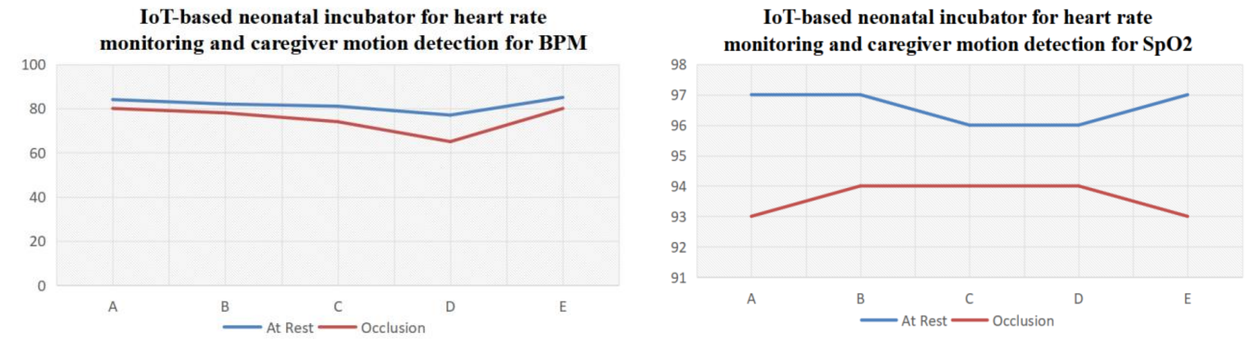
Table 1 *Data of each candidate for beat per minutes (BPM)*

Candidate	At Rest	Occlusion
A	84	80
B	82	78
C	81	74
D	77	65
E	85	80

Table 2 *Data of each candidate for oxygen saturation (SpO2)*

Candidate	At Rest	Occlusion
A	97	93
B	97	94
C	96	94
D	96	94
E	97	93

This simulates situations in which obstructions such as cuff-induced occlusion occurs. Heart rate readings are compared with baseline measures, and the system's reaction to variations in blood perfusion during occlusion is attentively observed. The systems accuracy, and response value are evaluated in both resting, and occlusion scenarios. The findings contribute the systems effectiveness and reliability in real-world scenarios, offering valuable data for further refinement and optimization. In Fig.7 shows a graph of analysis for measurement heart rate taken under both testing conditions.



(a) **(b)**

Fig. 7 *Heart rate candidates in conditions of at rest and occlusion (a) for beat per minute (bpm); (b) for Oxygen saturation (SpO2)*

The mean (μ) and standard deviation (σ) of the sensitivity sensor in detecting the heart rate and to transmit the message from the system to the user through Blynk are calculated using the formula shown in Eq. (1) and Eq. (2), respectively.

$$\text{Mean, } \mu = \frac{\sum x_i}{x} \quad (1)$$

$$\text{Standard Deviation, } \sigma = \frac{\sqrt{\sum (x_i - \bar{x})^2}}{N} \quad (2)$$

The dataset presents a comprehensive overview of heart rate readings in Fig.8 for two vital physiological parameters: oxygen saturation (SpO2) and beats per minute (BPM). The measured mean heart rate at rest for BPM is 81.8, with a standard deviation of 2.79. This shows the heart rate distribution in this condition is reasonably stable and densely clustered. On the other hand, the mean BPM drops to 75.4 after occlusion, and the standard deviation rises to 5.64, indicating a more diverse and scattered distribution of heart rates in this situation. With a tiny standard deviation of 0.49 and a mean oxygen saturation level of 96.6 at rest for SpO2, the data show a stable and narrowly dispersed range of results. The mean SpO2 falls to 93.6 during occlusion, while the standard deviation stays at 0.49, showing a comparable degree of variability in the decrease in oxygen saturation. By illuminating the fluctuations and fundamental trends of heart rate and oxygen saturation levels, these tables offer insightful information about how the body reacts under various circumstances.

(a) **(b)**

Fig. 8 *The mean and standard deviation for at rest and occlusion condition (a) Mean for bpm and SpO2; (b) standard deviation for bpm and SpO2 System*

System responses can be captures and analyzed by thorough testing at different distances, starting from the lowest defined range and increasingly rising. Based on Table 3, the full results of testing, recommendations, and findings are recorded to give an accurate assessment of the motion sensor sensitivity systems centimeter-level motion detection capabilities.

Table 3 *Motion detector sensitivity in distance*

Distance	Detection	No Detection
1 Centimeter, cm	/	
2 Centimeter, cm	/	
3 Centimeter, cm	/	
4 Centimeter, cm	/	
5 Centimeter, cm	/	
6 Centimeter, cm	/	
7 Centimeter, cm	/	
7.5 Centimeter, cm		/
8 Centimeter, cm		/
8.5 Centimeter, cm		/

4. Conclusion

IoT-based Health Monitoring System designed for heart rate and motion detection in neonatal care represents a groundbreaking development, offering real-time insights while addressing traditional monitoring limitations. The system ensures privacy and security for sensitive health data, with thorough testing validating component dependability. Challenges, such as potential disturbances in motion detection, are acknowledged, promoting awareness of system capabilities. Recommendations emphasize implementing precision-focused sensor technologies, optimizing user interfaces, enhancing wearable technology for continuous heart rate monitoring, and integrating predictive analytics for early health concern detection. Attention to data security measures remains critical. Looking ahead, challenges in implementing IoT-based health monitoring in neonatal incubators necessitate integrating various sensor technologies adhering to standards. Recommendations aim to improve system practicality and efficiency by focusing on continuous real-time heart rate monitoring, cutting-edge sensor technology, user-friendly interfaces, and robust data security measures. Overall, this system significantly enhances medical data availability, paving the way for future IoT integration in infant care.

Acknowledgement

The authors would like to thank the Faculty of Electrical and Electronic Engineering, Universiti Tun Hussein Onn Malaysia for its support.

Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

The author attests to having sole responsibility for the following: planning and designing the study, data collection, analysis and interpretation of the outcomes, and paper writing.

References

[1] de, I., da, O., Yousef Nadya, & Salama, K.N. (2019) Non-invasive IoT sensing and monitoring system for neonatal care. 31st International Conference on Microelectronic (ICM). pp.90-93, https://doi.org/10.1109/ICM48031.2019.9021760

[2] Rajasekaran, K., Chakaravarthi, M.S., & Lokaswar, P. (2023) Continuous Health Monitoring System for Patients Using IoT. IEEE Xplore, https://doi.org/10.1109/ICM48031.2019.9021760

[3] Konar, H., Patil, A., Turkane, K., & Bakare, R. (2023, May 31). Infant Posture Analyzer and Wet Diaper System. International Journal for Research in Applied Science and Engineering Technology, 11(5), 5253–5258. https://doi.org/10.22214/ijraset.2023.52885

[4] Alam, H., Burhan, M., Gillani, A., Haq, I. U., Arshed, M. A., Shafi, M., & Ahmad, S. (2023, April 11). IoT Based Smart Baby Monitoring System with Emotion Recognition Using Machine Learning. Wireless Communications and Mobile Computing. https://doi.org/10.1155/2023/1175450

[5] Keethana, B., Vishalini, P., Varshinne, P., Navina, P., & Sriharipriya, K.C. (2023, May 5). IoT Based Nenonatal Patient Monitoring System. IEEE Conference. IEEE Xplore, https://doi.org/10.1109/vitecon58111.2023.10157185

[6] Tso-Sutter, K. H., & Karg, L. M. (2010, December). Generic compliance check tool in examining the conformity of company-specific standards to public standards. 2010 IEEE International Conference on Industrial Engineering and Engineering Management. https://doi.org/10.1109/ieem.2010.5674542

[7] Özdemirci, E., Ozarslan, M., Duran, F., & Cnal, R. (2014, January 1). Reliability assessments of infant incubator and the analyzer. ResearchGate, https://www.researchgate.net/publication/288696073_Reliability_assessments_of_infant_incubator_and_the_analyzer