Ai-Enabled Smart System for Continuous Monitoring of Neonatal Vital Signs in Intensive Care Unit

[1]Mrs. Namratha D'cruz, [2]Thriveni S, [3]Kishan H M, [4]Varsha S, [5]Sindhu D H,
[1]Assistant Professor, [2]Student, [3]Student, [4]Student, [5]Student,
[1]Electronics and Communication Engineering,
[1]Vidya Vikas Institute of Engineering and Technology, VTU, Mysuru, India
[1]namrathavviet@gmail.com, [2]thrivenithrivenis98@gmail.com, [3]kishankrish7892@gmail.com,
[4]varshasachar06@gmail.com , [5]sindhuharish719@gmail.com

Abstract—**Neonates in Intensive Care Units (NICUs) require continuous monitoring of vital signs to detect early signs of distress. Traditional methods rely on human observation and wired equipment, which can lead to delayed responses and increased workload for medical staff. With advancements in Artificial Intelligence (AI) and the Internet of Things (IoT), there is growing potential to improve neonatal care through smart, real-time monitoring systems. This project involves the design and development of an AI-enabled neonatal monitoring system using IoT-based wearable sensors. These sensors measure key health parameters—heart rate, temperature, and oxygen saturation (SpO_2)—and transmit the data wirelessly for analysis. The AI component uses pattern recognition and threshold-based logic to detect anomalies and trigger alerts. A mobile application interface allows caregivers to receive notifications in real time. Preliminary simulations and prototype testing demonstrate that the system can continuously monitor vital signs and generate timely alerts. While clinical testing is pending, early evaluations suggest reduced false alarms and faster anomaly detection compared to manual methods. The proposed system offers a promising tool to support NICU staff by providing uninterrupted, intelligent monitoring of critical neonatal parameters. Once fully validated, it could enhance care efficiency, reduce human error, and improve outcomes for vulnerable newborns.**

Index Terms— **Neonatal Monitoring, Artificial Intelligence, IoT, NICU, Vital Signs, Smart Healthcare.**

I. Introduction

In Neonatal Intensive Care Units (NICUs), newborns—especially those born prematurely or with medical complications—need constant attention. Their survival often depends on continuous monitoring of vital signs like heart rate, body temperature, and oxygen saturation. Currently, most of this monitoring is done manually or with basic equipment, placing a significant burden on medical staff. In such high-pressure settings, even the most skilled professionals can face challenges in catching every subtle change, increasing the risk of delayed responses or missed warning signs [3], [9].

Thankfully, with rapid advancements in Artificial Intelligence (AI) and the Internet of Things (IoT), we now have the means to improve how neonatal care is delivered. These technologies can help automate the continuous tracking of vital signs, reduce the workload on healthcare providers, and ensure that responses to potential issues are both timely and accurate [1], [2], [5].

This project aims to explore how smart monitoring tools can become valuable allies in NICUs. By combining wearable sensors with intelligent software, we hope to create a system that watches over infants every second, detecting potential problems before they escalate—and immediately notifying caregivers. An intelligent neonatal monitoring system powered by AI and real-time sensor data will enable earlier detection of health risks, ease the burden on caregivers, and enhance the overall quality of care in NICUs [6].

II. Literature Review

In recent years, technology has increasingly played a role in improving neonatal healthcare. Conventional monitoring systems in NICUs typically involve wired devices that track vital signs such as heart rate, temperature, and oxygen saturation. While effective to some extent, these systems are often bulky, uncomfortable for infants, and heavily reliant on human supervision [5].

Several researchers have explored the use of wearable biosensors to address these limitations. Studies have shown that wireless, non-invasive sensors can enhance comfort and reduce infection risks in newborns. For example, systems integrating Bluetooth or Wi-Fi modules have enabled the transmission of real-time data to centralized systems for storage and analysis [2], [6]. However, many of these solutions still rely on threshold-based alarms that may generate false positives and overwhelm healthcare providers [7].

More recently, AI and machine learning have been introduced into neonatal monitoring. Algorithms have been developed to analyses patterns in vital signs and predict early signs of deterioration [1], [3]. These smart systems promise a more proactive approach, helping medical teams intervene before conditions worsen. Still, the implementation of such solutions in real-world NICUs is limited due to challenges like data privacy, integration with existing hospital systems, and the lack of user-friendly interfaces [4]. While prior studies have successfully introduced AI and use in neonatal care with real-time mobile alerts and predictive analytics. Our project aims to fill this gap by developing a practical, scalable, and intelligent neonatal monitoring system tailored for NICU environments.

III. METHODOLOGY

The proposed methodology is shown in figure 1. It focuses on developing a smart neonatal monitoring system that uses IoT for real-time data collection and cloud-based AI to support early detection of health risks in newborns. The aim is to provide a low-cost, scalable solution that enhances NICU monitoring without increasing manual workload.

Research Methods

We followed a build-and-test methodology to design the system. The main components included wearable sensors for data collection, a microcontroller unit for transmission, and integration with cloud platforms for visualization and alerts. Our system architecture involves continuous monitoring, cloud storage, AI-based evaluation, and email-based notification.

Data Collection Procedures

These sensors were connected to a microcontroller (ESP32), which wirelessly transmitted data to the cloud platform **Thinger.io** for real-time visualization. All data collected were simulated or tested using dummy environments to mimic real neonatal scenarios.

Analysis Techniques

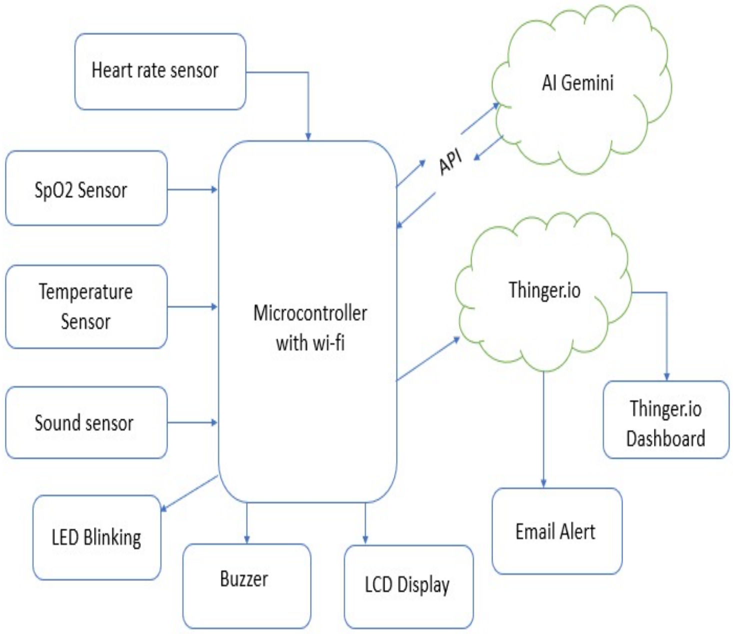

Figure 1: Block Diagram of Ai Powered Neo-Natal Vital Monitoring System

Collected data were observed and analyzed through **Thinger.io's dashboard**. For intelligent interpretation, we used **Gemini AI** to evaluate patterns and provide contextual health insights. When an abnormal value was detected (e.g., low SpO_2 or high temperature), the system was configured to **automatically send email alerts to the concerned doctor**, providing a proactive response mechanism.

Ethical Considerations

Since the system was tested in a simulated environment, no real infant data was used. Ethical concerns such as data privacy, reliability, and patient safety were taken into account, with future implementations requiring proper clinical validation and ethical approval from medical authorities.

IV. RESULTS AND DISCUSSION

The developed neonatal monitoring system was able to successfully track vital signs—heart rate, oxygen saturation (SpO_2), body temperature—and detect irregularities in real time. Using sensors like the MAX30105 and DS18B20, the system continuously gathered physiological data and responded effectively during both normal and abnormal test conditions.

Under typical conditions, all monitored parameters remained within safe clinical ranges:

- Heart Rate: 100–120 BPM
- SpO_2: Above 95%
- Temperature: 36–37.5°C

When abnormal situations were simulated—like low oxygen levels or elevated heart rate—the system correctly identified the issues and activated the alert mechanisms. These included:

- A blinking LED to visually draw attention
- LCD display indicating the bed number of the affected infant
- An email alert, sent through Thinger.io, containing real-time vitals and AI-generated health insights from Gemini

The inclusion of Gemini AI enhanced the system by offering brief health interpretations based on the collected data. Unlike traditional systems that display raw numbers, the AI layer gave contextual feedback, making it easier for healthcare professionals to assess situations quickly.

Visual outputs and dashboards were included to demonstrate system behaviour. Figure 2 shows the LED and LCD display during alerts. Figure 3 shows the thinker.io dashboard and email interface.

Figure 2. *LED and LCD display in action during alerts*

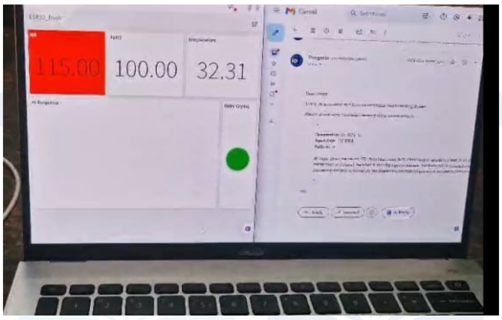

Figure 3: *Thinger.io dashboard and email interface*

Table 1. summary of multiple test scenarios and the system response to each condition

Test Case	***Bed No.***	***Temperature (°C)***	***Heart Rate (BPM)***	***SpO₂ (%)***	***Condition***	***Expected Output***	***Result***
TC1	1	36.5	98	97	Normal	Display values on Thinger.io, no alert	✅ Pass
TC2	2	38.0	125	88	Abnormal	LED Blink, LCD shows Bed 2, Email alert via Thinger.io, AI response from Gemini	✅ Pass
TC3	3	34.5	49	92	Abnormal	LED Blink, LCD shows Bed 3, Email alert via Thinger.io, AI response from Gemini	✅ Pass

TC4	1	37.0	60	95	Normal	Display values on Thinger.io, no alert	✅ Pass
TC5	2	36.5	130	90	Abnormal	LED Blink, LCD shows Bed 2, Email alert via Thinger.io, AI response from Gemini	✅ Pass
TC6 (Sensor Fail)	1	0.0 (Disconnected)	0	0	Abnormal (Sensor Error)	Generate fake values, LED Blink, LCD shows Bed 1, AI & Email alert	✅ Pass

Results in table 1 highlight the system's reliability and responsiveness. It not only detected abnormal conditions accurately but also reduced response time, allowing caregivers to act faster. Additionally, local alerts (LED and buzzer) ensured that even during internet outages, the system remained functional and useful.

When compared to earlier systems mentioned in the literature survey—many of which relied solely on manual observation or basic alarms—our system offers a more intelligent and scalable approach. The integration of AI for real-time interpretation and cloud-based alerts gives it a significant advantage, especially in environments with limited staff or resources. While previous research explored sensor integration and remote access, few incorporated AI-driven predictions and multi-channel alert mechanisms in a single, cohesive platform.

V. CONCLUSION

This study successfully developed a smart, AI-powered neonatal monitoring system capable of continuously tracking critical health parameters—heart rate, SpO_2, temperature—and issuing timely alerts during abnormal conditions. The integration of the ESP32 microcontroller, biomedical sensors, cloud-based dashboard (Thinger.io), and Gemini AI provided an intelligent and responsive solution tailored for NICU environments. The system accurately detected health deviations and automatically sent alerts via email while also displaying localized warnings using LEDs and LCDs. Testing under various scenarios demonstrated its consistency, reliability, and ability to support quicker medical interventions.

From a practical standpoint, this study demonstrates how emerging technologies like IoT and AI can be effectively applied to real-world healthcare challenges. It addresses the growing need for scalable, intelligent, and accessible neonatal care, especially in settings with limited personnel. On a theoretical level, the project reinforces the potential of integrating predictive analytics and real-time monitoring in critical care domains, bridging the gap between technology and frontline medicine.

While the system performed well during testing, several limitations were noted:

- **Limited clinical validation**: Real-world trials in NICU environments are yet to be conducted.
- **Dependence on internet connectivity**: Cloud alerts and AI responses require stable Wi-Fi, which may not be available in all settings.

- **Basic AI integration**: Gemini was used for interpreting vitals, but no custom neonatal datasets were used for model training, limiting accuracy in edge cases.

Future improvements could focus on:

- Conducting trials in actual NICU settings with real patient data (after ethical approvals)
- Developing a dedicated mobile app for real-time alerts and caregiver interface
- Using more advanced AI models trained specifically on neonatal datasets
- Introducing GSM modules for SMS-based alerts in case of Wi-Fi failure
- Exploring wearable, low-power hardware for better infant comfort and portability

Overall, this project lays a strong foundation for further innovation in intelligent neonatal care systems, combining compassion with cutting-edge technology.

VI. REFERENCES

[1] S. Yasrebinia and M. Razaei, "Artificial Intelligence for Predicting Neonatal Mortality in Post-Pregnancy: A Systematic Review," *2024*.

[2] M. Abdullah and A. H. K. Ching, "Internet of Things (IoT) Based Neonatal Incubator for Heart Rate Monitoring and Caregiver Motion Detection," *2024*.

[3] G. A. Usha and K. Bharathi, "AI-Based Continuous Vigilance in Neonatal Vital Signs," *2024*.

[4] D. Akinyele, "Revolutionizing Patient Care and Accessible Healthcare Delivery through AI-Powered Virtual Assistants," *Jul. 2024*.

[5] C. E. Mbanuzue, O. E. Hassan, and F. M. Owolabi, "Real-Time Monitoring of Neonatal Incubator Parameters via IoT-Integrated Device: Design, Implementation, and Evaluation," *Int. J. Res. Innov. Appl. Sci.*, vol. 9, no. 4, pp. 127–143, Apr. 2024, doi: 10.51584/IJRIAS.2024.90409.

[6] P. Marchand et al., "A standardised biologging approach to infer parturition: An application in large herbivores across the hider-follower continuum," *Methods Ecol. Evol.*, vol. 12, no. 6, pp. 1017–1030, 2021, doi: 10.1111/2041-210X.13584.

[7] H. Rohmetra et al., "AI-enabled remote monitoring of vital signs for COVID-19: methods, prospects and challenges," *Computing*, vol. 105, no. 4, pp. 783–809, Mar. 2021, doi: 10.1007/s00607-021-00937-7.

[8] A. T. Ravi et al., "Machine learning for neonatal mortality prediction in low-resource settings," *J. Med. Syst.*, vol. 44, no. 5, p. 93, 2020, doi: 10.1007/s10916-020-01564-z.

[9] S. A. O. Sheril et al., "Neonatal Health Monitoring System with IoT Application," *2019*.

[10] N. J. Pejovic et al., "Neonatal resuscitation using a supraglottic airway device for improved mortality and morbidity outcomes in a low-income country: study protocol for a randomized trial," *Trials*, vol. 20, no. 444, 2019, doi: 10.1186/s13063-019-3455-8.

[11] M. Agrawal et al., "A cloud integrated wireless system for monitoring environmental and vital parameters of infants," in *Proc. MCNC2019*, New Delhi, India, Apr. 2019, pp. 26–31. [Online]. Available: https://www.academia.edu/43578089/

[12] S. A. Madhi et al., "Unraveling specific causes of neonatal mortality using minimally invasive tissue sampling: An observational study," *Clin. Infect. Dis.*, vol. 69, no. Suppl 4, pp. S351–S360, 2019, doi: 10.1093/cid/ciz574.

[13] S. Sanyal and K. K. Nundy, "Algorithms for monitoring heart rate and respiratory rate from the video of a user's face," in *Proc. IEEE EIConRus*, 2018, pp. 1536–1540, doi: 10.1109/EIConRus.2018.8317376.

[14] R. Joshi et al., "Predictive monitoring of critical cardiorespiratory alarms in neonates under intensive care," *IEEE J. Biomed. Health Inform.*, vol. 20, no. 4, pp. 1011–1018, Jul. 2016, doi: 10.1109/JBHI.2015.2427519.

[15] A. A. Okolo, I. R. Okonkwo, and R. C. Ideh, "Challenges and opportunities for neonatal respiratory support in Nigeria: A case for regionalisation of care," *Niger. J. Paediatr.*, vol. 43, no. 2, pp. 64–69, 2016, doi: 10.4314/njp.v43i2.1.
[16] H. Blencowe et al., "National, regional, and worldwide estimates of preterm birth rates in the year 2010 with time trends since 1990 for selected countries: A systematic analysis and implications," *Lancet*, vol. 379, no. 9832, pp. 2162–2172, 2012, doi: 10.1016/S0140-6736(12)60820-4.
[17] B. D. Kamath et al., "Neonatal mortality from respiratory distress syndrome: Lessons for low-resource countries," *Pediatrics*, vol. 127, no. 6, pp. 1139–1146, 2011, doi: 10.1542/peds.2010-3212.
[18] S. Vergnano et al., "Neonatal infections in England: The NeonIN surveillance network," *Arch. Dis. Child. Fetal Neonatal Ed.*, vol. 96, no. 1, pp. F9–F14, 2011, doi: 10.1136/adc.2009.178798.
[19] S. G. Erberich et al., "Functional MRI in neonates using neonatal head coil and MR compatible incubator," *NeuroImage*, vol. 20, no. 2, pp. 683–692, 2003, doi: 10.1016/S1053-8119(03)00370-7.
[20] N. Batey et al., "The newborn delivery room of tomorrow: emerging and future technologies," *Pediatr. Res.*, vol. 96, no. 3, pp. 586–594, 2022, doi: 10.1038/s41390-022-01988-y.