Smart cradle for efficient monitoring of babies : An unique approach using IoT

Kishore Mohan K.B.[1]
Professor Biomedical engineering and Medical electronics engineering
Saveetha engineering college
Chennai
Kishorekbmtech@yahoo

Md Firoj Alam[2]
Medical Electronics engineering
Saveetha engineering college
Chennai
mdfirojalam432002@gmail.com

Md Firoz[3]
Medical Electronics engineering
Saveetha engineering college
Chennai
Md003firoz@gmail.com

Abstract— **The emerging growth of technology and supportive things around the technology created a way for innovations in health care industry. The critical challenges in baby monitoring are considered as the research scope here. The infant monitoring in incubator needs continuous manual observations. The critical raise and fall values of the heart rate, skin temperature, wetness of the body are important to measure. The proposed system is developed with configurable internet of things (IoT) enabled smart cradle for baby monitoring. The system architecture contains embedded Arduino UNO hardware for sensor control panel, temperature sensor, wetness detection sensor, heart beat sensor, IR sensor etc. The complete process is monitored via customized IoT platform and prediction of abnormality is developed in the cloud through neural computing blocks. The data storage and stampings are helpful to create a detailed log for making forecast on abnormal condition. The early detection of abnormality in infants are the primary goal of the system.**

Keywords— ***Artificial intelligence, Wireless communication, Baby monitoring, Internet of things, Forecast system.***

I. INTRODUCTION

The concept of a smart cradle system revolutionizes baby monitoring in hospitals, replacing manual methods with embedded sensors. Through the integration of Internet of Things (IoT) technology,[1] this system facilitates remote monitoring of infants, ensuring secure communication between cloud-based servers and hardware components. Accessible globally, the cloud platform enables parents and hospital staff, including nurses and doctors, to monitor infants in critical stages directly from their devices. Real-time data transmission from the incubator[2] to the cloud provides a common platform for accessing vital information. Immediate alerts and notifications, facilitated by sensors like temperature, humidity, wetness detection, skin resistance, and air quality sensors, enhance monitoring capabilities, ensuring timely responses to infant needs.

The advancement of machine learning algorithms and the widespread implementation of artificial intelligence in hardware environments have significantly improved the early detection of abnormal conditions[3]. Additionally, the development of efficient protocols for transmitting data from transmitters to receivers ensures that highly sensitive information remains secure. The proposed smart cradle system addresses numerous challenges encountered in hospital environments, emphasizing the importance of flexibility to maintain continuous communication with the cloud without interruptions. Any disruption between the smart cradle system and the cloud could cause distress for parents, underscoring the system's critical role in providing peace of mind. Through remote accessibility, parents can monitor their baby's health condition in real-time, accessing timestamped data values. Recent advancements in data analytics have introduced innovative solutions to overcome challenges encountered in smart cradle systems, further enhancing their effectiveness[4].

In the realm of IoT-enabled communication, smart hospital environments encounter significant challenges, notably in privacy and security. The collection of highly sensitive data from baby monitoring systems necessitates stringent privacy and security protocols, ensuring data protection through unique IDs and robust encryption methods. Reliability and stability are paramount for seamless communication between embedded components and the cloud environment. Continuous monitoring of network continuity is essential, promptly addressing any malfunctions to prevent interruptions. Self-repairing algorithms swiftly resolve issues to ensure uninterrupted data transmission to the cloud. Integrating diverse sensors and devices from various manufacturers can lead to compatibility issues, mitigated through proactive monitoring and resolution mechanisms facilitated by data analysis techniques such as machine learning. Power consumption of IoT-connected devices is continuously monitored and optimized through power management systems to prolong battery life[5]. The user interface is adaptable, with self-analysis modules swiftly resolving any detected issues to enhance user experience. Compliance with regulatory standards, power supply stability, electromagnetic interference, and short circuit prevention are meticulously addressed to ensure an effective and scalable smart cradle system[6].

- The developed system incorporates embedded sensors and a Microcontroller unit to promptly detect and relay any abnormalities in infants to the cloud seamlessly.
- Sensors including temperature, heart rate, wetness detection, and IR sensors are employed to continuously monitor both the baby's health status and the incubator conditions.
- In case of any short circuits within the smart cradle system, an immediate alert is generated via a buzzer notification, ensuring swift response to potential issues.

The remaining sections of the paper are structured as follows: a comprehensive background survey from inception leading to the system design architecture challenges in existing systems, followed by an exploration of the hardware modules necessary for designing the proposed architecture in Section III. Section IV delves into the proposed methodology and implementation procedure. Various research findings related to the proposed architecture are showcased in Section V. Finally, the paper concludes with essential results and outlines future scopes for further exploration.

II. BACKGROUND STUDY

Hina Alam et al. (2023) The author introduces a smart child monitoring system, utilizing Blink software to process sensor data through machine learning algorithms. This system continuously monitors the baby's condition and transmits it to the Blink cloud, enabling remote monitoring of the baby's health status by parents. The proposed system comprehensively addresses both the hardware components and the challenges associated with them. The difficulties in handling these hardware components are thoroughly explored within the presented system [7].

E. Grooby et al., (2021) The author introduces a novel methodology emphasizing signal quality enhancement in heart rate and breath monitoring systems for children in incubation. Notably, the noisy nature of neonatal chest ultrasound impedes accurate heart rate measurement. The proposed system addresses this challenge by incorporating a filtering process to enhance heart rate monitoring accuracy, achieved through future extraction techniques from lung sounds. A comprehensive Audio Processing Unit is developed, alongside data balancing and optimization of binary classification. Hyperparameters are carefully considered and implemented in the analysis, with performance evaluation conducted through binary classification metrics [8].

D. Xia et al., (2024) The author introduces a novel approach for multi-target, high-resolution detection of children's respiration status using a MetaBreath digital multisurface harmonic detection system. This system accurately detects respiration rate and addresses the challenge of noise from motion artifacts in the existing system by implementing independent component analysis(ICA) modules for respiration sound verification [9].

J. Berrezueta-Guzman et al. (2020) The author introduces an intelligent home environment system utilizing the Internet of Things for detection purposes. This approach includes a disability detection module tailored for home environments. Interaction with children facilitates the collection of various data from the home environment, enabling the robotic system to automatically detect and process children's behavior and voice. These data are then utilized to create a therapist for supervision and verification of normal activities [10].

M. M. E. Yurtsever et al. (2022) The author introduces a baby pose detection system utilizing video clips sourced from various online videos to identify both normal and abnormal baby positions. Leveraging deep sort algorithms, the system achieves an impressive accuracy rate of 99% and a minimal loss ratio of 0.072. Different datasets, collected in video format, are processed using LSTM algorithms. Comparative analysis of performance metrics against existing approaches is conducted, highlighting challenges encountered in the existing system [11]. Various state-of-the-art approaches are examined to identify the challenges encountered by baby monitoring systems. A key issue highlighted is the inability of current systems to facilitate parents hearing their baby's voice or communicating with them, particularly applicable for infants aged one year or younger. To address this limitation, there's a proposed emphasis on securing baby monitoring systems under the Internet of Things framework to ensure a safe environment.

III. SYSTEM DESIGN

The proposed architecture prioritizes sensors and cloud forecasting to ensure an accurate and secure baby monitoring system. Beyond mere surveillance, it serves as a secure communication platform within a wireless area network. The web application utilizes the Sakue protocol to transmit incubator data to the cloud, enabling continuous monitoring of baby health issues by both parents and hospital staff to promptly detect any signs of illness. Nursery-provided updates are instantly synced with the cloud, while any health anomalies trigger immediate alerts via buzzer sounds, ensuring swift updates in the cloud environment. All smart cradle system updates are promptly uploaded to the cloud, ensuring global data accessibility, and login information aids in developing future prediction models. A standout feature of this approach is its forecasting capability for early anomaly detection.

Hardware modules

NodeMCU

Fig 1. Node MCU

Fig 1. Shows the NodeMCU module to configure the wireless connectivity between the network cloud and the controllable hardware device. The NodeMCU module serves as a reliable bridge between the hardware environment and the internet, providing seamless connectivity. Equipped with both analogue and digital input pins, it facilitates straightforward communication. Various serial communication protocols such as Serial Peripheral Interface (SPI) and Inter-Integrated Circuit (I2C) are supported by the NodeMCU module. Its memory capacity includes 128 kilobytes of RAM and 4 megabytes of programmable flash memory, ample space for storing programs and essential data.

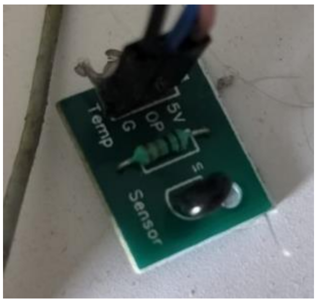

Fig 2. Temperature Sensor

Fig 2. Shows the temperature sensor module utilized in the proposed Baby monitoring system. The temperature sensor is a compact embedded module known for its dependable temperature sensing capabilities. It operates efficiently with a 5-volt DC power supply, making it suitable for remote applications. With a power consumption of just 60 microamps, it can function within a voltage range of 4 volts (minimum) to 30 volts (maximum).

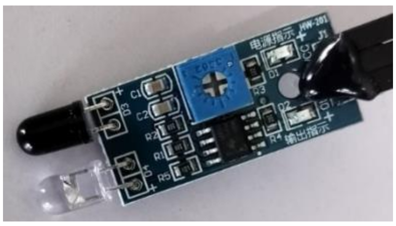

Fig 3. IR sensor

Fig 3. Shows the IR sensor utilized in the proposed smart cradle system. The IR sensor module operates within a range of 3 volts DC minimum to 5 volts DC maximum. It detects objects within a range of 32 cm to 10 cm and has a detection angle of 35 degrees. Its compact size, with a mountable 3 mm diameter module, makes it easy to install alongside digital components.

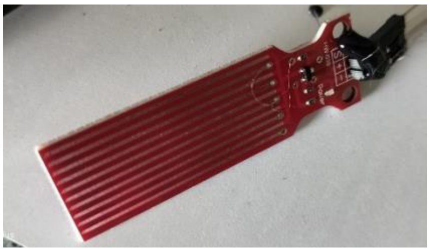

Fig 4. Wetness detection sensor

Fig 4. Shows the wetness detection sensor. The wetness sensor is a distinctive hardware component designed to detect the presence of water through an array of conducting lines integrated into the printed circuit board. Any moisture triggers a short circuit within the incubator. These sensors are employed to identify short circuits in the incubator and facilitate prompt detection.

Fig 5. Buzzer

Fig 5. Shows the buzzes module activated with DC power supply of +5V. This compact electronic component generates sound when triggered by a small DC input from the programmable controller, such as an Arduino. It promptly alerts to any abnormal activity detected in the baby's body through audible signals emitted by the buzzer.

IV. PROPOSED METHODOLOGY

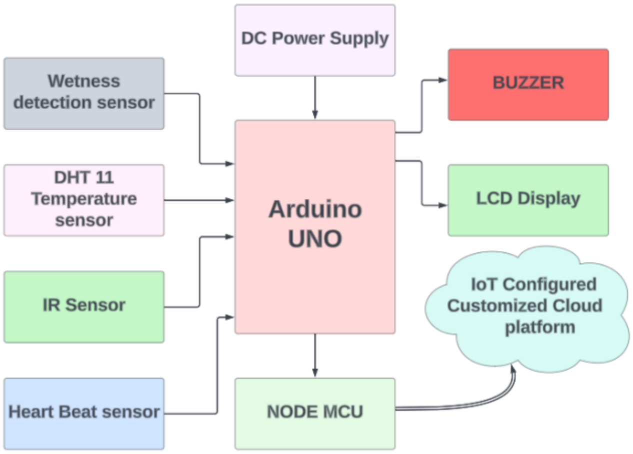

Fig 6. Proposed system architecture on Baby monitoring system

Fig 6. Shows the proposed system architecture of baby monitoring system using IoT. In the cradle system, all updates from the smart cradle environment are swiftly uploaded to the cloud, ensuring global access to the collected data. Login information is instrumental in crafting future prediction models. The key highlight of this proposed approach lies in its forecasting methodology, designed for early abnormality detection within the system

The proposed system integrates wetness detection, air module, temperature sensor, IR detection sensor, and heartbeat detection sensor, all powered by a DC power supply for seamless communication with the Arduino UNO. The NodeMCU or ESP8266 module facilitates Wi-Fi communication between the hardware and cloud environments. Configuration of the cloud is facilitated by a flexible IoT platform, requiring unique user input and password for simplified setup. Accessible globally, the IoT cloud employs the unique user ID provided for access. Processes within the proposed model are visualized through an LCD display, with any anomalies promptly detected and signalled via the buzzer.

The IoT platform serves not only to monitor the baby's health status but also aids in forecasting by continuously updating timestamps and their corresponding values for predictive analysis. Log data is subjected to analysis through neural computing blocks using data analytics, establishing a structured framework for the forecast model. This forecasting mechanism proves invaluable for the early detection of abnormalities.

IV. RESULTS AND DISCUSSIONS

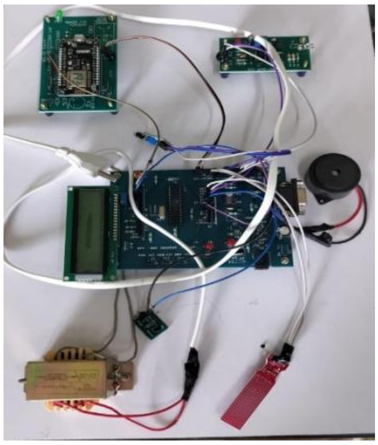

Fig 7. Integrated Smart Cradle

Fig 7. Shows integrated smart cradle for baby monitoring system. The hardware is tested with various test inputs with baby monitoring environment.

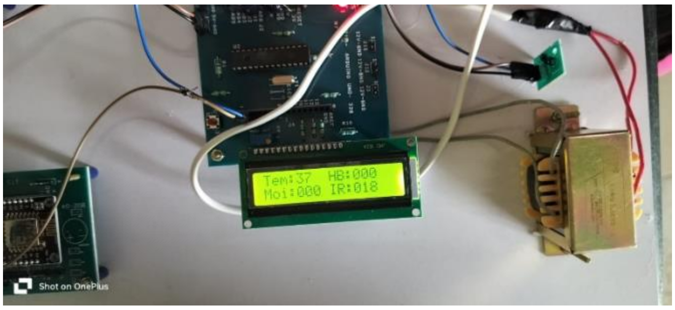

Fig 8. LCD display

Fig 8. Shows LCD display showing the values of each sensors during testing phase. The monitoring through LCD is helpful for taking timely readings too. The real-time updations are uploaded into the cloud.

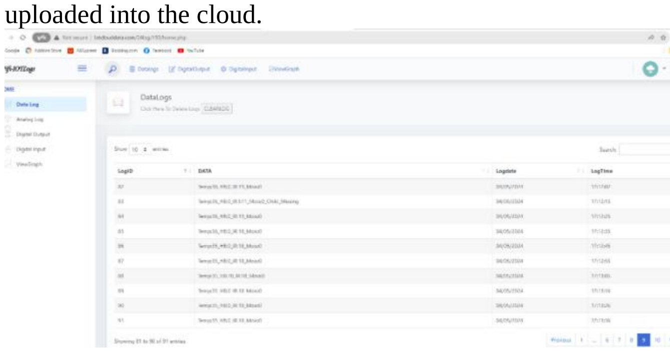

Fig 9. IoT Platform

Fig 9. IoT Platform customized for monitoring the smart baby cradle system. The IoT platform not only monitors the baby's health status but also assists in forecasting by consistently updating timestamps and their corresponding values for predictive analysis. Log data undergoes analysis through neural computing blocks using data analytics, establishing a structured framework for the forecast model. This forecasting mechanism is invaluable for the early detection of abnormalities.

V. CONCLUSION

The rapid advancement of technology and its applications have paved the way for innovations in the healthcare industry, particularly in the realm of baby monitoring. This research focuses on addressing critical challenges in infant monitoring, especially within incubators, where continuous manual observations are necessary. Monitoring parameters such as heart rate, skin temperature, and body wetness are crucial for detecting fluctuations. To address these needs, a configurable Internet of Things (IoT) enabled smart cradle system for baby monitoring is proposed. The system architecture incorporates an embedded Arduino UNO hardware control panel, along with various sensors including temperature, wetness detection, heart rate, and IR sensors. Monitoring and analysis of data are facilitated through a customized IoT platform, with abnormality prediction algorithms developed in the cloud using neural computing blocks. Detailed data logging and timestamping aid in forecasting abnormal conditions, with the primary objective of the system being the early detection of abnormalities in infants.

REFERENCES

[1] N. J. Kumar, H. R, A. N. Kumar, G. T, G. S and T. A, "A Lightweight (Recurrent Neural Network) RNN Architecture for IoT Based Baby Monitoring System to Provide Real Time Alerts and Notification to Parents or Care Takers," 2023 Intelligent Computing and Control for Engineering and Business Systems (ICCEBS), Chennai, India, 2023, pp. 1-6, doi: 10.1109/ICCEBS58601.2023.10449327.

[2] N. L. Pratap, K. Anuroop, P. N. Devi, A. Sandeep and S. Nalajala, "IoT based Smart Cradle for Baby Monitoring System," 2021 6th International Conference on Inventive Computation Technologies (ICICT), Coimbatore, India, 2021, pp. 1298-1303, doi: 10.1109/ICICT50816.2021.9358684.

[3] T. J. Claude, N. Gaudence, M. Didacienne and N. J. Pierre, "Fuzzy logic Applied to Smart Baby's Health and Feeding Sequence Monitoring System," 2020 21st International Arab Conference on Information Technology (ACIT), Giza, Egypt, 2020, pp. 1-7, doi: 10.1109/ACIT50332.2020.9300087.

[4] H. M. Ishtiaq Salehin, Q. R. Anjum Joy, F. T. Zuhra Aparna, A. T. Ridwan and R. Khan, "Development of an IoT based Smart Baby Monitoring System with Face Recognition," 2021 IEEE World AI IoT Congress (AIIoT), Seattle, WA, USA, 2021, pp. 0292-0296, doi: 10.1109/AIIoT52608.2021.9454187

[5] P. Simmen et al., "Multichannel Esophageal Heart Rate Monitoring of Preterm Infants," in IEEE Transactions on Biomedical Engineering, vol. 68, no. 6, pp. 1903-1912, June 2021, doi: 10.1109/TBME.2020.3030162.

[6] M. Zhao, H. Duan, W. Huang and K. Sun, "Central Real-time Monitoring System for Premature Baby Incubator," 2020 IEEE 3rd International Conference of Safe Production and Informatization (IICSPI), Chongqing City, China, 2020, pp. 385-390, doi: 10.1109/IICSPI51290.2020.9332206.

[7] Hina Alam, Muhammad Burhan, Anusha Gillani, Ihtisham ul Haq, Muhammad Asad Arshed, Muhammad Shafi, Saeed Ahmad, "IoT Based Smart Baby Monitoring System with Emotion Recognition Using Machine Learning", Wireless Communications and Mobile Computing, vol. 2023, Article ID 1175450, 11 pages, 2023. https://doi.org/10.1155/2023/1175450

[8] E. Grooby et al., "Neonatal Heart and Lung Sound Quality Assessment for Robust Heart and Breathing Rate Estimation for Telehealth Applications," in IEEE Journal of Biomedical and Health Informatics, vol. 25, no. 12, pp. 4255-4266, Dec. 2021, doi: 10.1109/JBHI.2020.3047602.

[9] D. Xia et al., "MetaBreath: Multitarget Respiration Detection Based on Space-Time-Coding Digital Metasurface," in IEEE Transactions on Microwave Theory and Techniques, vol. 72, no. 2, pp. 1433-1443, Feb. 2024, doi: 10.1109/TMTT.2023.3297413

[10] J. Berrezueta-Guzman, I. Pau, M. -L. Martín-Ruiz and N. Máximo-Bocanegra, "Smart-Home Environment to Support Homework Activities for Children," in IEEE Access, vol. 8, pp. 160251-160267, 2020, doi: 10.1109/ACCESS.2020.3020734.

[11] M. M. E. Yurtsever and S. Eken, "BabyPose: Real-Time Decoding of Baby’s Non-Verbal Communication Using 2D Video-Based Pose Estimation," in IEEE Sensors Journal, vol. 22, no. 14, pp. 13776-13784, 15 July15, 2022, doi: 10.1109/JSEN.2022.3183502.