MASTERS THESIS PROPOSAL

IoT based Smart Cradle for Baby Monitoring System using Rasberry Pi

Student:
Wenqian Li
UNI
wli6@uw.edu

Committee Chair:
Prof. advisor name
Committee Member:
Prof. Someone else
Committee Member:
Prof. Somebody else

School of Engineering and Technology
December 9, 2024

Abstract

This paper presents an IoT-based Smart Cradle for Enhanced Baby Monitoring System using Raspberry Pi and Azure Vision. The project aims to provide real-time monitoring of the baby's environment by leveraging sensors, cloud computing, and computer vision technologies. The system enables parents to promptly respond to abnormal conditions, enhancing the safety and security of the baby. With instant alerts and automated responses, parents can have peace of mind and remotely interact with their baby. The system stores sensor data over time, allowing for trend analysis and providing valuable insights into the baby's health and well-being. The intuitive interface enhances the user experience, making it easy for parents to monitor their baby's environment and access historical data analysis.

Contents

1 Introduction

Infant monitoring is a crucial aspect of ensuring the safety and well-being of babies, particularly when parents may not always be able to be physically present[15]. As babies are highly vulnerable to sudden health changes or environmental disturbances, real-time monitoring becomes essential for their protection. Traditional baby monitoring systems, which typically focus on sound or motion detection, have significant limitations in providing comprehensive, real-time data. While these monitors are helpful, they often lack the advanced capabilities necessary to address dynamic and real-time issues that may arise in a baby's environment[14]. They also fail to integrate newer technologies such as cloud computing, computer vision, and IoT, which could offer enhanced monitoring, data processing, and actionable insights to parents[16].

One of the major subproblems in infant monitoring is accessibility. Many existing systems are either standalone devices with limited functionality or rely on mobile applications that may not offer sufficient real-time capabilities or insights into the baby's overall health and well-being[13]. Moreover, traditional systems often fail to integrate environmental monitoring, making it difficult for parents to receive alerts for abnormal conditions like temperature fluctuations, air quality issues, or the baby's emotional state. These challenges highlight the need for a more comprehensive and accessible solution that not only monitors the baby's vital signs but also provides valuable insights into their environment and health[7].

Existing approaches to baby monitoring largely rely on basic sensors such as sound or motion detectors, sometimes paired with cameras. Some systems have introduced basic computer vision technologies, but they remain limited in their ability to provide meaningful, real-time alerts or responses. Additionally, the integration of cloud computing and machine learning for analyzing large datasets and detecting complex events is often overlooked or underdeveloped. These approaches are often soiled and do not provide a holistic view of the baby's well-being[14]. Furthermore, many current systems are prone to false positives and lack the sophistication needed to interpret subtle events like the baby's emotional state or movements during sleep.

This project proposes an IoT-based Smart Cradle for Enhanced Baby Monitoring System using Raspberry Pi and Azure Vision to address these limitations[12]. By integrating IoT technologies, cloud computing, and computer vision, the system will offer a more comprehensive solution to infant monitoring. The key innovations of the proposed system include real-time monitoring and automated alerts for abnormal conditions, remote interaction with the baby through automated responses, and a data-driven approach to analyzing the baby's health and environment over time. Parents will be provided with an intuitive user interface that allows them to monitor environmental conditions such as temperature, humidity, and air quality, as well as track the baby's emotional state and movements.

The specific contributions of this project include:Integration of Sensors, Cloud Computing, and Computer Vision Technologies: This system combines IoT for continuous monitoring, cloud computing for scalable data processing, and computer vision for real-time event detection, addressing the limitations of traditional systems. Real-Time Monitoring and Automated Alerts: The system will provide immediate notifications to parents in response to abnormal conditions such as temperature changes, crying, or movement anomalies, ensuring swift interventions. Remote Interaction: Through automated actions and alerts, parents will be able to interact with the baby remotely, enhancing safety and security. Data Analysis for Insights: Over time, the system will track environmental trends and the baby's health data, enabling parents to make informed decisions based on historical data, helping them ensure a safe and comfortable environment for their baby.

It enables features such as data storage, analytics, and remote access, making it easier for parents to monitor their infants from anywhere. The ability to analyze data collected over time also helps in identifying trends and anomalies in the baby's behavior and environment[3]. This approach not only offers an enhanced baby monitoring experience but also provides an opportunity to improve the accessibility and reliability of monitoring systems, leveraging modern technologies to their fullest potential.

2 Related Work

Sensor Technology: Previous research has explored the use of various sensors for monitoring infant vital signs and environmental conditions. These sensors may include temperature sensors, humidity sensors, motion sensors, sound sensors, and air quality sensors. Different sensor types are employed to provide comprehensive monitoring of the baby's environment and detect abnormalities or changes in conditions that may affect the baby's well-being[4, 11]. In[18], T. Wu and P. Chen proposed an independent baby care system with an Arduino-based system to check on the heartbeat, temperature, and humidity of a premature baby. The Arduino microcontroller is interfaced with input from the temperature sensor and heartbeat sensor. It sends that data through a Wi-Fi module to a web-based server to show constant real-time data from different sensors regarding the baby. If heartbeat or temperature is above or below a preset value, it will be displayed instantly on the website, and the website will command the buzzer and bulb accordingly.

M. P. Joshi and D. C. Mehetre proposed a mobile application-based system that shows a constant update of a baby placed in their smart cradle system [6]. The system can detect if the mattress for the baby is wet or not by using a moisture sensor. It can identify the baby's crying with a noise sensor and contains a camera for live-streaming to the app. The cradle also swings automatically when crying is detected with the help of a driver circuit. Finally, the authors have also proposed using IR cameras for night vision as a future scope for advancement.

Edge Computing: Identify applicable funding agency here. If none, delete this text box. Edge computing plays a crucial role in IoT-based infant monitoring systems by enabling real-time data processing and analysis at the edge of the network, closer to the data source. This reduces latency and allows for faster response times to detected abnormalities or events. Edge computing platforms, such as Raspberry Pi, are commonly used in these systems to process sensor data locally and trigger alerts or actions as necessary[9, 8].

Cloud Services: Cloud computing services are utilized to store, manage, and analyze large volumes of sensor data collected from IoT devices. Cloud platforms, such as Azure, AWS, and Google Cloud Platform, offer scalable and reliable infrastructure for hosting IoT applications and processing sensor data. Cloud services enable features such as data storage, analytics, visualization, and remote access to monitoring systems[3].

Computer Vision: Computer vision technologies are increasingly integrated into IoT-based infant monitoring systems to analyze visual data captured by cameras. Computer vision algorithms can be used to detect specific events or objects, such as a crying baby, facial expressions, or gestures, enabling more advanced monitoring capabilities and automated responses[17, 4].

Data Analysis and Visualization: Data analysis techniques are applied to sensor data collected over time to identify patterns, trends, and anomalies in the baby's behavior and environment. Time-series databases, such as InfluxDB, are commonly used for storing and querying sensor data. Data visualization tools, such as Grafana, are employed to create visual representations of sensor data, enabling caregivers to gain insights into the baby's health and well-being[4].

Dashboards: User-friendly interfaces, such as mobile applications or web dashboards, provide caregivers with easy access to monitoring systems and real-time data insights. These interfaces allow caregivers to remotely monitor the baby's environment, receive alerts, and access historical data analysis from their smartphones or other devices.

3 Background

The safety and well-being of infants are critical concerns for parents and caregivers, especially when continuous supervision is not feasible. Advances in technology have opened pathways for addressing these concerns through the development of smart monitoring systems leveraging Internet of Things, cloud computing, and artificial intelligence.

Emerging technologies such as IoT, edge computing, and computer vision have shown immense potential to transform infant monitoring by enabling more comprehensive solutions. IoT facilitates continuous monitoring of vital signs and environmental conditions, while edge computing processes this data locally, reducing latency and enabling faster responses. Cloud platforms such as Microsoft Azure and Amazon Web Services (AWS) provide scalable data storage and analytics, allowing remote access and real-time visualization of the baby's health and environmental parameters. Computer vision further enhances these systems by analyzing visual data to detect events such as crying, sleep positions, or unusual movements, offering a more holistic understanding of the baby's behavior[1, 5].

The Internet of Things (IoT) is a transformative technology paradigm that involves the interconnection of physical devices, sensors, and systems through the internet to facilitate communication, data exchange, and automation. IoT has emerged as a pivotal component in modern technology, enabling the creation of smart environments in areas such as healthcare, agriculture, transportation, and home automation. The concept of IoT traces back to the early 1980s when connected devices, like a modified Coke vending machine at Carnegie Mellon University, were first envisioned. However, the term "Internet of Things" was coined by Kevin Ashton in 1999, referring to a network of "smart things" capable of sensing and transmitting data without human intervention.

This project proposes an IoT-based Smart Cradle for Enhanced Baby Monitoring System to address these challenges. The system, utilizing Raspberry Pi and Azure Vision, combines sensor technology, cloud computing, and computer vision to enable real-time monitoring, automated alerts, and remote interaction. By providing parents and caregivers with actionable insights through an intuitive interface, the system ensures a safe and comfortable environment for the baby while empowering users with data-driven decision-making capabilities.

The development of this IoT-based Smart Cradle system builds upon existing frameworks, models, and tools that have demonstrated efficacy in similar applications. By integrating advanced software and hardware components, this project leverages state-of-the-art technologies to address the limitations of traditional infant monitoring systems. Below, we provide an overview of the tools and technologies used in this system, highlighting their roles and contributions.

4 Methodology

This section outlines the methodology for developing the IoT-based Smart Cradle for Enhanced Baby Monitoring System. The system integrates software and hardware components to provide real-time monitoring, alert notifications, and insights into the baby's health and environment. Below, we detail the roles of each tool and component and how they contribute to the system's overall functionality.

Software:

Node-RED: A visual programming tool that allows for wiring together hardware devices, APIs, and online services. Node-RED facilitates the integration of various system components, enabling the automation of tasks such as data collection and alert notifications[2].Data collected from Grove Pi sensors is transmitted to Node-RED for initial processing and routing.Automated workflows are set up to trigger alerts when abnormal conditions, such as crying or temperature fluctuations, are detected. Node-RED communicates with Azure for advanced analytics and with Grafana to update dashboards in real time.

Grafana:Grafana serves as the front-end visualization tool. Dashboards are configured to display:Live sensor data, such as temperature, humidity, and noise levels. Alerts and historical trends of environmental and health parameters. Customizable alerts that caregivers can monitor via mobile or web interfaces.

InfluxDB: Sensor data streamed through Node-RED is stored in InfluxDB, a time-series database. This setup allows:Efficient storage of high-frequency data streams from sensors. Querying and retrieval of data for historical trend analysis. Seamless integration with Grafana for visualization of time-series data.

Azure:Azure provides the cloud infrastructure for advanced analytics and storage:Data processed locally on the Raspberry Pi is transmitted to Azure for machine learning analysis, such as detecting crying patterns using computer vision. Azure hosts computer vision algorithms that process video streams captured by cameras, identifying specific events like baby crying face. Scalable storage is used to retain historical data for long-term analysis and to facilitate remote access to system metrics.

STL Files: These 3D model files are used for printing the prototype crib. The designs ensure that the hardware components are housed securely while allowing for functionality and safety.

Hardware:

Raspberry Pi: A single-board computer that serves as the core processing unit for the Smart Baby Monitor system. The Raspberry Pi runs the necessary software and processes data from connected sensors. Runs Node-RED to process and route sensor data. Interfaces with the Grove Pi module to collect real-time data from sensors.

Grove Pi Sensors: The Grove Pi interface connects multiple sensors to monitor the baby's environment: Sound Sensors: Detect ambient noise and trigger alerts if big noise is detected. This data is processed locally and transmitted to Azure for verification. Motion Sensors: Track the baby's movements to identify abnormalities or potential distress. Temperature and Humidity Sensors: Continuously monitor environmental conditions to ensure comfort and alert caregivers in case of deviations from optimal ranges. Air Quality Sensors: Monitor for harmful gases or poor air quality, triggering immediate alerts if unsafe conditions are detected. Gas Sensors: Detect the presence of specific harmful gases such as carbon monoxide (CO), methane, or ammonia.[11].

3D Printer: Used to create a prototype of the crib that houses the Raspberry Pi and sensors. The 3D-printed components are designed to integrate seamlessly with the electronic hardware.

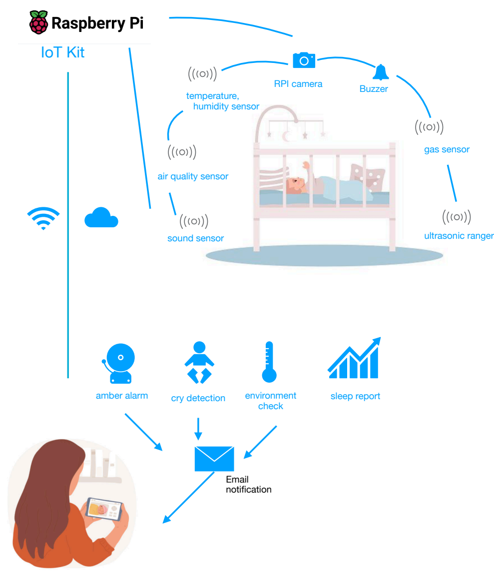

Figure 1: High Level Overview of Baby Monitor

Data Collection: Sensor Integration: All sensors, including sound, motion, temperature, humidity, air quality, and gas sensors, are connected to the Raspberry Pi via the Grove Pi interface. Real-Time Data Streams: The Raspberry Pi serves as the central hub, collecting continuous data streams from all connected sensors. Preprocessing: Local algorithms running on the Raspberry Pi perform initial preprocessing of the sensor data, such as noise filtering and basic anomaly detection.

Instant Alerts for Abnormal Conditions: The system generates immediate alerts when sensor readings deviate from predefined thresholds: Email Notifications: Sends detailed information to caregivers for remote monitoring. Push Notifications: Instantly informs caregivers via mobile applications or web dashboards. Alerts is sent when baby cry.

Automated Responses for Enhanced Interaction In response to detected abnormalities or caregiver input, the system triggers automated actions:Rocking Mechanism: Activates the crib's rocking function to soothe the baby.

5 Experiments

The experiment was designed to evaluate the functionality, accuracy, and usability of the IoT-based Smart Cradle system. This experiment involved deploying the cradle in both controlled and real-world settings to simulate real-life scenarios and test its ability to monitor, detect anomalies, and respond appropriately.

5.0.1 Experiments Setup

Controlled Environment: The cradle was set up in a lab where specific conditions could be controlled and repeated for consistency. Simulated anomalies included playing pre-print baby cries pictures, artificially varying temperature and humidity, and introducing air quality changes (e.g., simulated smoke).

Hardware Configuration: The cradle was equipped with: Grove Pi+ sensors (sound, motion, temperature, humidity,buzzer, gas and air quality). A high-resolution camera is mounted to capture the baby's face and transmit video frames to Azure Vision SDK. Motors for rocking the crib.

Software Configuration: Install and configure Node-RED on the Raspberry Pi. Integrate all sensors (sound, motion, temperature, humidity, air quality) using Node-RED nodes. Sending alerts to caregivers via email or push notifications. Azure Vision SDK: The SDK is configured to analyze facial expressions and emotions indicative of crying. Node-RED Workflow: Audio and video inputs are processed in Node-RED, which triggers alerts and actions based on the detected events. Triggering automated actions, such as rocking the crib, based on when detect baby cry. Test each workflow independently and then as a unified system to ensure smooth integration. Expected Outcome: A complete Node-RED workflow capable of processing sensor data, detecting anomalies, sending alerts, and triggering automated responses in real-time.

5.1 Evaluation

The evaluation process for the IoT-based Smart Cradle system involves multiple phases aimed at assessing the system's reliability, accuracy, usability, and functionality under real-world conditions. Each step is designed to ensure the system meets the intended goals of providing real-time monitoring, automated responses, and actionable insights. Below is a detailed description of the evaluation process:

1. Setup: Deploy the prototype system and ensemble all the sensor. Simulate various scenarios, such as crying, temperature fluctuations, and poor air quality, to test system response.

2. Testing:

2.1 Real-Time Monitoring: The system's sensors are tested for their ability to accurately capture data in real-time. This involves: Monitoring the precision and reliability of each sensor (e.g., sound, motion, temperature). Comparing the sensor readings with reference devices to ensure accuracy. Verifying that the data is transmitted and logged without delays or errors.

2.2 Automated Responses: The system's capability to trigger automated responses is evaluated under different scenarios: Cry detection triggers actions like playing a soothing lullaby or gently rocking the crib. Temperature or air quality anomalies prompt alerts or activate mechanisms to adjust conditions (e.g., turning on a fan or notifying caregivers). The timing and effectiveness of these responses are analyzed to ensure immediate comfort and safety for the baby.

2.3 Alerts: The alert system is tested for: Correctness: Verifying that alerts correspond accurately to the detected anomaly. Timeliness: Measuring the time elapsed between anomaly detection and alert delivery to ensure real-time notifications. Clarity: Reviewing the message content for clarity, ensuring caregivers understand the issue and suggested actions.

5.1.1 Dataset

The dataset for the IoT-based Smart Baby Cradle system consists of real-time and historical data collected from sensors and camera footage.The IoT-based Smart Baby Cradle system leverages InfluxDB as a time-series database for storing sensor data and Grafana for visualizing this data in real-time.

6 Deliverables

The project deliverables will include source code, hardware prototype, Grafana Dashboard(Figure2), InfluxDB Dashboard(Figure3), Azure Dashboard(Figure4), presentation of the IoT-based Smart Baby Cradle system. Source Code: Comprehensive Python codebase for: Sensor integration and data collection.

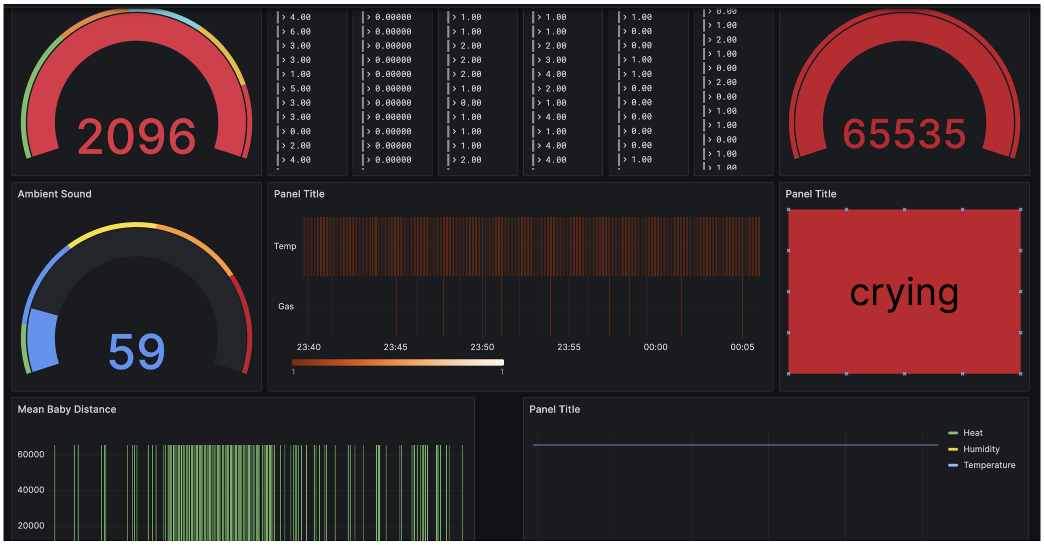

Figure 2: Grafana Dashboard

Azure Vision SDK-based cry detection. Node-RED workflows for automation. Grafana dashboard setup and InfluxDB integration. Includes modular, reusable functions for scalability.

Hardware Prototype: A functional 3D-printed cradle integrated with all hardware components, including: Raspberry Pi, Grove Pi+ sensors, camera, and motors. Demonstrates the system's ability to collect data, detect anomalies, and execute automated responses.

Presentation: A professional presentation detailing: The project's objectives, methodology, and technical implementation. Results from experiments, including system accuracy and user feedback. Challenges faced and future directions for improvement.

7 Conclusion

The IoT-based Smart Baby Cradle system offers a comprehensive solution for modern infant care by combining advanced technologies with user-friendly functionality. Its real-time monitoring capabilities ensure that parents can promptly respond to any changes in the baby's environment, such as fluctuations in temperature, air quality, or motion, thereby enhancing the baby's safety and security.

Figure 3: InfluxDB Dashboard and 3D print crib

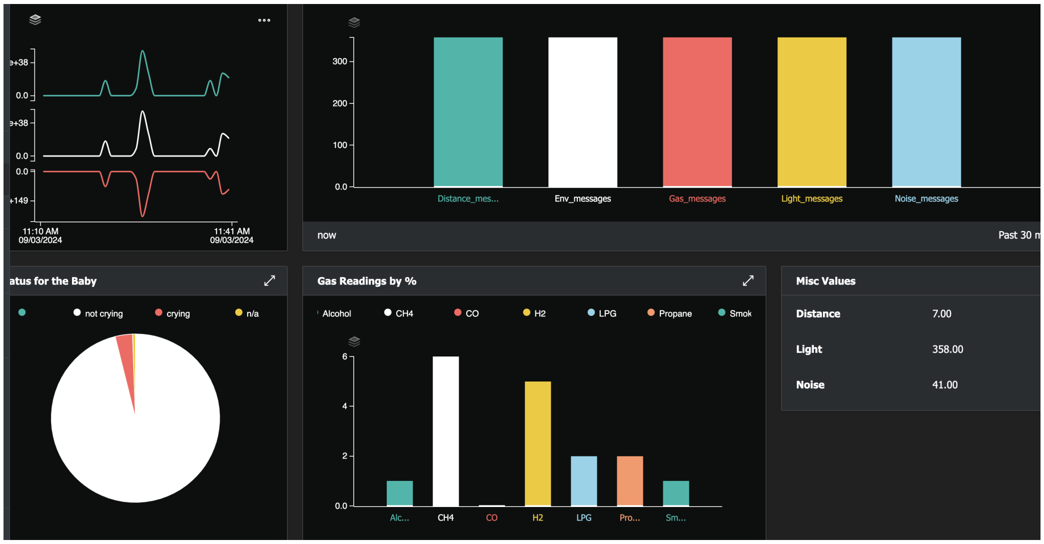

Figure 4: Azure Dashboard

With instant alerts and automated responses, the system provides parents with peace of mind, knowing that they will be notified of any issues even when they are not physically present. This empowers them to take timely actions, ensuring the baby's comfort and well-being.

The ability to store and analyze sensor data over time adds a valuable layer of insight, enabling caregivers to understand trends in the baby's sleep patterns and environmental conditions. These insights support informed decision-making and proactive adjustments to caregiving practices. By incorporating automated responses, such as activating a rocking crib or playing soothing lullabies, the system facilitates remote interaction, offering comfort and reassurance to both the baby and the parents.

Additionally, the intuitive interface, accessible via a mobile app or web dashboard, simplifies monitoring, alert management, and historical data review, enhancing the overall user experience.

In conclusion, this system bridges the gap between traditional monitoring and modern technology, providing a safer, smarter, and more accessible way to care for infants while addressing the challenges of contemporary parenting.

8 Timeline

Autumn 2024

Week 1: Finalize project requirements and objectives

Week 2: Research sensors, hardware, and software tools. Configure Sensor APIs.

Week 3: Select sensors and hardware components for the project.

Week 4: Set up the Raspberry Pi environment and install necessary software (Node-RED, InfluxDB, Grafana). Integrate Grove Pi sensors with the Raspberry Pi.

Week 5: Develop Node-RED workflows for basic data collection from sensors. Test initial sensor functionality and verify data flow to the Raspberry Pi.

Week 6:Implement Python scripts for data logging and integration with InfluxDB. Configure InfluxDB to store sensor data efficiently.

Week 7:Begin integrating Azure Vision SDK for cry detection using the camera. Test cry detection in a controlled environment with different baby face picture.

Week 8: Refine the Node-RED workflows to include anomaly detection and alert mechanisms. Integrate additional sensors (e.g., air quality, motion) into the workflow.

Week 9: Complete the implementation of Azure Vision SDK and validate cry detection results. Combine audio (sound sensor) and visual (camera) data for enhanced accuracy.

Week 10: Finalize Grafana dashboards, including alert configurations and trend analysis features. Validate data flow between InfluxDB and Grafana.

Week 11:Set up the Azure dashboard for cloud-based analytics and visualization. Integrate Azure IoT Hub for data management and remote access.

Winter 2024

Week 12: Design the cradle prototype and create STL files for 3D printing. Begin 3D printing cradle components.

Week 13: Assemble the cradle prototype, integrating hardware components (Raspberry Pi, sensors, camera, actuators). Ensure hardware fits and functions seamlessly within the cradle.

Week 14: Conduct hardware-software integration testing. Debug issues in sensor communication, automation, and data visualization.

Week 15: Perform controlled environment testing for sensor accuracy, cry detection, and system response

Week 16:Simulate various scenarios (e.g., crying, temperature fluctuations, air quality anomalies).

Week 17:Monitor system performance in real-world conditions, focusing on anomaly detection and automated responses. Collect caregiver feedback on usability and system reliability.

Week 18: Continue real-world testing, refining system settings and thresholds based on observed performance.

Week 19: Gather and organize all collected data for analysis. Evaluate the system's accuracy, response time, and usability.

Week 20: Finalize data analysis. Prepare a summary of testing results and recommendations for improvement.

Week 21: Write the thesis, documenting methodology, results, and conclusions.

Week 22: Deliver the final presentation and defend the project. Submit the thesis and all deliverables, including source code, datasets, and documentation.

9 Education Statement

This project aligns with the educational objectives of fostering interdisciplinary knowledge and hands-on experience in the fields of IoT, machine learning, cloud computing, and data visualization. By working on the IoT-based Smart Baby Cradle system, I will gain practical expertise in both hardware and software development, as well as an in-depth understanding of system integration and user-centric design. This project integrates theoretical knowledge with practical implementation, bridging the gap between academic learning and real-world applications, while also addressing a meaningful problem in infant care.

10 Acknowledgement

Lastly, I would like to express my deepest gratitude to Dr.Eyhab Al-Masri (ealmasri@uw.edu),Associate Professor School of Engineering and Technology in University of Washington Tacoma for the generous grant and anticipated support that aim to make the project possible. He has introduce the Iot related knowledge to us and make guidance to finish this project[10].

References

[1] Comparative study of iot- and ai-based computing disease detection approaches. *Data Science and Management* (2024).

[2] Chen, C.-Y., Wu, S.-H., Huang, B.-W., Huang, C.-H., and Yang, C.-F. Web-based internet of things on environmental and lighting control and monitoring system using node-red, mqtt and modbus communications within embedded linux platform. *Internet of Things 27* (2024), 101305.

[3] Chen, J., Wang, C., Li, J., Jiang, C., and Duan, C. A non-isolated three-level bidirectional dc-dc converter. In *2018 IEEE Applied Power Electronics Conference and Exposition (APEC)* (2018), pp. 1566–1570.

[4] Iannini, L., Mancinelli, A., Lopez-Dekker, P., Hoogeboom, P., Li, Y., Uysal, F., and Yarovoy, A. Prf sampling strategies for swarmsar systems. In *IGARSS 2019 - 2019 IEEE International Geoscience and Remote Sensing Symposium* (2019), pp. 8621–8624.

[5] Jabbar, W. A., Shang, H. K., Hamid, S. N. I. S., Almohammedi, A. A., Ramli, R. M., and Ali, M. A. H. Iot-bbms: Internet of things-based baby monitoring system for smart cradle. *IEEE Access 7* (2019), 93791–93805.

[6] Joshi, M., and Mehetre, D. Iot based smart cradle system with an android app for baby monitoring. pp. 1–4.

[7] Krbec, B. A., Zhang, X., Chityat, I., Brady-Mine, A., Linton, E., Copeland, D., Anthony, B. W., Edelman, E. R., and Davis, J. M. Emerging innovations in neonatal monitoring: a comprehensive review of progress and potential for non-contact technologies. *Frontiers in Pediatrics 12* (2024).

[8] Matthews, E., Gao, Y., and Shannon, L. Exploring writeback designs for efficiently leveraging parallel-execution units in fpga-based soft-processors. In *2020 IEEE 28th Annual International Symposium on Field-Programmable Custom Computing Machines (FCCM)* (2020), pp. 120–128.

[9] Nakamura, S., Murabayashi, F., Ieda, M., and Sawa, G. Degradation of polyethylene by combination of thermal aging and radiation. In *1984 IEEE International Conference on Eletrical Insulation* (1984), pp. 271–274.

[10] OpenAI. Chatgpt: A large language model. https://chat.openai.com/, 2024. Version 4.0.

[11] Park, Y., Lee, S. B., Yun, J., Sasic, M., and Stone, G. C. Air gap flux-based detection and classification of damper bar and field winding faults in salient pole synchronous motors. *IEEE Transactions on Industry Applications 56*, 4 (2020), 3506–3515.

[12] Saude, N., and Vardhini, P. H. Iot based smart baby cradle system using raspberry pi b+. In *2020 International Conference on Smart Innovations in Design, Environment, Management, Planning and Computing (ICSIDEMPC)* (2020), pp. 273–278.

[13] Shamsir, S., Hassan, O., and Islam, S. K. Smart infant-monitoring system with machine learning model to detect physiological activities and ambient conditions. In *2020 IEEE International Instrumentation and Measurement Technology Conference (I2MTC)* (2020), pp. 1–6.

[14] Singh, G., Shekhar, A. R., Yu, X., and Saniie, J. Smart infant monitoring system using computer vision and ai. In *2023 IEEE International Conference on Electro Information Technology (eIT)* (2023), pp. 1–6.

[15] Stoumpos, A. I., Kitsios, F., and Talias, M. A. Digital transformation in healthcare: Technology acceptance and its applications. *International Journal of Environmental Research and Public Health 20*, 4 (2023).

[16] Tanveer, K., and Salman, A. Intelligent baby behavior monitoring using embedded vision in iot for smart healthcare centers. pp. 110–124.

[17] Tegos, S. A., Diamantoulakis, P. D., Lioumpas, A. S., Sarigiannidis, P. G., and Karagiannidis, G. K. Slotted aloha with noma for the next generation iot. *IEEE Transactions on Communications 68*, 10 (2020), 6289–6301.

[18] Wu, T.-H., and Chen, P.-Y. Baby care system design for multi-sensor applications. In *2019 International Symposium on Intelligent Signal Processing and Communication Systems (ISPACS)* (2019), pp. 1–2.