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Calmnest: IOT Based Smart Cradle Using Controller Ble Sense

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Abstract: *This paper presents CalmNest, an IoT-based smart cradle designed to enhance infant safety and comfort using a microcontroller integrated with BLE Sense technology. The system monitors key parameters such as motion, sound (cry detection), temperature, and humidity in real time. Upon detecting abnormal conditions, the cradle automatically performs soothing actions, including controlled rocking, and sends alerts to caregivers via a mobile interface. The use of Bluetooth Low Energy (BLE) ensures low power consumption and efficient wireless communication. The proposed system offers a reliable, cost-effective, and user-friendly solution for remote infant monitoring. Experimental results demonstrate improved responsiveness and reduced caregiver intervention, highlighting the potential of IoT-enabled smart childcare systems.*

Keywords: *IoT, Smart Cradle, BLE Sense, Infant Monitoring, Automation, Embedded Systems.*

Introduction

The rapid advancement of the Internet of Things (IoT) has transformed conventional monitoring systems into intelligent platforms capable of collecting, analyzing, and transmitting real-time information. In healthcare and home automation, IoT-based devices have significantly improved remote monitoring by enabling continuous observation of critical parameters and timely intervention whenever abnormal conditions are detected. The integration of embedded sensors, wireless communication, and intelligent controllers has made it possible to design compact and energy-efficient systems that support both convenience and safety in everyday applications. These developments have encouraged researchers to explore IoT solutions for infant care, where continuous monitoring is essential for ensuring a safe and comfortable environment **[1]**.

Infant care demands constant attention because babies cannot communicate discomfort, illness, or environmental changes verbally. Parents and caregivers often rely on manual observation to identify situations such as excessive crying, uncomfortable room temperature, or unusual movement. However, continuous supervision is difficult in modern lifestyles where caregivers may be occupied with household or professional responsibilities. Recent advances in embedded sensing technologies have created opportunities for developing automated cradle systems capable of monitoring multiple environmental and physiological parameters while providing timely alerts to caregivers. Such systems improve infant safety by minimizing response time during emergency situations **[3]**.

Embedded controllers equipped with multiple sensing capabilities have become an important component of modern smart monitoring systems. Devices integrated with sensors for temperature, humidity, sound, and motion can continuously observe the surrounding environment and provide immediate feedback whenever abnormal conditions occur. These intelligent embedded platforms offer compact design, low power consumption, and reliable operation, making them suitable for healthcare-oriented applications requiring uninterrupted monitoring. Their flexibility also allows integration with wireless communication modules for remote accessibility and data sharing **[5]**.

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Bluetooth Low Energy (BLE) has emerged as one of the most effective wireless communication technologies for battery-operated IoT devices because of its low energy consumption and reliable short-range connectivity. Compared with conventional wireless communication protocols, BLE supports efficient data transmission while extending device operating life, making it particularly appropriate for smart home and healthcare applications. The availability of BLE-enabled microcontrollers has simplified the development of intelligent monitoring systems that can communicate directly with smartphones and mobile applications without requiring complex networking infrastructure **[6]**.

The increasing popularity of connected healthcare devices has also highlighted the importance of secure and scalable IoT architectures. Modern IoT systems require efficient middleware, reliable communication protocols, and standardized device interaction to support continuous monitoring and seamless information exchange. These architectural components ensure that sensor data can be processed accurately while maintaining dependable communication between embedded devices and user interfaces. Such characteristics are essential for smart infant monitoring systems where uninterrupted operation directly influences user confidence and system reliability **[9]**.

Recent research has further emphasized the role of IoT in enabling intelligent automation across various healthcare environments. Smart monitoring platforms not only collect environmental information but also perform automated actions based on predefined conditions, thereby reducing manual intervention. In infant monitoring applications, this capability can be utilized to initiate cradle rocking, activate soothing mechanisms, or notify caregivers whenever discomfort is detected. Such automation contributes to improved infant comfort while reducing caregiver workload and enhancing overall system responsiveness **[10]**.

Motivated by these developments, this paper presents **CalmNest**, an IoT-based smart cradle developed using a BLE Sense-enabled microcontroller for intelligent infant monitoring and automated caregiving assistance. The proposed system continuously observes motion, crying, temperature, and humidity while automatically performing controlled rocking and transmitting notifications to caregivers through a mobile interface whenever predefined thresholds are exceeded. The integration of low-power BLE communication with embedded sensing technology provides an economical, user-friendly, and reliable solution suitable for both home and healthcare environments. The proposed design aims to improve infant safety, minimize caregiver effort, and demonstrate the practical applicability of IoT-enabled smart childcare systems **[4]**.

2. Literature Review

A. Morchid et al. presented an IoT-enabled healthcare monitoring framework that combines embedded sensing technologies with intelligent communication to improve remote patient observation. Their study demonstrated how continuous real-time data acquisition enhances healthcare responsiveness while supporting reliable monitoring through interconnected IoT devices. The work provides valuable insight into designing continuous monitoring systems suitable for healthcare-oriented embedded applications **[1]**.

R. El-Naddar et al. investigated sustainable embedded systems for IoT applications with particular emphasis on low-power hardware design and energy-efficient operation. The authors highlighted the importance of optimizing embedded controllers for continuous sensing applications while maintaining reliable performance under resource constraints. Their findings support the selection of energy-efficient controllers for long-duration monitoring systems such as smart cradles **[2]**.

K. Sutradhar et al. developed an IoT-based smart cradle that integrates multiple environmental sensors for infant monitoring. Their research demonstrated that real-time observation of motion and surrounding environmental conditions significantly improves caregiver awareness while enabling timely intervention whenever abnormal conditions arise. The study established the effectiveness of sensor-based automation in intelligent childcare applications **[3]**.

N. Senthur et al. proposed an intelligent baby monitoring system using embedded IoT devices capable of continuously observing infant activities and environmental parameters. The authors incorporated wireless communication to notify caregivers whenever unusual events were detected, thereby reducing dependence on continuous manual supervision. Their work emphasized the practical advantages of automated monitoring in improving infant safety and caregiver convenience **[4]**.

A. Wilson et al. presented an embedded sensor platform for real-time healthcare monitoring using multiple sensing devices integrated within compact hardware architectures. Their study demonstrated reliable acquisition of environmental and physiological information while maintaining high measurement accuracy and efficient system performance. The proposed sensing methodology is applicable to smart cradle systems requiring continuous environmental monitoring **[5]**.

M. Al-Shareeda et al. reviewed Bluetooth Low Energy communication for Internet of Things applications and discussed its advantages in terms of low energy consumption, communication reliability, and simplified wireless connectivity. The authors concluded that BLE provides an effective communication platform for battery-powered embedded devices operating in healthcare and home automation environments, making it highly suitable for smart infant monitoring systems **[6]**.

L. Schuhmacher et al. introduced an energy prediction framework for Bluetooth Low Energy devices that evaluates communication efficiency under different operating conditions. Their analysis demonstrated that optimized BLE communication significantly extends battery life while maintaining dependable wireless performance. These findings reinforce the suitability of BLE technology for continuously operating embedded monitoring systems **[7]**.

J. Fernandez et al. investigated quality-of-service-aware Bluetooth Low Energy mesh communication for smart IoT environments. Their work addressed communication reliability, network scalability, and efficient data delivery among interconnected embedded devices. The proposed communication strategy improves the robustness of wireless sensor networks used in intelligent monitoring applications **[8]**.

A. Al-Fuqaha et al. provided a comprehensive survey of enabling technologies, communication protocols, and application domains within the Internet of Things ecosystem. Their review emphasized interoperability, intelligent sensing, cloud integration, and efficient communication as essential components of successful IoT implementations. These concepts provide a strong architectural foundation for designing scalable smart cradle systems **[10]**.

M. A. Khan and K. Salah reviewed security challenges associated with IoT deployments and discussed approaches for protecting connected devices against unauthorized access and cyber threats. The authors emphasized secure communication, device authentication, and reliable data transmission as critical requirements for modern IoT healthcare applications. Their recommendations highlight the importance of incorporating secure wireless communication into smart cradle monitoring systems **[14]**.

Methodology

The proposed system, Calmnest, is an IoT-based smart cradle designed to monitor and ensure the safety and comfort of infants. The system uses a BLE Sense controller as the main processing unit, which is connected to various sensors and modules.

Initially, sensors such as temperature and humidity sensor, sound sensor, and motion sensor are installed in the cradle. These sensors continuously collect real-time data related to the baby's environment and activities. The collected data is sent to the controller for processing.

Based on the sensor inputs, the system performs necessary actions. If the baby starts crying, detected by the sound sensor, the controller activates a motor to gently swing the cradle. If any abnormal conditions such as high temperature or unusual motion are detected, the system generates alerts.

The BLE (Bluetooth Low Energy) feature is used to send data to a mobile application. Parents can monitor the baby's condition and receive notifications in real time.

Specifications

The Calmnest: IoT-based Smart Cradle using Raspberry Pi Pico W and BLE Sense is designed as an intelligent baby monitoring system that integrates both hardware and software components for automation and safety. It uses the Raspberry Pi Pico W microcontroller, which provides built-in Wi-Fi and efficient processing for real-time operations. The system incorporates multiple sensors such as sound, temperature, humidity, motion, and gas sensors to continuously monitor the baby's condition and surroundings. The cradle is programmed using Embedded C/MicroPython through the Arduino IDE or Thonny platform. When the sound sensor detects a baby's cry, the controller automatically activates a motor to gently swing the cradle, ensuring comfort. Additionally, the system can send alerts and data updates to a smartphone via wireless communication, enabling parents to monitor the baby remotely. The design focuses on low power consumption, quick response, reliable connectivity, and safety features like smooth motor operation and secure voltage levels, making it an efficient and dependable smart cradle solution.

Proposed Framework

The proposed framework of Calmnest: IoT-Based Smart Cradle using BLE Sense Controller is designed to provide an intelligent and automated infant monitoring system using the Raspberry Pi Pico W microcontroller as the central unit. The system integrates multiple sensors such as a sound sensor to detect baby crying, a temperature and humidity sensor to monitor environmental conditions, a motion sensor to track movement, and a gas sensor to ensure air quality. These sensors continuously send real-time data to the controller, which processes the information and performs necessary actions like automatically swinging the cradle and playing soothing sounds when the baby cries. In case of abnormal conditions such as high temperature or harmful gas levels, alerts are sent to parents through a mobile application using the built-in Wi-Fi

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connectivity of the Raspberry Pi Pico W. This framework ensures a smart, safe, and responsive environment for infants while reducing the effort of caregivers.

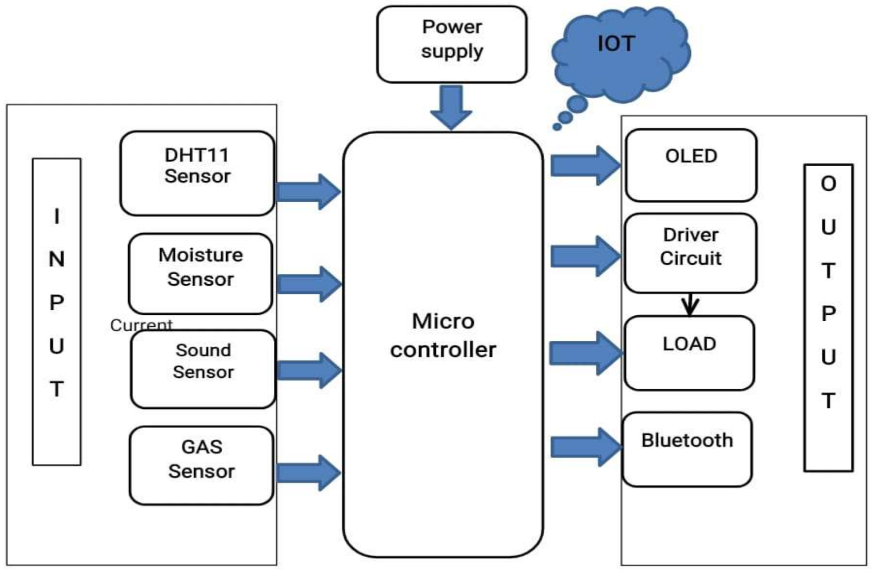

Figure 1: Block diagram

Working Flow of the Proposed Smart Monitoring System

The proposed smart monitoring system is designed to continuously monitor environmental conditions using multiple sensors integrated with a microcontroller. As illustrated in the block diagram, the entire system is powered by a regulated power supply that provides a stable operating voltage to the microcontroller, sensors, and output devices. Once the system is switched on, the microcontroller initializes all connected modules and begins acquiring data from the sensing unit.

The input section consists of a DHT11 sensor, moisture sensor, sound sensor, and gas sensor, each responsible for monitoring a specific environmental parameter. The DHT11 sensor continuously measures the surrounding temperature and humidity to evaluate the environmental conditions. The moisture sensor detects the presence of water or excessive moisture that may affect the monitored area. The sound sensor measures ambient sound levels and identifies abnormal acoustic signals, while the gas sensor continuously monitors the concentration of harmful gases to ensure a safe environment. These sensors collect real-time information and transmit their measurements directly to the microcontroller for further processing.

The microcontroller acts as the central processing unit of the system. It continuously receives sensor data, converts the incoming signals into meaningful values, and compares them with predefined threshold limits stored in the program. Based on this comparison, the controller determines whether the monitored conditions are normal or require immediate attention. Since the processing is performed continuously, the system is capable of responding quickly whenever any monitored parameter exceeds its safe operating range.

After processing the sensor information, the current environmental status is displayed on the OLED module. The display provides users with real-time values of the monitored parameters, allowing easy observation of the system without requiring additional equipment. If an abnormal condition is detected, the microcontroller activates the driver circuit, which supplies the necessary current to operate the connected load safely. Depending on the application, the load may be a warning indicator, alarm, relay, motor, or another control device that performs the required corrective action.

The system also incorporates a Bluetooth communication module that enables wireless transmission of monitoring data to a nearby smartphone or other compatible device. This feature allows users to observe system status remotely and receive notifications whenever critical conditions are detected. The IoT functionality further extends the monitoring capability by enabling data exchange

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with connected applications for continuous observation, data logging, and future analysis.

Overall, the proposed system follows a continuous sensing, processing, decision-making, and response cycle. Environmental data are acquired through multiple sensors, analyzed by the microcontroller, displayed locally on the OLED screen, transmitted wirelessly through Bluetooth, and used to control external devices whenever necessary. This integrated workflow ensures reliable real-time monitoring, timely response to abnormal conditions, reduced manual supervision, and efficient operation, making the system suitable for intelligent IoT-based monitoring applications.

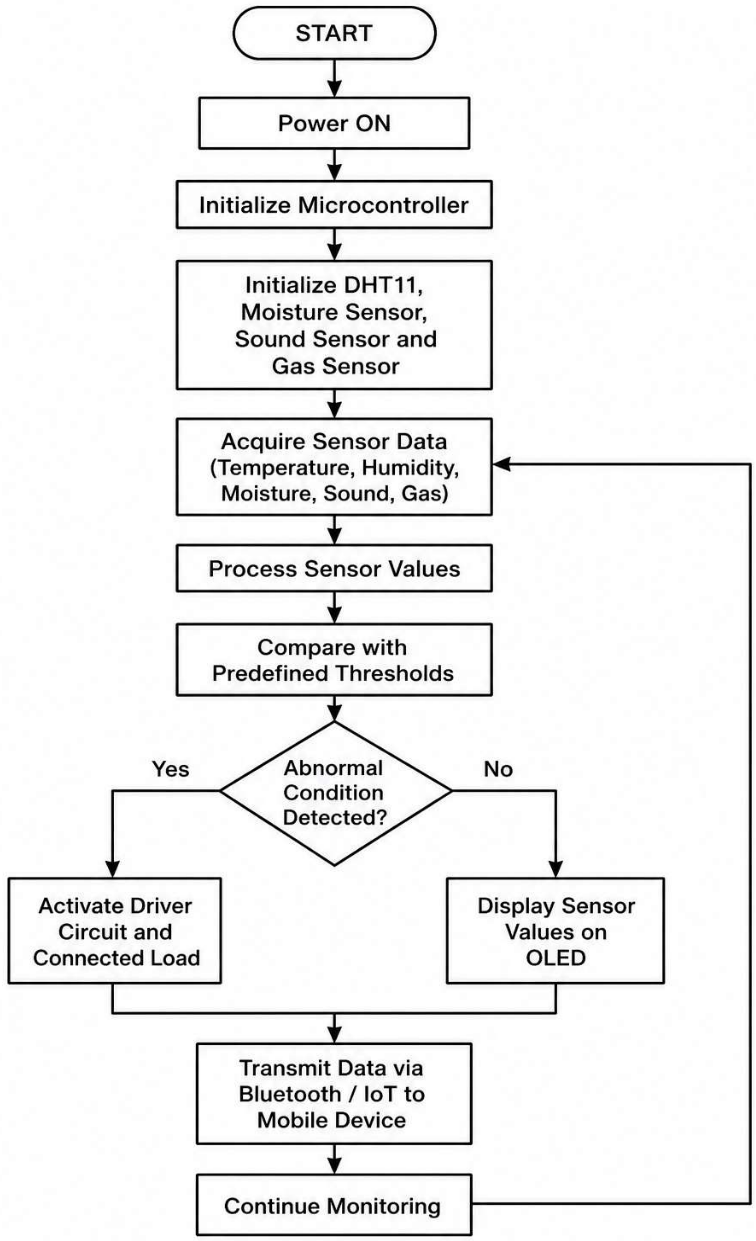

Figure 2 : Work Flow

Results And Discussion

The CalmNest: IoT-Based Smart Cradle using Controller BLE Sense was successfully developed and tested to provide smart monitoring and care for infants. The system effectively uses sensors such as the DHT11 sensor, sound sensor module, and gas sensor module to continuously track environmental conditions and the baby's activity. The cradle responded accurately by detecting crying, monitoring temperature and air quality, and providing alerts or

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automatic soothing actions when needed. The integration of BLE Sense ensured low-power and real-time communication with a mobile device. Overall, the system demonstrated reliable performance, enhanced infant safety, and reduced the need for constant manual supervision, making it an effective and practical solution for smart childcare.

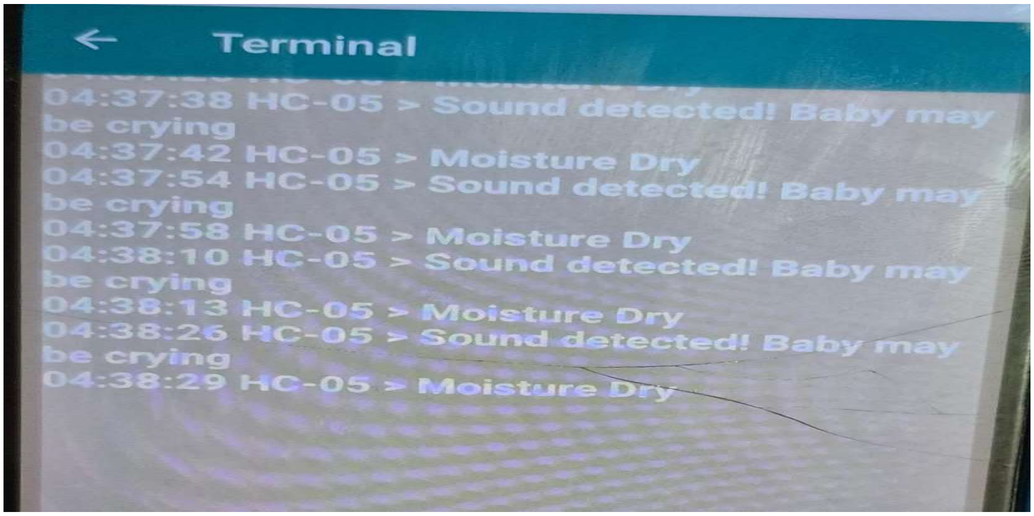

Fig .2: Hard ware kit

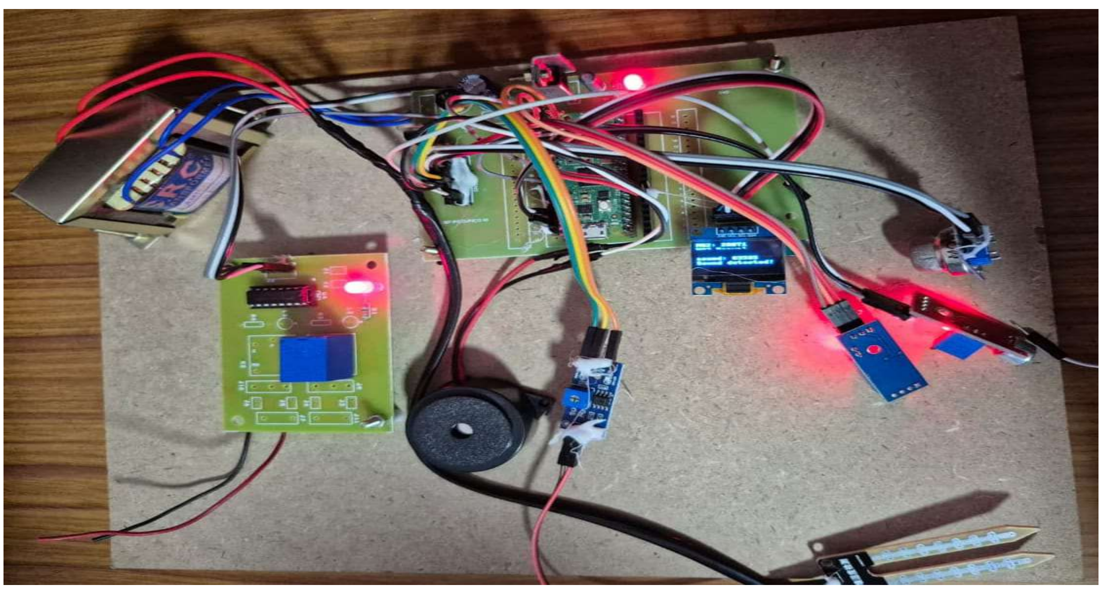

Fig 3: Outputs on mobile app

Discussion

The proposed CalmNest system demonstrates an effective IoT-based solution for real-time infant monitoring by integrating multiple environmental sensors with a BLE-enabled microcontroller. The system continuously monitors temperature, humidity, moisture, sound, and gas levels, processes the collected data, and responds automatically whenever abnormal conditions are detected. The OLED display provides instant status updates, while Bluetooth communication enables caregivers to monitor the cradle remotely. The modular design, low power consumption, and automated operation make the system reliable, user-friendly, and suitable for enhancing infant safety and reducing caregiver effort.

Conclusion

Calmnest IoT-based smart cradle system presents a modern and efficient approach to infant care by combining automation with real-time monitoring using the Raspberry Pi Pico W microcontroller. The system integrates multiple sensors such as a sound sensor to detect the baby's crying, a temperature and humidity sensor to monitor environmental conditions, a motion sensor to observe the baby's movements, and a gas sensor to ensure safe air quality. These sensors continuously collect and transmit data to the controller, which processes the information and makes intelligent decisions. Based on the analysis, the system can automatically activate the cradle swinging mechanism and play soothing sounds to calm the baby, ensuring comfort without constant human intervention.

One of the major advantages of the system is its ability to provide real-time alerts and notifications to parents through Wi-Fi connectivity. Whenever abnormal conditions such as high temperature, unusual movement, or harmful gas levels are detected, the system immediately informs caregivers via a mobile application. This feature enhances safety and allows parents to monitor their baby remotely, even when they are not physically present near the cradle. The use of the Raspberry Pi Pico W ensures efficient performance, low power consumption, and reliable communication, making the system both practical and cost-effective.

Future Scope

The proposed system can be further enhanced by integrating additional health-monitoring sensors such as heart rate, respiration, and body temperature sensors for comprehensive infant care. Cloud-based IoT platforms and mobile applications can be incorporated to enable remote monitoring from any location. Artificial Intelligence and machine learning algorithms may also be implemented to analyze infant behavior, predict discomfort, and automate cradle operation more intelligently. Future improvements may include enhanced data security, voice assistant integration, and energy-efficient power management to develop a more advanced and fully autonomous smart childcare system.

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