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Advances in Smart Cradle Design: Automation and Monitoring Systems for Infant Care

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Abstract

With the hectic schedules of working parents currently, raising a baby has become difficult. The arduous juggling between career obligations and childcare responsibilities can strain the very limits of human capacity. The choices have historically been to entrust the child's care to either senior family members or hiring a dedicated infant carer in situations like these, where time's unrelenting passage leaves little time for a full 24-hour commitment to the well-being of a priceless newborn. However, the innate anxieties of parental love persist, and doubts linger like shadows in the minds of these devoted guardians. Parents frequently request frequent, occasionally upsetting visits during valuable business breaks because they are constantly concerned about the safety and comfort of their cherished children. A smart cradle system offers a real-time resolution to this concern. It consists of a microphone and two sound sensors to identify the baby's cries. When crying is detected, the system sends a message through the GSM module to the parent on the mobile phone. A wiper motor is used to swing the cradle. with a constant speed. In this project, we will use one dataset, that is, recordings of baby cries. The toy will move in response to the lower-frequency sobbing sound, while the mother's voice and other higher-frequency music will play. The temperature sensor automatically turns on the fan and alerts the parent to the ambient temperature close to the infant. The speed of the mini fan remains constant as it is not adjustable to different speed settings. The web application also includes reminders for scheduled vaccinations and medicines in an application.

Keywords: Embedded systems, sensor technology, wireless communication, internet of things (IoT), global system for mobile communications (GSM)

INTRODUCTION

Ensuring your child's safety, comfort, and well-being is a top priority during the parenting journey. In this project, an innovative "Smart Cradle for Baby," a significant invention that aims to give parents peace of mind and the best possible care and comfort for their infants is described. The typical infant cradle is redefined by this state-of-the-art technology, which includes numerous innovative features that make parenting simpler, safer, and more pleasurable. The Smart Cradle for Baby is more than just a crib—it is a companion, a guardian, and a caregiver all in one. It prioritizes the sensitive needs of newborns while meeting the changing needs of today's parents. The "Smart Cradle for Baby" – is an innovative solution in the domain of internet of things (IoT) and wireless communication, with a focus on childcare technology [1–3]. Many parents who are working in today's fast-paced world struggle to balance caring for their infants with their professional lives. This

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delicate juggling act often results in increased stress and worry. Our project showcases a cutting-edge system designed to alleviate these concerns and provide parents with real-time support. The "Smart Cradle for Baby" is a comprehensive solution that incorporates advanced technology to enhance infant care. Through the integration of components such as microphones, global system for mobile communications (GSM) modules, noise sensors, and thermal sensors, this system ensures the well-being of infants while giving parents peace of mind.

LITERATURE REVIEW

In recent years, many healthcare and health management systems have been designed to cater to the needs of adults and the elderly, offering various monitoring capabilities, automatic alerts, and additional features. However, these systems are not suitable for infants due to the need for cautious handling. Unlike adults, infants require a distinct approach to healthcare as they rely entirely on their parents. Infants cannot provide feedback on their health conditions, expressing discomfort solely through crying. Therefore, a specially designed healthcare system is essential for infant care, aiming to alleviate the burden on parents, particularly mothers. Supporting this notion, authors have developed a system based on a commercial GSM network. The microcontroller gathers filtered data from sensors such as the DHT11 for room temperature and a sound sensor to detect infant crying. Authors suggest mounting a camera on the cradle to provide live images of the infant to parents when they are away. Additionally, a speaker communication system allows infants to hear their parents' voices to calm them, along with a moving toy in the sleeping area to comfort them. A remote subsystem with a GSM module receives and forwards data to the microcontroller for further processing [4]. In a distinct research paper, the author devised a system harnessing the commercial GSM network. This system aims to sense essential parameters such as body temperature (measured via LM35), heart rate (detected through an infrared [IR] transmitter and receiver), respiratory rate (captured through a piezo film sensor on the patient's chest), and blood pressure. After being detected, these characteristics are filtered, amplified with varying gain, and sent to a microcontroller [5]. A remote subsystem equipped with a GSM module receives the data, subsequently transferring it to a server via a USB port. The server stores and remotely displays the data on a website. Additionally, a separate SMS-based telemedicine system is described, wherein the patient's temperature is measured using an IR temperature sensor (MLX90614), and electrocardiogram (ECG) signals are acquired via electrodes interfaced with the PIC16F877 microcontroller [6]. Furthermore, motion, temperature, and heart rate sensors (both optical and pressure) are integrated into a wearable hardware device that is controlled by a microcontroller and linked to a Bluetooth module for wireless communication to track the baby's biological health. Furthermore, the paper addresses the monitoring of temperature and humidity parameters by utilizing skin temperature and air-temperature probes to monitor the baby's surroundings. The humidity level within the incubator is measured using a humidity sensor from the SYHS2XX series. These signals are interfaced with the PIC (peripheral interface controller) microcontroller 18F4550, with communication facilitated through a GSM modem [7]. The author has devised an efficient and cost-effective baby monitoring system based on IoT technology, operating in real time. A novel algorithm is pivotal in ensuring optimal baby care. The system utilizes a node microcontroller unit to collect and transmit data via Wi-Fi to the Adafruit MQTT (message queuing telemetry transport) server. The baby's vital signs, such as crying, moisture content, and ambient temperature, are tracked by a variety of sensors [1–3]. Red Meranti wood was chosen as the cradle's material, and a prototype was made using Nx Siemens software. The system architecture encompasses an automatic cradle swing mechanism activated by a motor in response to the baby's cries. Furthermore, parents can remotely monitor their baby via a webcam and activate a lullaby toy through the MQTT sensor for the baby's amusement. This demonstrates the effectiveness of the baby monitoring system in monitoring both the baby's well-being and the surrounding environmental conditions, as evidenced by the prototype [8].

COMPONENTS

ESP32-WROOM 32

It controls all sensors, actuators, and communication and is shown in Figure 1.

Temperature Sensor

To maintain ideal conditions for infant comfort. DHT11 sensor is shown in Figure 2.

Sound Sensor

LM393 sensor is shown in Figure 3. It detects the crying or noise levels.

GSM Module

Using GPRS (general packet radio service), electronic projects can link to GSM networks for voice, SMS, and occasionally data communication through a specialized device called a GSM module see in Figure 4 [9, 10].

Wiper Motor

The wiper motor is shown in Figure 5. It powers the windshield wiper mechanism and is an essential part of vehicle systems.

DC Motor

An electric motor known as a direct current (DC) motor is shown in Figure 6. It uses the interplay of magnetic fields to transform electrical energy from direct current into mechanical energy [11].

Figure 1. ESP32-WROOM.

Figure 2. DHT11 sensor.

Figure 3. LM393 sensor.

Figure 4. SIM800A GSM (global system for mobile communications) module.

Figure 5. Wiper motor.

Figure 6. Direct current (DC) motor.

DESIGN AND DEVELOPMENT

Methodology

The Smart Cradle System is equipped with advanced features to ensure the comfort and well-being of infants, primarily focusing on temperature regulation and sound recognition. The flowchart of the proposed system is shown in Figure 7. The temperature sensor DHT11, which continually tracks the outside temperature, is the first component of the system. If the temperature exceeds the threshold of 24°C, indicating a potentially uncomfortable environment for the baby, the system automatically activates a fan to provide cooling relief. If the ambient temperature drops below 24°C, the fan will turn off. Additionally, the system integrates the LM393 sound sensor, which is designed to detect the frequency of the infant's cries. This sensor operates in two distinct modes to address different crying patterns. If the cry frequency falls within the range of 500 to 600Hz, indicative of a relatively low-intensity cry, the system triggers a motor-assisted toy rotation to help soothe the infant. On the other hand, if the cry frequency registers between 900 to 1000Hz, suggesting a higher intensity cry, the system initiates the playback of preloaded songs accompanied by the comforting voice of the mother through a built-in speaker. In both scenarios, the cradle swings gently using a 12-V wiper motor, providing a calming motion to aid in the baby's relaxation. By combining temperature regulation with intelligent sound recognition capabilities, the Smart Cradle System offers a comprehensive solution to support infant comfort and promote peaceful sleep patterns. Additionally, the cradle is constructed with wood, ensuring the infant's safety as it does not conduct electricity, even with various components present. The diagram illustrates the interfacing process of DHT11, 12Fan, and ESP32 WROOM (Figure 8) and interfacing of LM393 sound sensor and ESP32 WROOM (Figure 9). The prototype design and physical structure of the cradle is shown in Figures 10 to 12.

Algorithm for Temperature Sensor:

Step 1: Start
Step 2: Record the template
Step 3: Temperature exceeds 24°C.
Step 4: Fan starts.

Algorithm for Sound Sensor:

Step 1: Start
Step 2: Sound detects the range between 500 and 600 Hz
Step 3: Toy rotates
Step 4: Sound detects the range between 900 and 1000 Hz
Step 5: Music plays

SOFTWARE DEVELOPMENT

The website application is designed in a more user-friendly manner. Graphics and pictures are used to represent the functionality/options of the smart cradle system.

The user will receive the content in this way, and they will be able to go to their needs with little difficulty. Smart cradles for babies can be easily controlled by the web application through any kind of device. Among its features are the following.

- Play music
- Swing the cradle
- Turn the fan on/off
- Checking the room temperature
- Get notifications about vaccinations

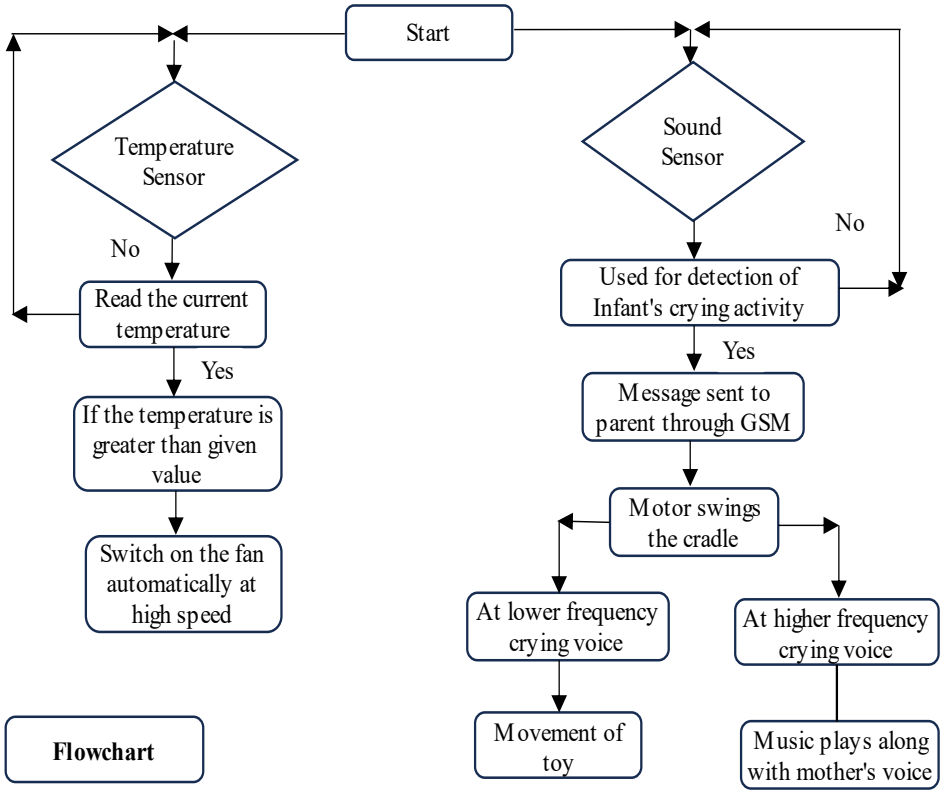

Figure 7. Flowchart of the proposed system.

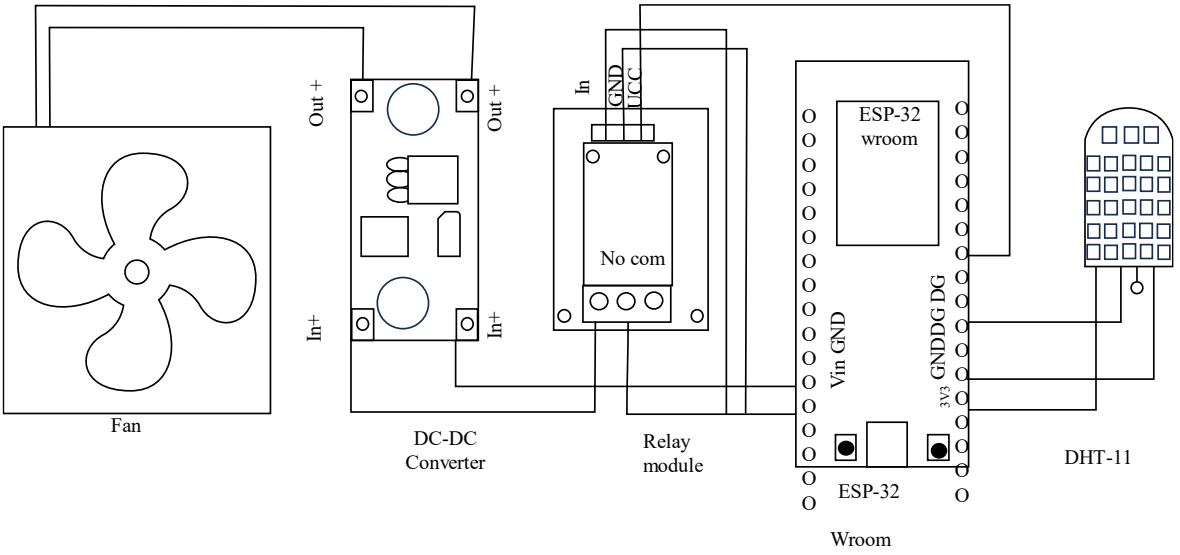

Figure 8. Interfacing of DHT11, 12Fan and ESP32 WROOM.

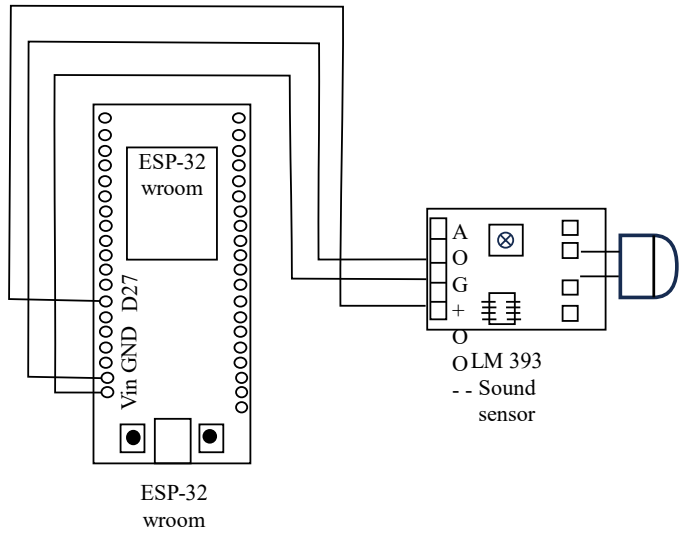

Figure 9. Interfacing of LM393 sound sensor and ESP32 WROOM.

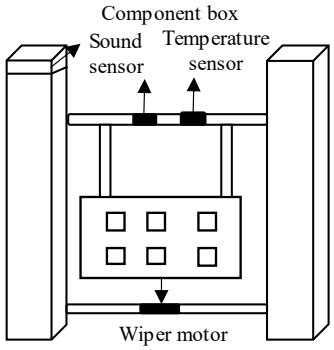

Figure 10. Prototype design of cradle.

To start with the application first and use the features available in the application, you need to have an account, if the user already has an account, the user can login. Otherwise, create a new account. Once the login and sign-up process is done, a dashboard web page opens. The dashboard contains several buttons/options through which we can control the cradle. Following are the main features:

1. *Swing of the Cradle:* When the button gets on, the cradle starts to swing in a specific pattern which is mentioned in the hardware part of the project.
2. *Temperature and Fan:* When the temperature exceeds more than 24°C it indicates that the temperature is hot for the baby and the fan should be turned on, which one can do with the help of the application.
3. *Playing Music:* When the frequency of the crying baby is detected by the sound sensor and comes to a level of 900 to 1000 Hz the music which is stored in the application can be played there will be different music's stored which also can include the mother's voice. Music may be a wonderful way to bond with a newborn or a great method to stop them from crying. So, one can make use of this application to play some music to soothe your baby.
4. *Rotating of a Toy:* When the frequency of the crying baby is detected by the sound sensor and comes to a level of 500 to 600 Hz, the toy starts to rotate in a particular direction and speed.
5. *Notifications about Vaccinations:* The user must set the date and time of the vaccination and on that day of vaccination a reminder will be generated on the application and there is no irresponsiveness regarding vaccinations.

The web application is done using two main parts: frontend and backend development. The frontend development is done through HTML, CSS, and JavaScript and the backend development is done using

Node.js. The data is stored in the SQL query language. This completes the features of the smart cradle for baby and how the process is to be done through a web application.

Figure 13 shows the prototype image of the login page of the smart cradle for baby which includes username and password. Figure 14 shows the prototype image of the dashboard page of the smart cradle for baby which includes the various features that can be controlled through the website.

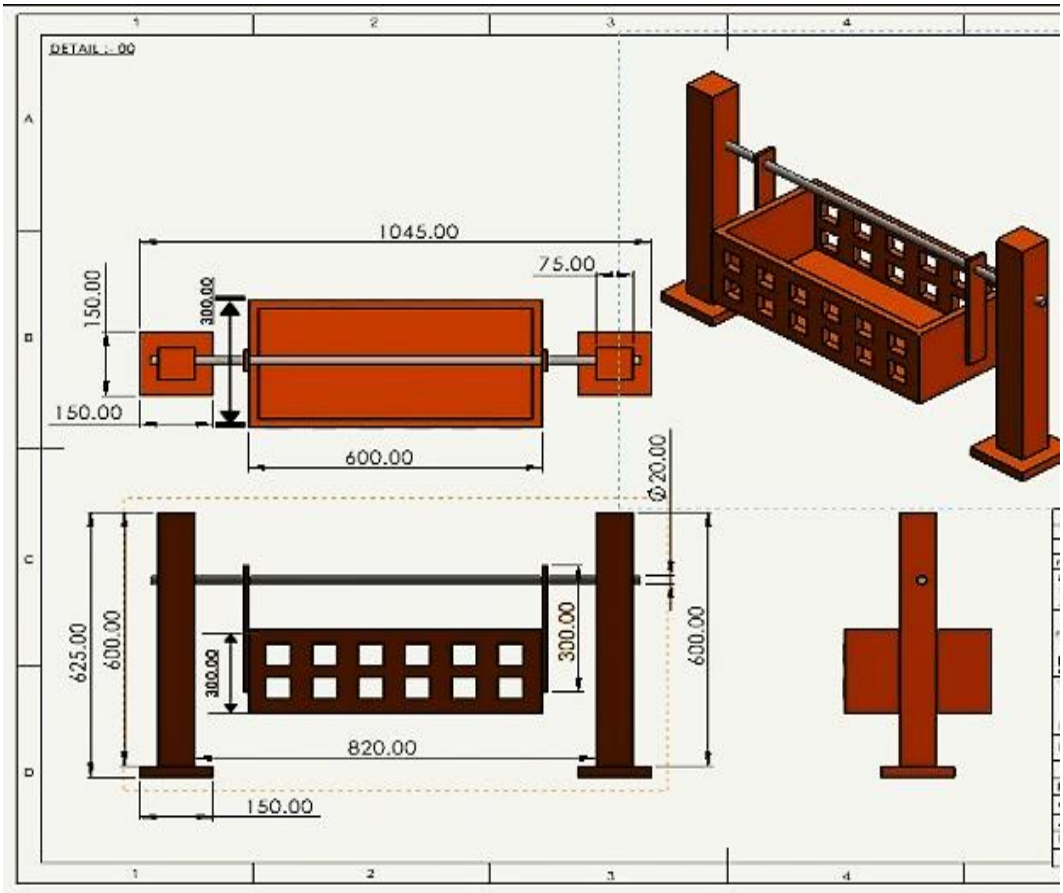

Figure 11. Prototype designing using solid works software.

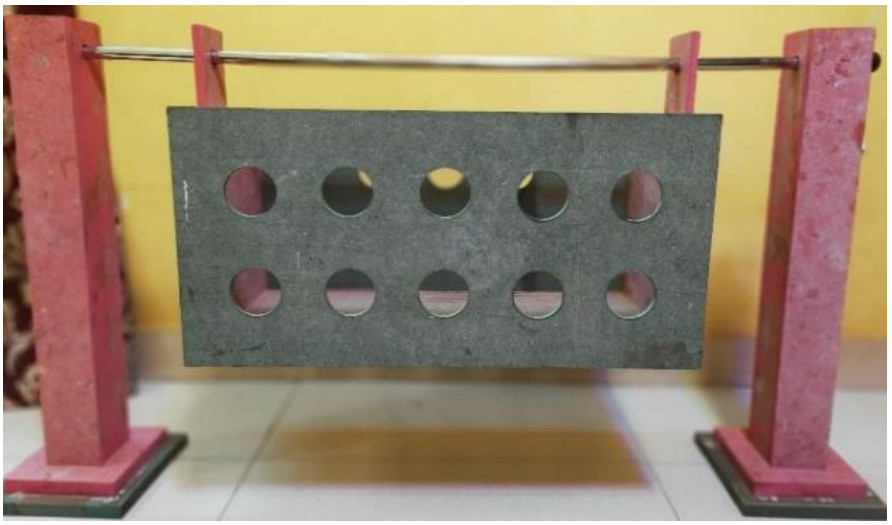

Figure 12. Physical structure of the cradle made from medium-density fiberboard (MDF) wood as wood is not a conducting material.

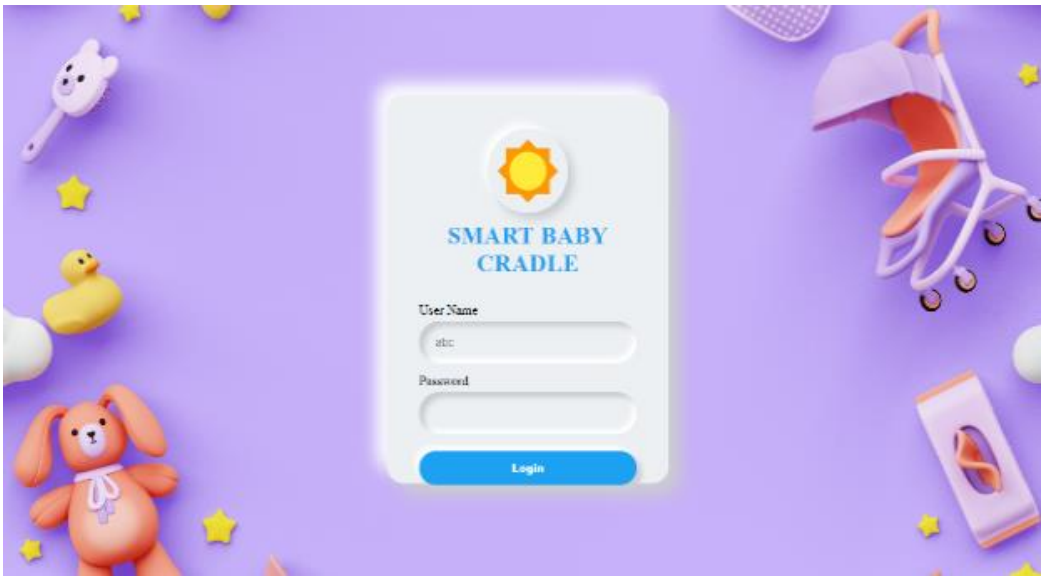

Figure 13. Prototype of the login page of the website.

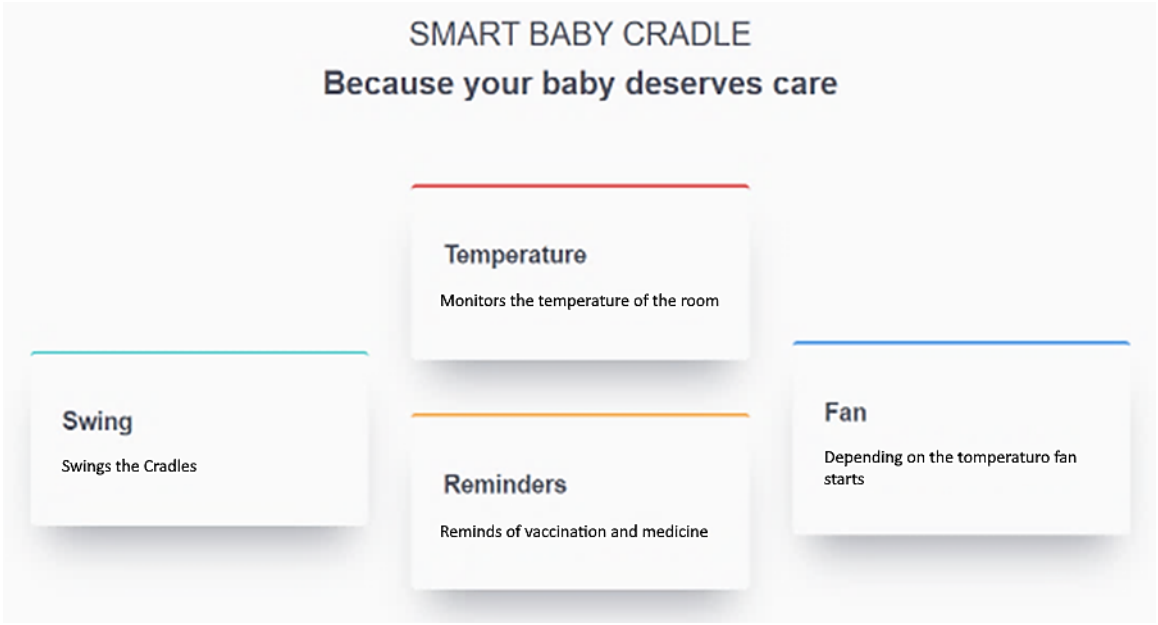

Figure 14. Prototype of the dashboard of the website.

REDUNDANCY STRATEGIES FOR SENSOR FAILURE MITIGATION

Manual Override

Provide manual controls so that in the event of a sensor failure, parents or other caregivers can manually operate the cradle. To operate the cradle's additional functions, like its rocking motion, this could utilize simple switches or buttons.

Redundant Sensor Systems

Use many sensors to detect the same parameter while implementing redundant sensor systems. Even if one sensor fails, the system can still function thanks to the data from the redundant sensor.

Fail-Safe System

When a sensor failure is detected, design a fail-safe system that causes the cradle to automatically convert to a safe mode. This can entail putting an end to the rocking action and making sure the infant is in a steady and safe posture while the problem is being fixed.

Regular Maintenance and Monitoring

To identify problems early and avoid sensor failure, put in place a system for routine maintenance and monitoring of the sensors. This can entail calibrating the sensors and conducting planned inspections to guarantee their dependability.

Redundant Communication Routes

Make sure the smart cradle has redundant communication routes if it interacts with servers or smartphones, for example. To guarantee continuing communication even in the event of a channel failure, this may entail the use of backup servers or several communication protocols.

Adaptive Control System

Create an adaptive control system that makes use of machine learning algorithms to continually modify the cradle's behavior and settings in response to past data and user preferences. This will reduce the impact of sensor failure by anticipating and making up for possible problems beforehand.

ADVANTAGES

Security of Infant

Smart cradles are designed to enhance infant safety and well-being. They can include features such as harness systems, temperature monitoring, and built-in sensors to detect and prevent potential risks.

Parental Peace of Mind

Smart cradles offer real-time monitoring, reducing parental anxiety and providing peace of mind. Even if parents are unable to be present in the same room, they can still keep an eye on their infant's safety and well-being.

Convenience for Parents

These systems provide parents with the convenience of remote monitoring and control via smartphone apps or other devices. This enables parents to change settings, get notifications, and monitor their baby's condition from any location.

Health and Safety Alerts

Smart cradles can be equipped to detect and send alerts for health and safety concerns, such as changes in an infant's breathing, room temperature fluctuations, or unusual movements.

Integration with Home Automation and IoT Systems

The scope may include integration with more extensive smart homes and IoT systems. This enables smooth communication with various gadgets, such security cameras, lights, and smart thermostats.

LIMITATIONS

Reliance on Technology

Smart cradle systems heavily depend on technology, making them susceptible to malfunctions or disruptions due to power outages, software glitches, or hardware failures.

Cost

The implementation of smart cradle systems may incur significant costs for both initial setup and ongoing maintenance, potentially limiting accessibility to certain socioeconomic groups.

Compatibility Issues

Integrating different components of the smart cradle system, such as sensors, actuators, and communication protocols, may face compatibility challenges, particularly when dealing with diverse hardware and software platforms.

False Alarms and Inaccurate Readings

Smart cradle systems may generate false alarms or provide inaccurate readings due to environmental factors, sensor inaccuracies, or signal interference, leading to unnecessary stress for caregivers or unreliable monitoring outcomes.

User Interface Complexity

Complex user interfaces or unintuitive control mechanisms may pose usability challenges for caregivers, especially those with limited technical proficiency or cognitive impairments.

CONCLUSION

In conclusion, the smart baby cradle offers parents valuable peace of mind by combining cutting-edge technology with thoughtful design. With a built-in temperature sensor, it ensures the optimal room temperature for the baby's comfort, adapting as needed. The sound sensor, attuned to the baby's cries, allows swift responses to their needs. Moreover, the inclusion of scheduled vaccination reminders through the accompanying app ensures parents never miss important healthcare milestones. This all-encompassing method of baby care not only improves the child's well-being but also reduces new parents' anxiety. The Smart Cradle for Baby represents a promising innovation in infant care, aiming to combine safety, comfort, and technology. This concept has the capability to enhance parental peace of mind through advanced systems, while also contributing to safe sleep practices. Its allure is increased using technological advances in smart homes and an emphasis on energy saving. However, to fully realize its potential, collaboration with healthcare professionals, adherence to regulations, and a keen understanding of user preferences will be crucial. As the smart baby care product market expands, the smart cradle is positioned to play a crucial role in reshaping how parents attend to the needs of their infants.

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