Tianjin Daxue Xuebao (Ziran Kexue yu Gongcheng Jishu Ban)/
Journal of Tianjin University Science and Technology
ISSN (Online):0493-2137
E-Publication: Online Open Access
Vol: 56 Issue: 12:2023
DOI: 10.5281/zenodo.10390889

A COMPREHENSIVE IOT-BASED CRADLE MONITORING SYSTEM FOR REAL-TIME DATA ANALYSIS AND DAILY SUMMARIES

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Abstract

In today's socio-economic landscape, many parents are engaged in full-time employment, which limits their ability to provide continuous care to their infants. This necessitates the exploration of advanced Baby Monitoring Systems (BMS) as a valuable solution to alleviate parental concerns about infant safety and well-being, ultimately enhancing the quality of care during parental absence. This research introduces an advanced BMS that enables real-time data monitoring, daily infant condition summaries, and remote video access via a web server. The BMS incorporates a variety of sensors (PIR, DHT11, LM393, Moisture sensor) and actuator (servomotor, DC motor), in addition to a high-definition camera (W100 HP). The system is integrated with Thing Speak and IFTTT, enhancing data visualization and simplifying the process of sending daily summaries via email with a single click on our website. Furthermore, the BMS ensures precise monitoring of temperature and humidity, detects sound events, senses motion, and triggers automatic alerts, demonstrating the potential of IoT in both infant care and healthcare applications.

Index Terms: BMS, ESP8266, Web Server, Thing Speak, IFTTT, IoT, DHT11, PIR, LM393, Servo Motor, DC Motor, Moisture Sensor, Infant Care.

1. INTRODUCTION

In the contemporary technological landscape, the imperative development of a sophisticated Baby Monitoring System (BMS) is evident, serving as both a necessity and a substantial stride towards ensuring the well-being of infants. This investigation delves into a groundbreaking (BMS), primarily anchored by the Node MCU ESP8266, which seamlessly integrates an array of sensors including PIR, DHT11, sound, and moisture sensors, in tandem with actuating components like servo and DC motors. The meticulous design of this BMS is geared towards meeting the increasing demand for enhanced and comprehensive infant care. Historically, infant care relied on manual monitoring and intermittent checks. Recent times have witnessed the emergence of standalone monitoring devices, such as baby monitors with audio or video capabilities. However, these solutions frequently fall short in providing a holistic and real-time understanding of an infant's environment and needs, as they lack seamless integration with automation and cloud-based services, constraining their scope for improvement and advanced caregiving.

The need for a unified system that encompasses infant safety, comfort, and health on a single platform is undeniable. Our BMS distinguishes itself in this context, offering a multifaceted approach to infant monitoring and care. The DHT11 sensor, with precise regulation of temperature and humidity, fosters an environment conducive to infant well-being. A DC motor controlling the fans speed according to the temperature and discomfort level .The sound sensor acts as an alert mechanism, promptly notifying caregivers of the baby's needs or distress. Simultaneously, the PIR sensor enhances security by detecting any unusual movements in the infant's surroundings. Moisture sensor to check for wet bed or diapers. A central aspect of the system revolves around its ability to capture real-time data from these sensors, which is subsequently presented on a web server hosted on the Node MCU. This secure website that we created to monitor the baby comes with a login feature, which allows only the registered user to view the baby's activities and its video lively on the website. This feature empowers caregivers to remotely monitor the infant's condition and receive real-time alerts. The system also generates daily summaries of the baby's activities, sleep patterns, and environmental conditions, simplifying caregiving and fostering a nurturing atmosphere. To elevate convenience and communication, the system seamlessly integrates with IFTTT, automating the process of sending email notifications with daily summaries. Thing Speak provides dynamic graphical representations of sensor data, offering parents and caregivers a comprehensive view of their infant's well-being. This research aims to illuminate the innovative design, implementation, and operational capabilities of the BMS. It endeavors to emphasize the pivotal role of IoT technology in infant care and aspires to transform the industry by giving a comprehensive, reliable, and user-friendly solution that caters to the evolving needs of caregivers and infants alike.

2. LITERATURE REVIEW

The authors in paper [1] came up with a BMS using Arduino Uno and monitoring using several sensors. A website has been created to remotely monitor the temperature in the surrounding of the baby and intimate if the baby is awake. This paper [2] introduces a GSM-based baby monitoring and automatic swing system that utilizes sensors to monitor a baby's condition and provides real-time SMS notifications to parents. The system also includes safety features like automatic swinging and safety cushions for enhanced baby care. [3] The system follows a 4-layer IoT architecture model, collecting data from various sensors and a camera module. When data exceeds predefined thresholds, it sends warnings via Raspberry Pi through the internet network and forwards the alerts to the user's email. The IoTBBMS is introduced [4] as an efficient and cost-effective system for real-time child monitoring, utilizing sensors, webcam, and automation. It also analyses data for health insights, providing a comprehensive childcare solution accessible remotely. [5] The smart cradle control system combines Node MCU and Raspberry Pi with various sensors and components to monitor and control the baby's status, optimizing computational tasks for efficiency. The project methodology [6] involves stages such as project planning, analysis, information gathering, requirement analysis, design and development, testing, and maintenance, with a focus on addressing common issues,

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gathering data, and ensuring successful project completion. Maintenance is crucial to handle potential problems and updates in the customer environment. This [7] highlights the growing challenges for working mothers in childcare and introduces a cost-effective IoT-based baby monitoring system, featuring automated cradle swinging and health monitoring through the Blynk app, implemented with Arduino IDE and Node MCU microcontroller. The [8] paper addresses the challenges faced by working mothers in childcare by proposing an affordable IoT-BBMS with real-time temperature, humidity, cry detection, and video surveillance. The system includes an automated cradle with cry detection and remote monitoring via an external webcam and lullaby functionality, demonstrating its cost-effectiveness and reliability for parents to access child data over the network. [9] Smart BMS to monitor the infants, utilizing IoT technologies like Raspberry pi, DHT11 sensor, detect if the baby is crying and video surveillance, enabling continuous monitoring through web browsers, automated cradle swinging, fan control, camera activation, and music playback when the baby cries. [10] The Internet of Things (IoT) has significantly reduced healthcare costs and improved treatment outcomes by enabling remote patient monitoring. While there are challenges such as funding and resistance to technology adoption, IoT has simplified doctor-patient interactions, increased patient satisfaction, and shortened hospital stays through effective remote monitoring. [11] Creating a testing model for healthcare IoT uses is challenging due to the continuous evolution of these applications with new devices and services. This paper introduces the HITA software architecture, addressing quality requirements and sharing experiences. [12] The editorial underscores the importance of accessible and affordable healthcare as a human right for all individuals, emphasizing the need for healthcare reform. It also discusses how the Internet of Things (IoT) is revolutionizing healthcare by enabling remote patient monitoring and predictive analytics, improving patient care and safety while extending healthcare monitoring to objects beyond humans, such as bridges and vehicles. IoT and sensor technologies enhance early detection, prevention, and overall safety.[13] this study explores privacy-enhancing techniques (PETs) and proposes a innovative architecture using block chain (BC) for improving the security and anonymity of IoT applications, demonstrating its effectiveness and resistance to security attacks through empirical investigation. Proposing a logical security framework to protect IoT-WSN networks. [14] Uses Raspberry pi to create a baby monitoring system, it monitors the baby on a website hosted using Rpi and data visualization using Thing Speak. It also show the live video of the baby in the website but it lacks proper UI and security. This paper [15] uses Arduino Uno along with few sensor to monitor the baby and uses a Bluetooth module for data transmission and reception. With a relay module, they were able to control the fan speed according to the temperature changes.

The following [16-19] literature review was done to explore what are all new things implemented in the CMC journal, in the IoT field and to get a good knowledge about performing IoT related research using new technologies. The review investigates mobile cellular network usage for IoT devices in smart cities carried in [16], focusing on security, particularly authentication. It introduces a novel authentication scheme, subjecting it to thorough security evaluations using the Real-or-Random model, and performance comparisons with existing cryptographic research. Keywords: IoT devices, e-healthcare, authentication, edge computing. This study [17] proposes two data compression methods, CSL and Ra-CSL, to enhance IoT security. CSL efficiently detects attacks by compressing event logs and applying machine learning. Ra-CSL improves detection rates through a two-step training process. Experiments demonstrate reduced memory usage, faster processing, and improved attack detection accuracy. [18] Discusses mobile cellular networks connecting IoT devices in smart cities, focusing on security challenges, specifically authentication. It introduces a secure authentication scheme, conducts security evaluations, and explores performance enhancement through data compression techniques. Keywords: IoT security, data compression, authentication, performance evaluation. This project employs [19] IoT technology to monitor catfish aquaculture in real-time and remotely, integrating IoT devices with Firebase's cloud data system. The results show low error rates (4.49% average) and cost-effectiveness (94.21% compared to labor costs), offering a precise, cost-effective, and user-friendly solution for fish cultivators. [20] This project addresses the increasing demand for energy production and distribution by introducing a user-friendly, real-time energy consumption monitoring system using Node MCU, current and voltage sensors. It aims to provide consumers and organizations with real-time energy usage data, notifications, and peak-hour alerts, reducing the need for periodic manual meter readings and improving data management. [21] Enables remote access and control using ESP8266 Node MCU. This project demonstrates real-time sharing of air quality, temperature, and humidity data between three remote food stores via ESP modules through a web server, facilitating automatic control of cooling and contamination removal while offering manual control options, all at a lower cost compared to GSM modules. [22] China's gaming industry has experienced significant growth, but there is still a gap compared to Europe, America, and Japan. This project aims to create a portable STM32-based Sokoban game, offering entertainment and education anytime and anywhere, using the STM32L476RG board and Keil software development system, with remote sensing control, music, and sound effects. [23] This study employs the STM32 microcontroller to drive a PM Micro LED display, benefiting from its simplicity, cost-effectiveness, and flexible programming. The design optimizes circuit structure and data transmission with a two-wire serial protocol and row-column integration, requiring only four connecting wires for any resolution display while addressing graphics distortion and metal fractures with GaN as a raised substrate. This paper [24] addresses the challenges in precise obstacle avoidance and sensitivity in sweeping robots, presenting a design based on the STM32 microcontroller. It combines infrared and ultrasonic ranging for accurate data acquisition and utilizes the PID algorithm to enhance system response, ensuring the robot's execution accuracy, and offering insights for the sweeping robot industry's development. [25] This paper introduces a charger field test device that uses STM32 as a data exchange interface between a host computer and chargers in charging stations for electric vehicles. It optimizes message decoding, reduces reliance on high-cost components, and enhances message collection and system intelligence, resulting in fast, reliable communication with a user-friendly interface.

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3. HARDWARE COMPONENTS USED

3.1 ESP8266 Node MCU

The ESP8266 Node MCU, an integral microcontroller board, plays a central role in the architecture of a baby monitoring system. Notably, it offers a diverse array of GPIO (General Purpose Input/Output) pins to interface with sensors and devices. Employing its inherent Wi-Fi capabilities, the Node MCU actively supports real-time data exchange, ensuring persistent connectivity between the baby monitoring system and the monitoring station or mobile device. Its programmable nature and extensive compatibility with diverse communication protocols empower the system to adeptly accumulate and transmit critical data, establishing it as a vital component in the baby monitoring system's operation.

3.2 DHT11 Sensor

The DHT11 sensor, an essential component in the Baby Monitoring System, serves the crucial role of monitoring ambient temperature and humidity levels. The sensor's working principle is based on changes in electrical resistance in the thermistor, which vary with temperature, and the capacitive humidity sensor that alters its capacitance in response to moisture levels. The Node MCU ESP8266 microcontroller processes data from the DHT11 sensor, facilitating real-time monitoring and alerting caregivers to deviations from preset comfort thresholds, thereby safeguarding the infant's well-being.

3.3 PIR Sensor

A passive infrared (PIR) sensor is a motion detection device predicated on the recognition of alterations in infrared radiation levels within its designated field of view. This, functions by discerning alterations in the infrared radiation emitted by the monitored infant. Its sensor employs a pair of pyroelectric detectors to measure temperature irregularities within the surveillance area, honing in on the baby's immediate surroundings. Variations in thermal emissions, driven by the baby's motions or body warmth, provoke temperature disparities across the dual detectors, generating distinctive voltage differentials. Subsequent signal amplification and processing of these voltage variations facilitate motion detection and alert generation within the baby monitoring system, heightening its capacity to perceive and respond to the infant's activities

3.4 Sound Sensor LM393

Sound sensor LM393 adeptly detects and analyses variations in sound pressure levels, subsequently converting them into electrical signals for seamless integration with microcontrollers. The sound sensor within the Baby Monitoring System assumes the pivotal role of audio data acquisition, contributing to infant safety and comfort. Operating on the principle of acoustic transduction, this sensor detects noise levels in the baby's vicinity. It translates variations in sound pressure into electrical signals, which are then processed by the ESP8266 microcontroller. When sound levels breach predefined thresholds, the system triggers appropriate alerts or actions; ensuring caregivers are promptly informed of any disruptions.

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3.5 Servo Motor

Its core components encompass a motor, a feedback system, devices such as potentiometers or encoders, and a controller. It has the ability to sustain a designated position or velocity. The servomotor assumes a pivotal role, contributing significantly to fostering a serene and comforting atmosphere for the infant. Employing a feedback control mechanism, this motor orchestrates the precise and regulated oscillations of the cradle. These oscillations are calibrated to create gentle, rhythmic movements of the cradle, enhancing the infant's comfort and promoting restful sleep. By emulating the soothing rocking motion, the servomotor establishes a tranquil environment, ultimately facilitating the infant's relaxation and overall well-being.

3.6 Camera W100 HP

“HP Camera W100” is a digital camera manufactured by HP (Hewlett-Packard). It is 480p 30fps camera with manual adjustable focus. This camera operates on the principles of image sensing and data transmission. It captures live video feeds and streams them to a designated interface, allowing caregivers to remotely monitor the baby's environment. Managed by the ESP8266 microcontroller, the camera facilitates seamless integration with the system, ensuring that caregivers maintain a constant visual connection to the infant's space. The HP WH-100P camera greatly enhances monitoring precision and accessibility, offering caregivers a valuable tool to ensure the infant's safety and well-being.

3.7 DC Motor

A Direct Current (DC) motor, succinctly named for its operation on direct current power, constitutes an electro-mechanical apparatus engineered to transmute electrical energy derived from a direct current source into mechanical rotation. It functions predicated on the principles underpinning Ampère's law, orchestrating the interplay of magnetic fields and conductors to incite rotational motion. Here DC motor have been used as a fan’s motor, adjusting its speed according to the temperature and humidity, controlled by ESP8266 using the feedback from DHT11 sensor’s readings.

3.8 Moisture Sensor

Moisture sensors represent electronic apparatus designed for continuous monitoring of moisture content or water levels within substrates such as soil, air, or analogous mediums. The moisture sensor, an integral element in the Baby Monitoring System, assumes a vital role in detecting wetness and maintaining the infant's comfort and hygiene. Operating on a resistive principle, this sensor measures changes in electrical conductivity within its sensing medium, typically in response to moisture or liquid. It continuously monitors the baby's surroundings for any signs of wetness, such as diaper leaks or spills. When the sensor detects elevated moisture levels, it signals the ESP8266 microcontroller. The system can then take appropriate actions, such as notifying caregivers or triggering an alert to ensure the infant's dryness and comfort.

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4. SOFTWARE USED

4.1 Website Development

The ESP8266 is a Wi-Fi module equipped with Node MCU firmware, functioning as a microcontroller and an internet connectivity device. We employ ESP8266 as a web server operating in its station mode. The developed code is designed to scan for the incoming requests from various sensors connected to the ESP8266, including the DHT11, sound, PIR, servo, DC motor, and moisture sensor. It then receives and processes input, and subsequently, the server parses the request and sends a response. This code is developed using C, HTML, CSS, and JavaScript. To access and open the webpage, the ESP8266's IP address is used. The webpage consists of two columns, one showing the sensor data and buttons to open the graphical view and one button to generate summary. The other column shows the video of the baby's cradle. This website also comes with button, which can send daily summaries for baby's activity, and a button with redirects to Thing Speak website to view the log in graphical manner.

4.2 Thing Speak

"Thing Speak" is an Internet of Things (IoT) software cum platform and open-source application for data collection, analysis, and visualization. It provides a cloud-based infrastructure that allows users to gather data from IoT devices and sensors, store that data in channels, and perform real-time analytics and visualizations. Thing Speak is commonly used for monitoring and managing IoT projects, enabling users to remotely track and analyze data from various sensors and devices, making it a valuable tool for applications like environmental monitoring, home automation, and industrial IoT solutions. Here we use it to view the temperature, humidity and sound level of the baby's surrounding graphically.

4.3 IFTTT

IFTTT, (If This Then That), a versatile web-based automation platform which enables users to developed automated workflows, also known as applets, by connecting various online services and devices. It follows a conditional logic format, where specific actions are triggered when certain conditions are met. Users can integrate and automate tasks between a wide range of applications, smart devices, and online services, making it a valuable tool for simplifying repetitive tasks, enhancing productivity, and streamlining digital interactions. IFTTT applets consist of two components: "this" represents the trigger, which could be an event, change in data, or user action, while "that" represents the resulting action or task to be executed. For instance, an IFTTT applet could automatically save email attachments to a cloud storage service when a new email arrives (triggered by "this") or adjust the thermostat when the weather forecast indicates a temperature change (triggered by "this"). IFTTT's flexibility and wide ecosystem of supported services make it a popular choice for individuals and businesses seeking to enhance their digital workflows and connectivity. Here we are using it to send summaries to the registered email using two applets "web hooks" and "Email". Web hooks receives the web request from ESP8266's website and Email applet sends e-mail to the user.

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5. ADVANTAGES OF USING NODE MCU ESP8266

Utilizing the Node MCU ESP8266 for our baby monitoring system project presents several key advantages. Its built-in Wi-Fi connectivity enables real-time data monitoring and remote access. The integrated microcontroller and Wi-Fi module on a single board reduce complexity and cost. Other microcontrollers like Raspberry Pi are very expensive compared to ESP8266. The Arduino compatibility and extensive open-source community support streamline development. Automation through IFTTT and graphical data visualization via Thing Speak enhance user experience and system effectiveness. The Node MCU's scalability ensures adaptability for future enhancements, making it an ideal choice for our comprehensive baby monitoring solution.

6. METHODOLOGY

The proposed baby monitoring system works based on the following methodology (refer Fig.1). Using the Service set identifier (ssid) and password of the Wi-Fi network esp8266 connects to it generated its Ip address used to host, and open the website. The DHT11 Sensor finds the humidity and temperature in the surroundings of the baby, fan speed will be increased (Dc motor speed) when the temperature gets high, the speed will be decreased when the temperature gets low. The PIR sensor detects the motion if the baby is moving and to check if the baby is crying, sound is used. If the baby is moving or crying that means it is discomfort. According to the level of discomfort, the cradle will be swinged with the help of servomotor. If baby is moving the servo motor swings the cradle five time and if it is crying, cradle will be swinged ten times. Depending on the feedback from the baby, this process will be repeated or terminated

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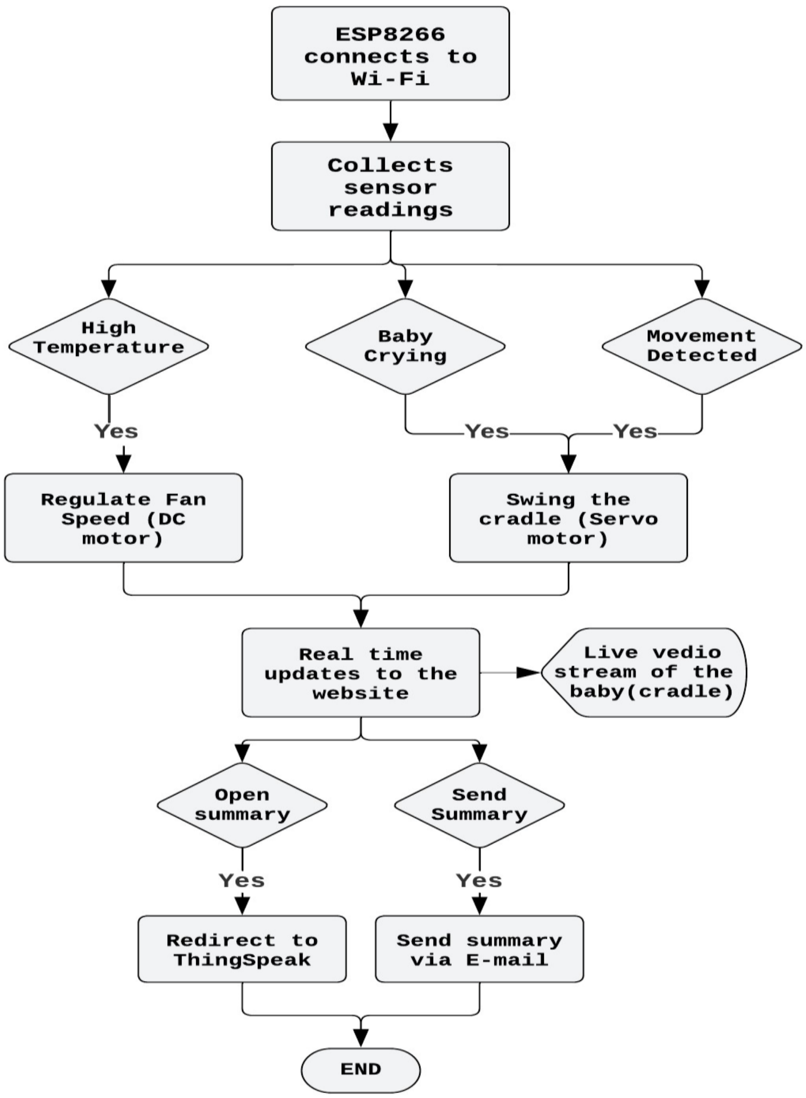

Figure 1: Flow Chart of the System

All the sensor values and activities will be updated on the website that we created in real-time. One can register themselves and login to the website to view the baby's activities (Sensor reading) and able to view the sensor reading in graphical manner by clicking the "Open summary" button which redirects to the Thing Speak website. Using "Send summary" button, daily summaries can be triggered. IFTTT is used here to send the summary via e-mail as mentioned earlier. Live video of the baby's cradle will be streamed on the website to monitor the baby remotely. The website created comes with a user-friendly design along with hoovering animation, translational effect and glassy gradient attractive look, making it less boring to use and spend time.

7. WORKING

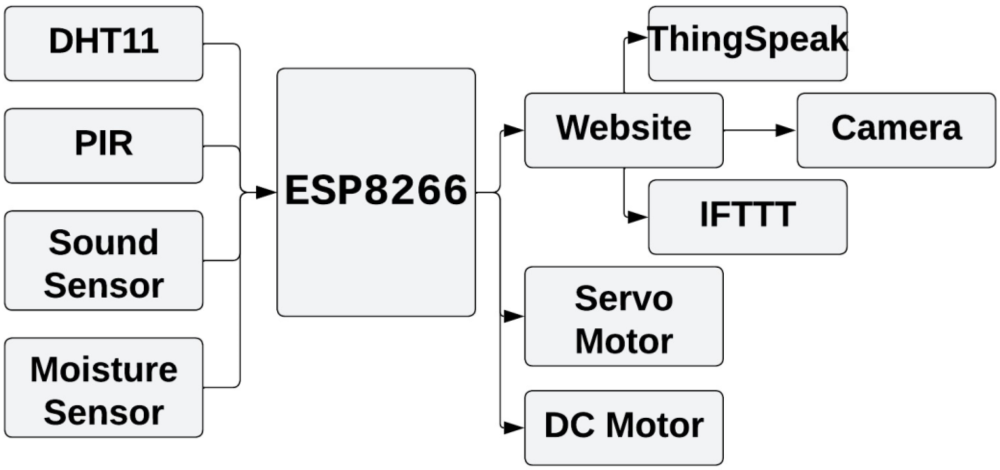

Figure 2: Sensors and Actuators Connection of the Model

As shown in Fig.2. DHT11, PIR Sound sensor (LM393), and moisture sensor will be connected to the ESP8266. They send the collected data to ESP8266. According to the sensors reading, actions will be taken. The DC motor will be attached to the fan and depending on the temperature; the DC motor speed is adjusted. The fan is kept near the cradle. The servomotor is responsible for swinging the cradle when the baby is not comfortable. It will be attached to the side part of the cradle. A camera is kept near the cradle to stream the love video on the website for remote monitoring. Here we are using a wired camera, but it can also be wireless depending on the tech that being used. Data collected from the sensors is processed in real-time on the ESP8266, and the updates are continuously pushed to the web

Server, providing caregivers with a live stream of information. To enhance the system's convenience, IFTTT is integrated, automating the process of sending daily summaries via email to caregivers. Furthermore, Thing Speak, a cloud-based platform, is adept at presenting graphical representations of sensor data in real time, offering a dynamic and user-friendly perspective of the baby's environment. This web server serves as the interface through which caregivers can access real-time data, video feeds, and daily summaries of the baby's activities and environmental conditions

8. RESULTS AND DISCUSSIONS

The fig.3. Shows the proposed hardware model of the BMS, using breadboard connections were made. The circuit and the sensors were placed on a cardboard box prototype. This model serves as a prototype miniature model of the actual BMS in real life.

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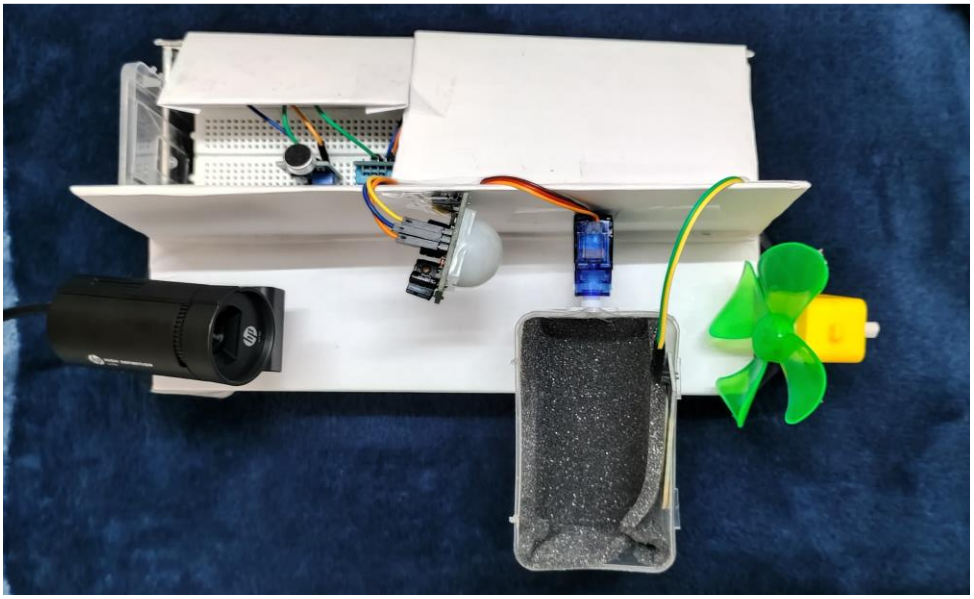

Figure 3: Working Model of the Proposed BMS (miniature)

The Fig.4. Shows the cradle connected with servomotor and a PIR sensor kept near cradle to check if the baby is moving and the cradle will be swinged according to the baby's discomfort level. To comfort the baby, a DC fan is kept near the cradle. The moisture sensor is kept in the cradle to detect the wetness.

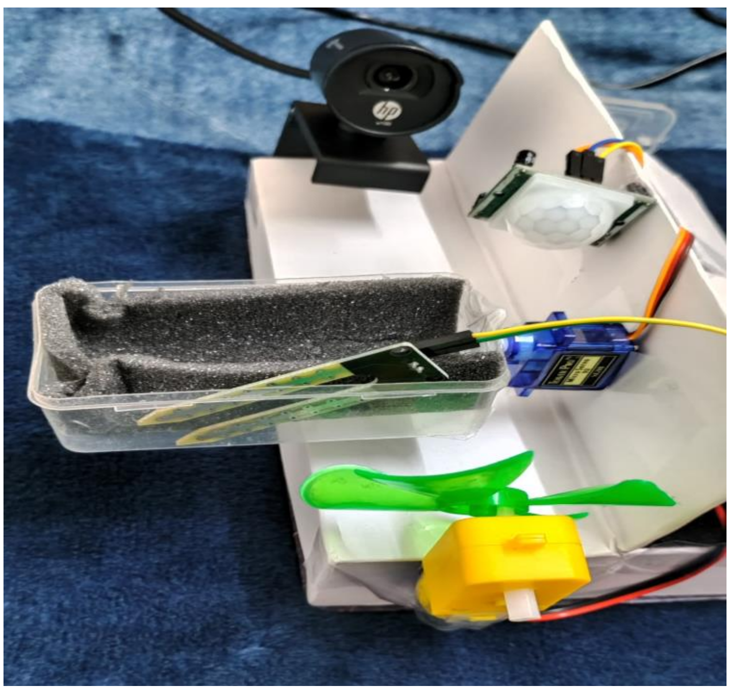

Figure 4: The Cradle along with the Sensors

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The website created is fully secure and authorized website. Only after logging in using, the registered username and password one can login to access the information, send summary and watch the live video of the baby remotely. This enhances the privacy of the parents while using the website. The login page and the developed website is shown in Fig.5. And Fig.6. Respectively.

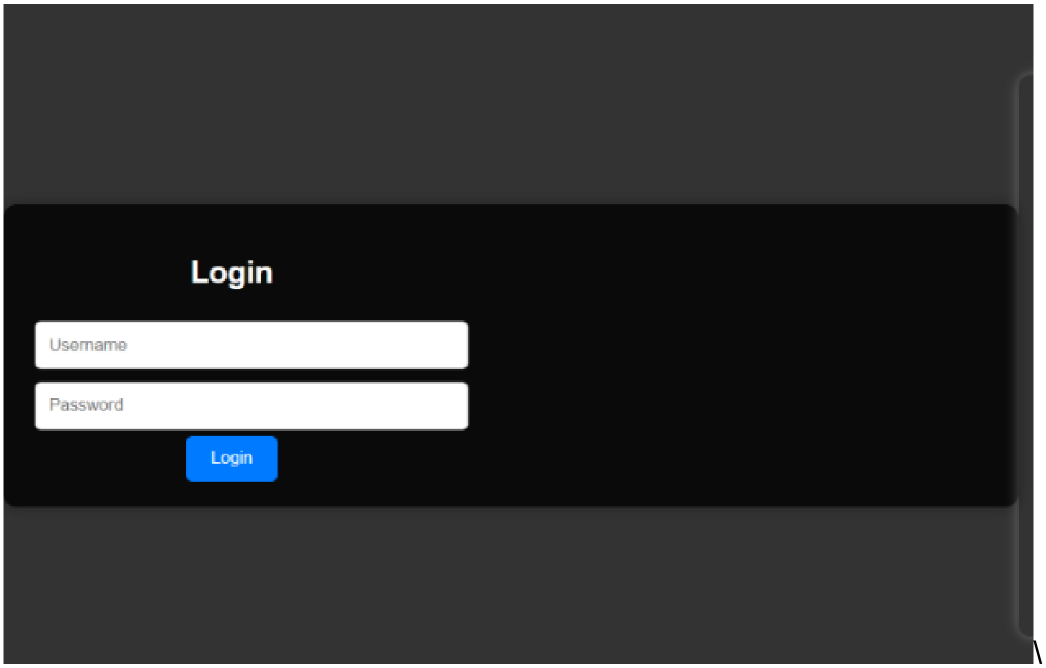

Figure 5: The Login Page of the Website

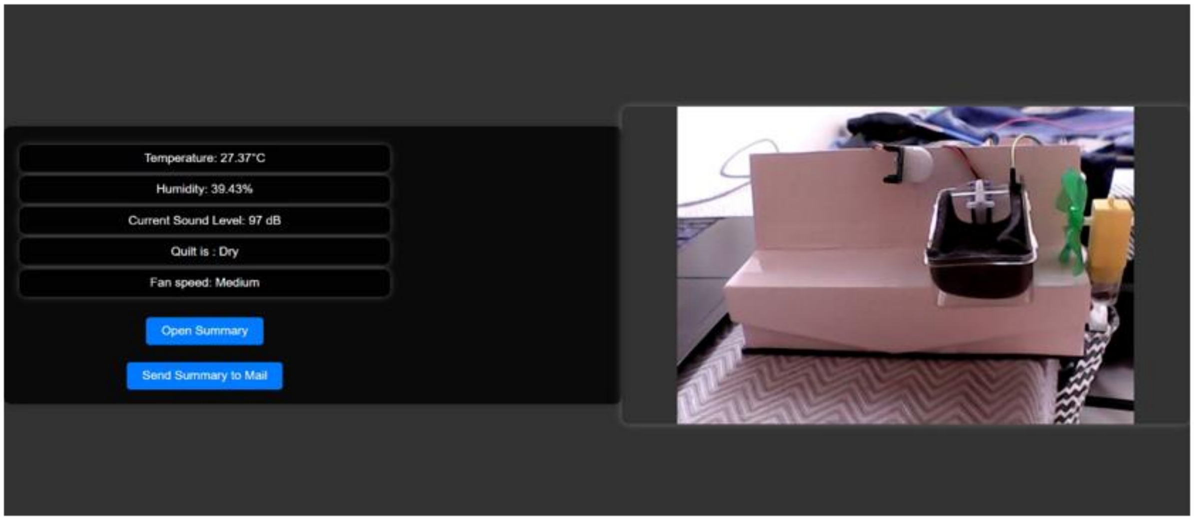

Figure 6: The Developed Website Showing the Sensor Reading and Summary Buttons

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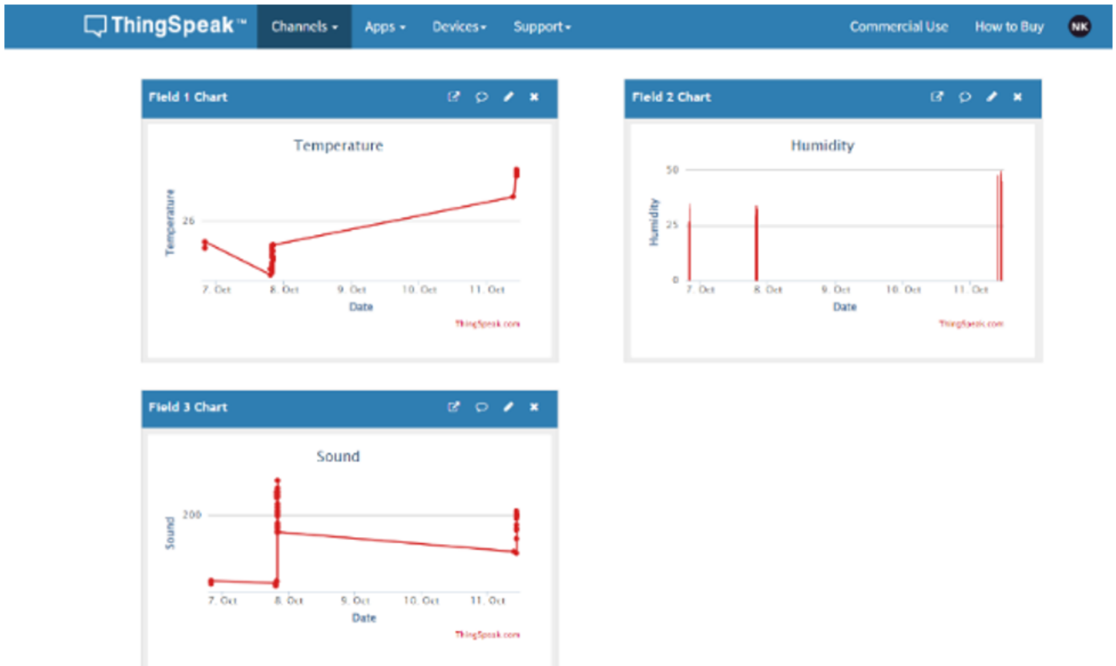

Figure 7: Sensor Data Visualization in Graphical from Thing Speak

Using the “Open summary” button, we can open the Thing Speak window to visualize the sensor data, the button will redirect us to the Thing Speak website as shown in Fig.7. The “Send summary” button triggers the IFTTT to send the summary via email as shown in the Fig.8.

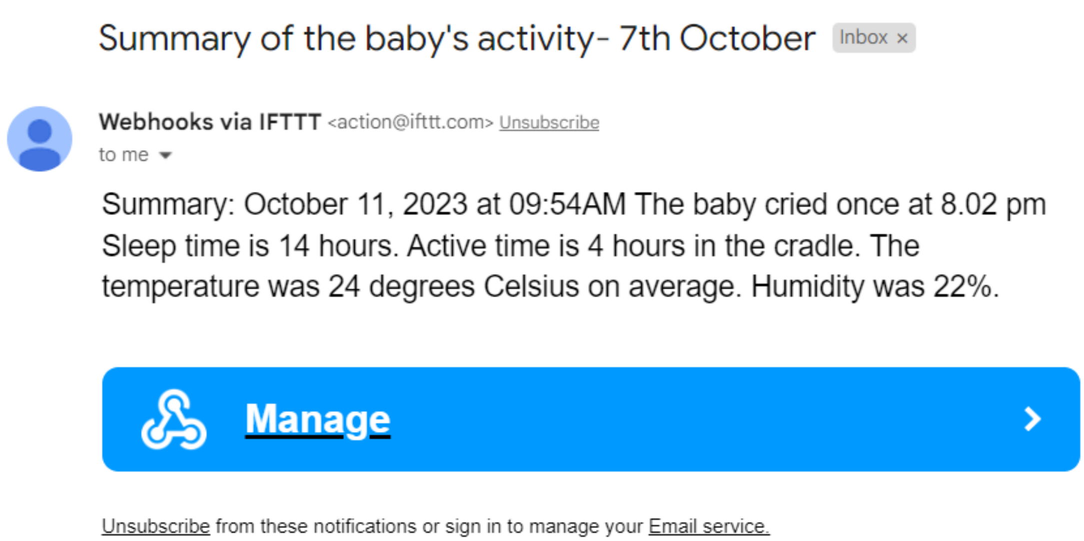

Figure 8: The Summary Received in the e-mail

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Table 1: Comparison with Previous Research Work on Bms

Parameters	This work	[1]	[14]	[15]
Microcontroller	ESP8266	Arduino uno	Raspberry Pi	Arduino uno
Remote monitoring	Yes	Yes	Yes	Yes
Website	Live hosting, fully secured	Yes, but not secured	Yes, but not secured	No
Live video feature	Yes	No	Yes	No
Summaries and data visualization	Yes	No	No	No
Practically feasible miniature prototype	Yes	Needs few Improv-ements	Yes	No

9. CONCLUSION

In conclusion, the Baby Monitoring System, incorporating Node MCU ESP8266, a multitude of sensors, actuators, and cloud-based software services, presents a comprehensive and innovative solution for infant care. It seamlessly combines real-time data monitoring, automation through IFTTT, and graphical data representation on Thing Speak, making it a powerful tool for caregivers. The integration of sound, motion, temperature, humidity, and moisture sensors ensures a well-rounded monitoring system, addressing multiple aspects of infant safety and comfort. The inclusion of the servomotor for gentle cradle swings and the DC motor for fan control enhances the baby's environment. Furthermore, the system fosters ease of use and peace of mind for parents with its email summary alerts. As we look to the future, this project opens the door to further enhancements and refinements, potentially incorporating advanced

AI-driven features and expanding its compatibility with a wider range of sensors and actuators. It stands as a testament to the potential of IoT technology in enhancing infant care, promoting safety, and providing caregivers with valuable insights into their child's well-being.

Recommendations for Future Work

(i) Machine learning approach can be used to monitor the face expression/ emotion of the baby.

(ii) A full-fledged server can be created to host the website and make it available for large sum of people.

Acknowledgement

The authors wish to extend their appreciation to Vellore Institute of Technology (VIT) in Vellore, India, for their invaluable support in facilitating the execution of this project at VIT.

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Tianjin Daxue Xuebao (Ziran Kexue yu Gongcheng Jishu Ban)/
Journal of Tianjin University Science and Technology
ISSN (Online):0493-2137
E-Publication: Online Open Access
Vol: 56 Issue: 12:2023
DOI: 10.5281/zenodo.10390889

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