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IoT based Smart Cradle for Baby Monitoring System

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***Abstract*—In recent years, baby care has become more important and challenging for working mothers. Even at home, working mothers will not have enough time to monitor their babies continuously. They give the responsibility of their baby to either a baby caretaker or they send the baby to their grandparents' house. In the proposed work, a smart cradle with an automated baby monitoring system was developed. In the baby monitoring system, the necessary parameters of the infant like temperature, heartbeat rate, gas molecules, capture the motion and position of the baby were measured and monitored. The S.ODI board is used for interfacing the sensors and actuators. The baby monitoring system is attached to the cradle so that an incubator kind of environment will be created for the baby. The baby monitoring system monitors the baby 24x7. The measured parameters regarding the baby's health like temperature, heartbeat rate, dampness on the baby bed will be displayed in the mobile application. If the recorded readings show any abnormalities, the necessary actions like controlling temperature, switching on or off the fan, setting up cradle's movement, playing music for the baby will be taken. If the readings seem abnormal, the caretaker along with the parents will get an alert message. The motion and posture status of the infant can be monitored using motion Eye OS. The baby monitoring system prototype helps the parents in time management and makes it easier for the caretakers as well. This baby monitoring system is proven to have less harm for the baby with the most accuracy. This monitoring system is a highly efficient IoT based system for real-time monitoring with the best security measures.**

Keywords: Baby monitoring system; Cradle; IoT device; Real-Time Monitoring; S.ODI IoT device; Surveillance.

I. INTRODUCTION

In India in recent years, both the parents working has been common. In these times baby monitoring will be the most difficult thing for working parents. While they can have a caretaker for the baby, but it would be difficult and hard for them to have a view of the baby and its health status[1].

In addition to this, almost one in every ten babies is born prematurely. Premature babies are the most sensitive than normal born babies. Premature babies suffer a lot with home atmospheres and after also coming from incubators in hospitals. Premature babies are those who are born more than three weeks before the baby's estimated time of delivery. They often have medical issues and higher risks of life [2]. The condition of the baby needs to be monitored for every second to second and time to time [3]–[5]. They will be kept in an isolated chamber or incubator, for a total minute to minute monitoring.

Premature babies need to have a longer stay in the hospital than a normal born baby in the nursery unit or neonatal intensive care unit (NICU) [6]. The most common problem that premature babies face is PDA and low blood pressure (hypotension), trouble in breathing due to an immature respiratory system. They also lose their body temperature and suffer due to an underdeveloped immune system etc., [2]. On a survey basis, 4 million babies worldwide would die in the first month of their life due to low birth weight [7]. The high temperatures and humid environments also make babies suffocate. These types of conditions create additional threats to the baby's health. To maintain the baby's condition, they require an additional controller in an incubator for maintaining the baby's body temperature[8], humidity, and pulse rate, and oxygen flows [9] without any assistance. In the same way, when the premature baby's period in hospital is completed, they need to be taken utmost care of in their homes too. Caretakers and parents alone cannot take care of baby minute to minute [3], [10], [11]. In general, in the hospitals, the incubator protects and monitors the baby's condition with every parameter that needs to be monitored. Whereas in homes there is something more compatible for the baby, where it can monitor the baby minute to minute regarding its health issues and surveillance also. The baby needs to be taken care of the humidity and temperature around it. The monitoring systems and automation with data exchange are growing rapidly with the Internet of Things (IoT). IoT devices consist of wireless sensors, software, actuators, cyber systems, computer devices, and all are attached to an object that provides the internet. It also enables the transfer of data and controlling of the sensors and any connected devices with its data transferring software [12]. With the help of the IoT, a minute to minute real-time monitoring is established without any human intervention.

IoT devices are integrated with the latest technology which makes a mix of communication or interaction over the internet, managed, and controlled remotely when required through, installed frameworks, constant investigation, and artificial intelligence. In real-time, cyber systems work and help at best in each stage over the internet [13], [14]. The IoT also enables surveillance mode for the monitoring system, which in turn helps better health and environmental monitoring. In this work, there are modules like room temperature control, humidity control, representation of unsafe gases, and monitoring of the heartbeat parameters are measured with the help of proper sensors. In addition to this, a video surveillance system is installed with the help of Raspberry Pi. The baby's health status containing the sensors readings are updated on the mobile application. The sensors are embedded into the S.ODI board i.e., the framework on board development interface [2]. This reduces the basic circuit complexity around the baby and the onboard complexity. The cradle is the first place for the baby in a home. By taking care of this, the baby's health status is monitored and controlled by regular updates and health readings. This cradle helps the baby in having both comfort and security. The cradle contains less complexity in circuits which reduces the risk of short circuits [15]. The cradle has a surveillance system and the baby's positional status and area are completely monitored every time either in an online web portal[16] or a mobile application.

II. DESIGN AND DEVELOPMENT OF SYSTEM

In this, an IoT-controlled baby monitoring system is designed that will continuously monitor and control the baby's condition like temperature, pulse, baby crying, and dampness, and sends the control signals according to it to the parents to alert the baby position. This system is designed by using an S.ODI microcontroller which has a built-in wi-fi module to utilize for remote surveillance, along with those sensors like temperature sensor, pulse sensor, microphone, gas sensor, humidity sensor, camera, etc. are interfaced with microcontroller to read the required data of infant for monitor and control the condition of the baby.

A. System Requirements:

The system hardware is designed with an S.ODI microcontroller board with DS18b120 sensor for sensing temperature, pulse sensor, MQ135 sensor as the gas sensor, Heater used for differentiating Temperature, microphone module for identifying the crying of baby and camera module, and the hardware requirements are tabulated below.

TABLE I HARDWARE USED

S.No	Components	Its Description
1	S.ODI Version 1.0	It incorporates the ESP32 module, which has wi-fi.
2	Temperature sensor (DS18b120)	It works at 3.3 to 5V and can quantify temperature in the scope of -55ºC to +125ºC which is adequate for the focus on internal heat level range.
3	Pulse sensor	It is an incorporated optical intensifying circuit and clamor dispensing with a circuit sensor. The working voltage is 5V or 3.3V and the current utilization is 4mA.
4	Gas sensor (MQ 135)	The working voltage is 2.5V to 5V. Both info and yield are simple both 0 to 5V
5	Sound sensor (LM393)	On-board has a mouthpiece, high affectability, and normally being utilized for sound identification.
6	Raspberry pi Zero	This module goes through Raspbian, and it resembles a small PC and charge card measured and it is the same as the other raspberry contraptions.
7	Pi Camera	It is a high quality 5 Megapixel camera image sensor crafted. It is capable of capturing 3280X2464 pixel pictures and 640X480 pixel recordings
8	Heater (TECI-12706)	The cooling module is a semi-conductor based component. It can also be used for the differential temperature to generate electricity.
9	3 Inch Fan	It runs on 12 DC and very pleasant air comes out of it. It cools down the hot environment to alternating good temperatures.

B. S. ODI

S.ODI is a hybrid IoT development board that is integrated with all communication interfaces and dual-controller units onboard for enhanced data handling and offers multiple sensor connectivity. It is a full-fledged IoT development board that is built tough for ruff hardly precise processing of data. Our device is uniquely equipped with multi-connectivity systems like Wi-Fi, communication system It is having two varieties. S.ODI standard – with 3 communications + 1 communication interface and (5+) sensors and Interfaces. It contains a set of 23 digital pins and another set of 7 analog pins. It works only on 3.3v and 5v. It is equipped with four modules [solo1, Solo2, MS1, MS2].

C. Features

S. ODI IoT device is a hybrid dual-controller unit. It contains 23 digital pins and 7 analog pins. This board has a speed of 8- bit processing and 4 modes with 2 master-slave modes. It has higher- level communications and can be integrated with any firmware(developed). S. ODI uses Wi-Fi 802.11 series (2 Mbps). It has Serial UART, ILC, SPC protocol interfaces for wired connectivity. It has a capacity of +5 onboard sensors and an interface. Micro USB-type b is used for flexible communication. Parallel processing is used for best performance. These are the specifications of the S.ODI Version 1.0.

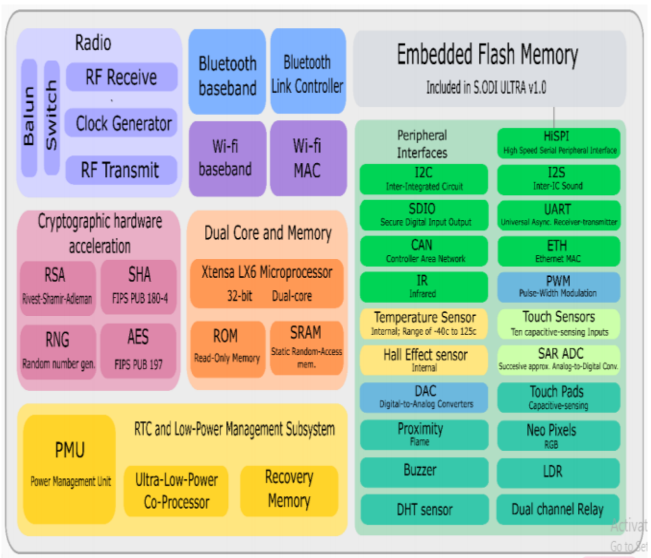


Fig. 1 Block Diagram of S. ODI

III. BLOCK DIAGRAM

The block diagram of IoT based baby monitoring is shown in Fig. 2. The hardware consists of multiple sensors like temperature sensor, humidity sensor, gas sensor, pulse sensor, microphone, camera (etc.) for reading different parameters of the baby to monitor and control the condition of the baby. The inbuilt Wi-Fi module is used to send the condition of the baby to their parents and doctors to alert them. The system is securely connected to the centralized third-party service provider referred to as the cloud to connect to the internet [18].

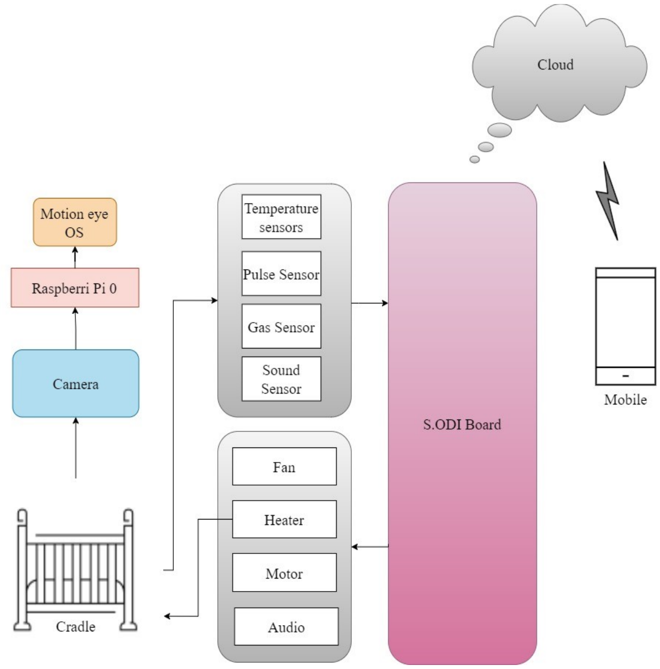


Fig. 2 Block Diagram of Smart Cradle for Baby Monitoring System

IV. WORKING & FLOWCHART

A. Working Mechanism

S.ODI is a multi-utility board with a dual microcontroller that works on the parallel mechanism with Wi-Fi and microcontroller. There are some necessary parameters for the infant that needs to be monitored on daily basis from time to time. Such parameters are body temperature, gas sensor, and pulse rate that are measured using sensors. A microphone module is attached to the cradle that gives the necessary indication of the baby, whether he/ she is crying or not. With this, the reason for the baby's crying is temperature, pulse rate difference, nature calls, or the baby's hunger can be identified. The sensor's readings will be processed by the microcontroller and the recorded data is transmitted using the Blynk channel via a Wi-Fi module. The sensor readings will be monitored, and the necessary actions will be processed according to the baby's condition. As per the readings, if the temperature is high and the baby is crying, the heater placed under the cradle provides sufficient heat for the baby to comfort. In the same way, when the temperature is too high, a portable fan is arranged on the top side of the cradle, which is operated with levels of speed. Along with this, if the baby cries, the attached music plays the songs, and that will be managed by the microcontroller or outer source. The cradle is controlled using a servo motor that makes the cradle swing whenever the baby cries. This will be detected using a microphone, and the controlling of the cradle will be done through the Blynk channel.

Blynk is a coding interface that works in the backend of the S.ODI, and it shows all the readings and statuses of the sensors and other interfaces (Heater, Fan, and Music System). All the sensors are connected, and their readings are measured according to the flow chart. A camera is interfaced with the raspberry pi 0 and is placed on the cradle in a position that covers the whole baby's posture and movement. Through this, the baby's sleeping posture and baby's daily activity in the mobile application through Motion Eye-OS can be monitored. Motion Eye-OS is an interface that helps to capture camera visualization. This whole continuous recording and monitoring help to check the baby's condition and health care up to date and it is user-friendly, so that it will be easier for anyone to understand the Infant's comfort and health conditions.

B. System Architecture

The S.ODI microcontroller board is the main firmware of the project, which will receive the data from sensors and process those data and control the output, and as well send the required data to parents and doctor to alert them. The dampness of the baby will check by using humidity sensor DHT11, the temperature of the baby will read by the temperature sensor DS18b120 and sends the data to the microcontroller, the heartbeat and pulse reading will be read by pulse sensor and

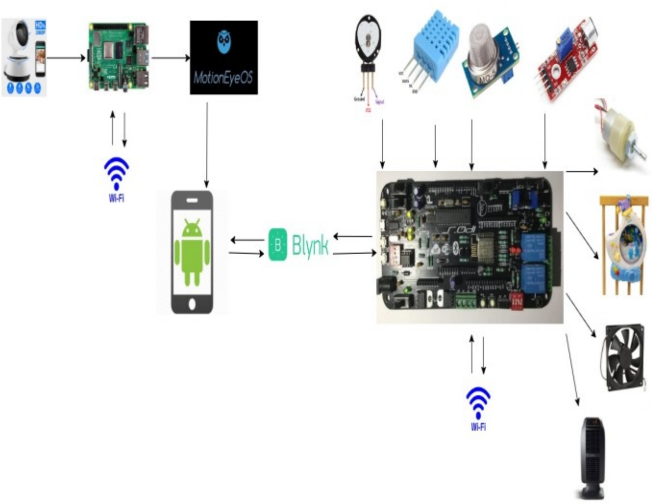


Fig. 3 Pictorial Representation of the System

sends to the microcontroller, the microphone module of the circuit will be used to check whether the baby was crying or not, the inbuilt Wi-Fi module is used to share the condition of the baby that is whether the baby is crying or not, how much temperature the baby has and pulse rate of the baby (etc.)., to the parents and doctor to alert them.

C. Flow Chart

The above diagram shows that the flowchart of the baby monitoring system, here initially the user mobile will be connected to the microcontroller of the baby monitoring system, by using different sensors of the firmware the baby condition is monitored, whether the baby is crying or not will be sensed by the microphone module, if the baby was crying then an alert message will be sent to the parent. The gas sensor will sense the ammonium gases which will help to identify whether there is a need to change the diaper or not.

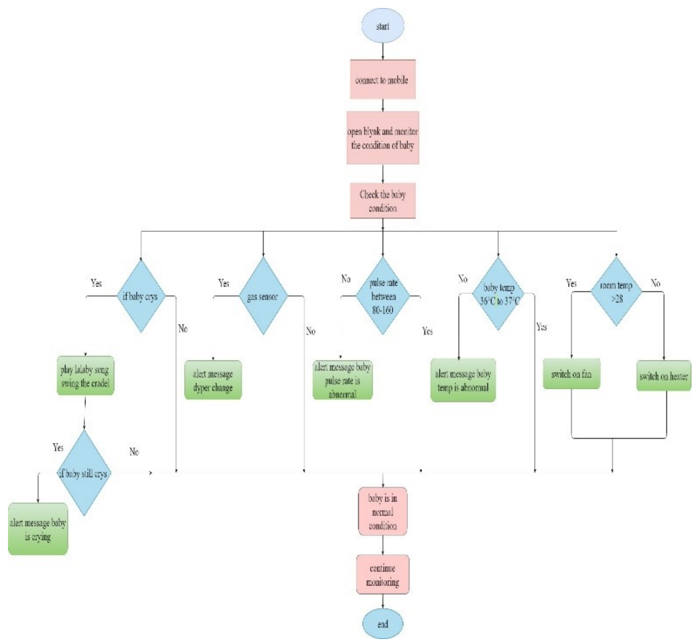


Fig. 4 Flow Chart of the Baby Monitoring System

The temperature sensor will read the temperature of the baby and if it is greater than 98.6^{o}F then an alert message will send to the parent. The pulse sensor will read the pulse rate of the baby and if it is less than 160bpm then an alert will send to the parent that the pulse rate of the baby is abnormal. Finally, the room temperature sensor will read the room temperature according to it the microcontroller will activate the cooler or heater according to the temperature. If all the sensors reading is ok, then the system will indicate that the baby's condition was safe and sends that the same message to the parents also.

V. RESULT AND DISCUSSION

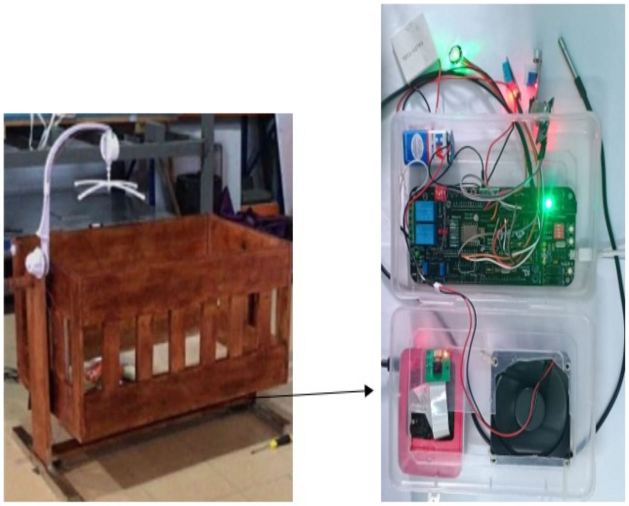
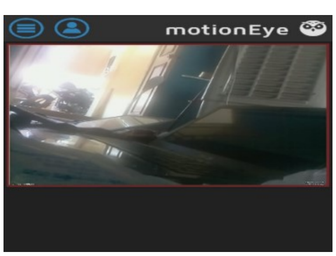


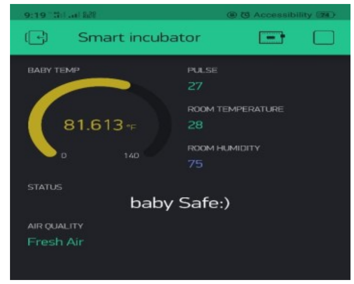
Fig. 5 Hardware Unit

The communication between hardware and software can be seen in the Blynk. In the Blynk, the data measured by the sensors like a gas sensor, temperature sensor, pulse sensor can be monitored. From fig 6, the results for the baby's condition is displayed whether the baby has a high temperature or low temperature, the baby is safe or any disturbances in heart rate, and whether the baby has gone for any nature calls. Considering each parameter, for the baby's motions, and then it displays that the baby is safe.

The proposed system provides an incubator kind of atmosphere for the baby in the cradle. It eases the caretaking easier for both parents and caretakers too. The system would be a very big relief for working mothers and normal parents also. This system assists mothers and caretakers in monitoring the baby's healthcare from time to time. This system makes the parents understand the baby health without any help of a doctor and parents can monitor their baby through video surveillance 24X7 and in future updates can be done regarding sensing cough and frequent sneezing of the baby with the help microphone attached and that will be alerted with a message or phone call, and the further updates can be done in many other ways.



(a)



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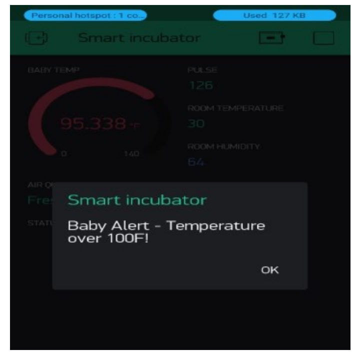
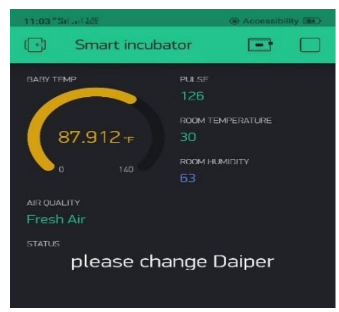


(c)



(d)

Fig. 6 Images of results on smartphone Blynk application
(a) Video surveillance (b) Baby Temperature
(c) High-Temperature Alert (d) Diaper Change Alert

VI. CONCLUSION

In the developed system all the necessary sensors that are used for measuring the parameters like temperature, moisture, pulse rate, microphone, and the camera is interfaced with the S.ODI and Blynk. Blynk is the backend coding interface for S.ODI. In the Blynk application, the caretaker gets necessary alarm messages or alerts regarding the baby's temperature, moisture, baby's bed dampness, and pulse rate of the baby. Minute to minute monitoring of the child and posture monitoring can be done with a spi camera that is installed with the Motion Eye-OS. The necessary framework for baby monitoring with the screening of necessary parameters like health monitoring and full-time surveillance of the baby is demonstrated.

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