Computational Intelligence based Smart Nest for Infants

Madhusudhan G [1], Srinivas S [2], Pranava Swaroopa K S [3], Sneha M S [4], Shamita Kamat [5]

[2,3,4,5] JNNCE, Shivamogga

Abstract: This project proposes the idea of automatic caretaker room for a baby. The main motive of this idea is to save time and energy of very busy parents. Working people are very busy these days. They do not have enough time to properly take care of their babies. So, the whole room is set up as it can sense the activities of the baby and work according to requirement. Parents can save their time and energy as they don't have to go and check their baby again and again until they don't get any information about baby. The idea of this scenario is accomplished by using sensors and a microprocessor. The sensors attached to the microprocessor sense the room condition and also monitor the activity of the baby. It works based on the condition we apply to it. Entire data will be visible to the user and get notified about the status of the baby

1. INTRODUCTION

Nowadays, childcare challenges have become a hurdle to work, especially for working mothers. Child care is necessary for parents, but parents cannot always take care of their babies and can spend time monitoring their babies because of their other responsibilities. Raising a child with care these days where both parents are working is a difficult task. It has become a challenge for many families to keep an eye on their children with everyday routines. Many parents are not satisfied with the daycare facilities provided in many countries. Babies need care and monitoring 24 hours a day which is difficult for working parents because they cannot always carry their babies with them at the time. Hiring a caregiver to watch infants is an option when parents are busy or the nursery is an alternative solution. But it is not always affordable for parents to hire a babysitter to monitor their babies. Thus, Computational Intelligence smart baby monitoring system is the best solution to minimize the gap between babies and parents. The revolution in technology proves that the Computational Intelligence is a mixture of multiple technologies. It connects billions of smart objects and sensors to the Internet, to collect data from the physical environment. These smart objects and sensors are aimed at reducing human intervention and expand automation to daily life. Moreover, these smart objects and sensors lead to various smart industries, such as smart homes, smart cities, intelligent transport systems, smart healthcare, and smart agriculture. By considering the progress of machine learning (ML) in this context, a Computational Intelligence based smart real-time baby monitoring system using machine learning has been proposed to overcome the issues faced by working parents. Many research works have been done but they mainly focus on adding sensors to the existing designs. However, there is a lot of room for enhancement in those proposed studies. We, therefore, have proposed the idea of a smart baby monitoring system, which is a kind of notification system that can detect the activities of the babies in real-time and send the message about the status of the babies to only the registered parents. In particular, we have focused on the vital parameters that are important in maintaining the comfort of the baby. The camera is also attached for live streaming and live updates of the baby using real-time facial expressions. By using the mobile application, the registered parents can control the hardware remotely, get the live stream of the baby, detect the crying sound, and monitor the humidity and temperature of the surroundings. The control system of the proposed system is equipped with a Raspberry Pi with a web camera, a DC motor, a cry detector, and a DHT11 sensor for reading vital parameters to monitor the condition of the infant. These connected sensors send the values to the controllers and immediately notify the parents about abnormal conditions. The proposed system also identifies the unknown face and detects the real-time emotion of a baby using the CNN. The rest of this paper is organized in the following manner. Section 2 explains the related work. Our proposed methodology is discussed in Section 3 to implement the system. Section 4 presents the experimental setup. Section 5 analyzes the results. Finally, we conclude our work.

2. RELATED WORK

IoT is considered a new paradigm, and a lot of research is being examined on IoT-based baby monitoring systems. Several research studies have made use of IoT sensors to col lect the movements and activities of babies and assist parents to monitor their children remotely. Goyal and Kumar [14] designed a low-cost e-baby cradle that is capable to swing only when a baby cry is detected. The user can change the speed of the swinging cradle. It also has a buzzer alarm that alerts the user that the baby's mattress is wet and when the baby's cry is detected for a certain time. A GSM network based smart system was suggested in [15]. The proposed system measures the health conditions such as body temperature, movement, pulse rate, and moisture condition of the baby. The parents get SMS alerts on their mobile numbers using the GSM interface. Palaskar [16] proposed an automatic low-budget baby monitoring system based on a micro controller with multiple features. The proposed system can swing the baby cradle automatically only when the cry sound is detected. A camera is also mounted above the cradle to observe the baby's condition. It also has an alarm that notifies the parents that the mattress is wet or the baby's cry is detected. The notifications via SMS were sent to the parents. However, parents cannot control the system using any application. Another similar approach is used in [17]. The authors make use of the Raspberry Pi along with a Pi camera, condenser mic, and PIR motion sensor to detect the crying and motion condition of the infant. The Pi cam era is turned on only when the sound or motion is detected. The information is sent to the Pi which further processes the data and sends it to the LCD and activates the buzzer. How ever, there is no application or any other way to remotely monitor child conditions. In [18], authors designed a smart cradle that supports video monitoring. It also swings the cradle automatically on detection of cry sounds and rotates a toy mounted on the cradle to comfort the baby. The primary feature of this system is a mobile application that sends alerts to parents when values exceed the threshold range. A new approach to an automatic baby monitoring system has been presented in a paper [19] in which authors used the wireless video monitoring technique to detect sound, motion, and other factors, the information is displayed on the

device that acts like an online server. Another similar study based on GSM has been carried out by Levy et al. [20] that focuses on the monitoring cry, non-respiratory, and respiratory movements of the baby using ultrasonic and accelerometer sensors. The FN-M16P module is used to record the voice of the mother and plays it whenever the baby's cry is detected. However, there is no live monitoring or face detection feature to notify the condition of the baby. In another research study [21], the author makes use of the Arduino and PIR sensors to notify the parents about the child's conditions through the GSM interface to android-based handsets. In addition, the system provides a predefined nutrition food chart to help the baby remain healthy. The system proposed in [22] has all the features that have been used in the previous systems. It supports the Arabic language which is the key feature. It also uses the Fire base cloud to send notifications to the parent's android application. Several similar studies on infant monitoring systems have been conducted in [8, 23] and [24]. Most of these studies conducted are usually based on the use of sensors to collect different information about the child using the previous techniques. In [25], additional methane sensor is used for detecting methane content, and it sends a live image of the baby along with various parameters information to the android application. The system developed in [26] incorporates IoT sensors for measuring vital parameters like moisture, temperature, and pulse rate. A microphone camera is also used for posture monitoring of the child. The parents will be updated about the infants' status through notifications using the Blynk application. In [27], Jabbar et al. designed a low-cost IoT-based system for real-time baby monitoring using NodeMCU and Adafruit MQTT server. The system is capable of detecting the temperature, moisture, and crying of the baby and notifying the user through the IFTTT mobile application. The parents can monitor the real-time status of the baby through the mobile application within the same network. However, such a solution is inappropriate if the parents are on the other network. Some similar solutions with few improvements were proposed in [9, 28]. These proposed systems can be improved by implementing face and emotion detection features. Cheggou et al. [29] designed an intelligent system that assists parents to monitor the vital parameters of the baby using a

web application either on a local network or on a remote network. The authors make use of a convolutional neural network (CNN) to identify the baby's position. This feature is unique and has not been implemented in the previous systems. In addition to the above research, many studies have been carried out that focus on the use of face and emotion detection in the context of baby monitoring systems. A software architecture for an intelligent baby cradle was proposed in [10]; the purpose of this study was to enhance the quality of the cry management module in the existing IoT cradles. The authors proposed four submodules in the cry classification process including face image analysis, voice analysis, body gesture analysis, and decision fusion for accurately detecting the rea- son for a baby's cry. Dubey and Damke [30] designed a baby monitoring system to detect the activities like crying, motion, and the present position of the baby. The main feature of this system is that they use image processing to detect the baby's movement. If the baby is near the edge of the bed, the Pi camera activate, click the snap, and send a notification to the parents through the mail. The body movement detection feature is unique in this system. However, there is no emotion detection module to detect why the baby is crying. In [31] a procedure based on a maximum likelihood approach using HMMs to recognize infants' emotions through their cries was proposed. One such study was carried out by Aiswarya et al. [32]. The authors proposed a monitoring system using Raspberry Pi 3 with different features like camera monitoring for emotion recognition, detecting the crying voice of a baby, automatic swinging of the cradle, monitoring the presence of the baby in the cradle, and sensing the wetness of the baby's bed. It also incorporates a notification module that notifies parents using a buzzer and LCD regarding the baby's condition. This system can be improved by adding mobile application notifications. In [33], automatic pain detection system through image analysis has been proposed. RBC is used to recognize the facial expressions of infants. This system could be accessed through wearable or mobile devices. Another study carried out by Salehin t al. [34] focuses on monitoring the baby's crying, temperature, and moisture level. They also use mobile calls and text message services to notify parents of the baby's condition. Moreover, a web page was designed for real-time monitoring purposes. The proposed

system can not only stream the real-time video of the baby but also uniquely identify multiple babies. The key feature of this system is the face recognition technique. In another research study, the authors proposed an AI-based solution to monitor the baby's laying posture, crying, and emotion, such as happiness [35]. Al-ishamol et al. [36] designed a system for recognizing the baby cry emotion using DNN. The proposed baby care system records the infant's cry, detects the humidity of diapers, and monitors the body and outdoor temperature by using appropriate sensors. The system proposed employed the GSM module to send the cry emotions values to the parent's mobile. Some authors [12, 13] and [37] incorporates different cloud platform to design a smart monitoring system. In addition, many researchers focus on the use of machine learning and deep learning in the context of the smart monitoring system [12, 38]. From the literature, we concluded that many research studies have been carried out that focus on designing a smart baby monitoring system. However, there is a need to improve the approaches in terms of face detection and emotion detection. Several types of baby cradles are available in the market, but they are very expensive, and not everyone can afford them. Moreover, from the literature, we conclude that the existing automatic cradles have many limitations in terms of cost, functionality, alert systems, and communication technology. We, there- fore, propose a system that makes use of all the necessary sensors and emotion recognition techniques to make a smart baby monitoring system. A comparison between our pro- posed system and the earlier systems is illustrated in Table 1. We have compared our system based on six key features; the temperature and humidity of the room, live video streaming, cry detection, swing cradle, connection to a mobile application, and emotion detection.

3. PROPOSED WORK

In the previous section, an extensive literature review is con- ducted to identify the limitations of the existing systems. Thus, a smart baby cradle system is proposed in this paper, which merges the concepts of machine learning along with the baby monitoring system to overcome the limitations in the existing systems. Our methodology is divided into four parts: methodology,

system component selection, system design, and implementation.

3.1. System Component Selection: In this section, the hard- ware and software components that we have used to design and implement the proposed system are discussed.

3.1.1. Hardware Components: In this work, a Raspberry PI is used to process the data from sensors. The Raspberry Pi OS is used as the main connecting link between the camera and mic sensors. Temperature and DC motor are connected to the Raspberry Pi. The hardware com- ponents included the following:

    i.   Raspberry Pi 4
    ii.   Web Camera
    iii.   Sound sensors
    iv.   DHT 11 temperature sensors
    v.   12 V DC motor
    vi.   Baby cradle
    vii.   Wet sensor
    viii.   Speaker
    ix.   LCD Display
    x.   DC Fan

3.1.2. Software Components: The software components are used to connect the sensors with the controllers. The sensor readings were taken from the babies and sent to the controller for further action.

    (i) Raspberry Pi OS
    (ii) Open CV, python

3.1.3. Communication Platforms: The Communication Platforms include the following:

(i) Network Server: Network Server is a server that is responsible for forwarding messages between mobile application and numerous microcontroller boards and SBCs. The server is used to connect the Raspberry Pi, and the application

(ii) Network Application

3.2 System Design and Architecture: This section will provide the details of our system design and its architecture. Although there are countless manual cradle designs available on the market that do not require any power supply to operate, the guardians have to cradle their children themselves whenever needed. We, therefore, propose a system that is automatic and equipped with the necessary sensors for monitoring the baby remotely in real-time.

3.2.1 Cradle Design: The baby cradle system is designed in a way that the baby feels comfortable and gets a good sleep. The cradle has a rectangular shape with boundaries that protect the baby from falling off. In addition, a DC motor is also attached, which is used to swing the cradle whenever the cry sound is detected and can also be initiated by the user. The cradle design is shown in Figure 1(a). The cradle was assembled using glue, screws, and nuts to hold each part firmly and to provide smooth motion to swing the cradle. The connection of the DC motor on the cradle with the help of nuts and screws is shown in Figure 1(b). The cradle designed in this work is small in size for a normal baby, but using the same sensors we can implement the monitoring system on a larger size cradle.

3.2.2 Architectural Details: The control system of the smart cradle is equipped with a Raspberry Pi with the camera, a Dc motor, a sound sensor, and a DHT11 sensor for reading vital parameters to control and monitor the current status of the baby. The complete hardware setup is shown in Figure 1(c). The memory of the Raspberry Pi is limited, so the proposed system incorporates two controllers to divide the computational task between these controllers to reduce the processing time. The camera and micro-phone are attached to the Raspberry Pi, and both of these controllers are linked together with the help of the Network Sensor.
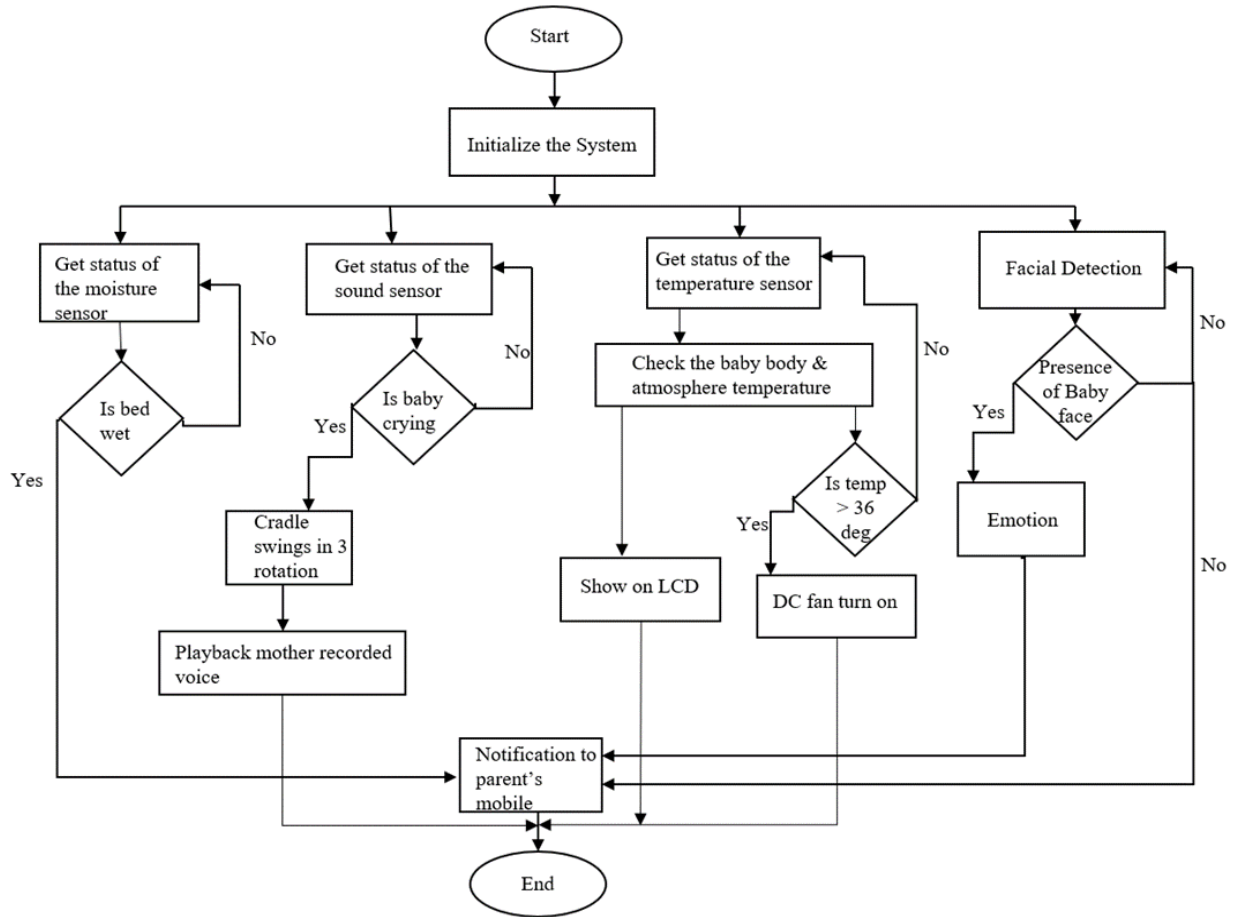
3.2.3. System Monitoring Features: Our work is aimed at developing a smart baby monitoring system, which provides the following key features:

(i) Cry detection: The sound sensor connected to the cradle continuously detects the baby's crying sound and sends a signal to the Raspberry Pi whenever a crying sound is detected. A notification is sent to the parent's telegram application to alert them that the baby is crying.

(ii) Swing cradle: Raspberry Pi switches the relay that is coupled to a DC motor and thus associated with the cradle for swinging purposes. Parents can control the cradle from swinging using the application.

(iii) Live streaming: the user can remotely monitor the real-time conditions of the baby through the mobile application. Since the Raspberry Pi device does not support a built-in camera, thus a web camera is plugged into the Raspberry Pi for live monitoring purposes.

(iv) Room temperature and humidity: DHT11 sensor measures the surrounding air and records the sensor values in the LCD displays.

(v) Face and emotion detection: In this work, a machine learning model is employed for infant facial and emotion recognition. A notification is sent to the parent's Telegram application to notify them about the current emotion.

(vi) Mobile application: the parents can observe the normal data collected from the sensor attached to the cradle, such as ambient temperature and humidity and live video of the baby, whereas the abnormal conditions are conveyed to the parents using Telegram notifications to take appropriate action.

4. SYSTEM IMPLEMENTATION

The implementation details of our system are divided into three modules: the connection of the controller with the sensors, emotion recognition, and the mobile application mod- ule. The overall methodology

adopted in this research is shown in Figure 3 in the form of a flowchart.

Implementing a computational intelligence-based smart nest for infants using Raspberry Pi and sensors is an exciting project! Here's a general outline of how you could approach this:

1.Sensor Selection: Choose sensors such as temperature sensors, humidity sensors, motion sensors, speaker and web cameras for monitoring.

2.Raspberry Pi Setup: Set up your Raspberry Pi with an operating system like Raspbian. Install necessary libraries for sensor interfacing and data processing.

3.Data Acquisition: Interface with the sensors using GPIO pins or appropriate communication protocols (e.g., I2C, SPI). Collect data from sensors at regular intervals.

4.Data Processing and Analysis: Implement computational intelligence algorithms for processing the sensor data. For example, use machine learning models to detect patterns in temperature and motion data to infer the infant's comfort level or sleep patterns.

5.Control and Feedback: Based on the analysis, control the environment within the smart nest. For instance, adjust temperature, humidity, or activate soothing sounds/lights based on the infant's needs. Provide feedback to caregivers through a user interface (UI) or notifications on their devices.

6.User Interface: Develop a user-friendly interface for caregivers to monitor and interact with the smart nest's features.

4.1 Face Detection and Emotion Recognition: The most important part of our system is the use of machine learning technique to automatically detect the emotion of the baby using live stream data. The web camera is set up in such a way that it can capture the baby's face correctly. These pictures are stored in the system's user profile folder. The CNN algorithm is used to detect the baby's face from a live webcam feed. If the image captured by the camera during the live stream does not match the picture stored in the system, the system will not send the notification to a user application. In this research work, a novel face emotion recognition system from photo frames is proposed. The facial expressions of a human being convey information about the person's emotions. The facial expression of a person provides information about his emotions. Furthermore, these expressions are produced by the changes in the specific facial features, for example, mouth, eye, and eyebrow as well. Along, the recognition of the expressions results in detecting the basic emotions, such as anger, disgust, fear, happiness, sadness, surprise, and many more.

However, the most common way to identify emotions from the facial expression comprises the processing of the images and distinguishing the changes in facial features.

Algorithm depicts the overall working methodology of the proposed work. We have used a dataset from Kaggle to train our machine learning model to identify the baby's emotions. We have classified these images into six predefined classes. These classes are categorized as anger, happiness, fear, cry, disgust, and surprise. We have divided this module into three phases, as described in Figure 4. In the initial phase, the baby's image is detected by capturing the video stream using OpenCV. These captured images are resized and converted to grayscale. Dlib has been used to extract the face from the image. In the second phase, the captured image data is passed to our classifier. CNN has been used for the recognition and classification of emotions from the captured face. Finally, the detected facial expressions are classified into appropriate emotions. Emotions such as sadness, happiness, and surprise are only notified in the parent's application.

4.2 Mobile Application: The process of controlling sensors using a mobile phone requires an application operating under the Android or iOS operating system. An application named "Telegram" is thus used for this purpose. For making the connection between controllers and the Telegram application, The Telegram application will send the notification to the registered mobile number which is then synchronized with the Network server. We employed the Telegram application for developing friendly environment with simplicity concerning usage and widgets. Moreover, the data measured by the utilized sensors is updated on the Internet, and the Network server and mobile application are used to retrieve.

5. RESULT:

In this section, the experimental results of our proposed system are presented. We have performed various experiments to test the feasibility of our smart system design. We have successfully connected all the sensors with the controllers and the server. The utilized sensors' data are updated on the Internet and can be accessed via the Network server and Telegram mobile application. Figure 5(a) shows the main screen of our user's Telegram application to check the baby's presence and wet condition of a baby. The values uploaded by the microcontrollers connected to the baby monitoring system to the user's application via the Network server. The real-time humidity and temperature of the baby's surroundings were determined, and measured temperature is compared with the specified threshold. The function of detecting and sending notifications of a baby crying was tested by playing a baby-crying ringtone. The sensor connected acquired the sound level as soon as the audio started, and a notification was sent to the parent's mobile phone to notify them that the baby was crying. The smart cradle swings automatically when a crying sound is detected. A notification is forwarded to the parents to inform them that their child is crying. The icon below the sensor values shows the notification alert. An external web camera is used to achieve real-time baby monitoring. The algorithm implemented for face recognition will check if the recognized baby is in the cradle or not. If not, it will generate a notification and send it to the user application, as shown in Figure 5(b). Our proposed system is intended to develop a smart baby monitoring system with emotion detection using the ML technique. And then the face region of the baby is detected from the input image after every 10 seconds. Finally, the facial emotion of the baby is identified in front of the web camera connected to the baby's cradle, and different emotions were captured by the system, these emotions were notified to the user application.
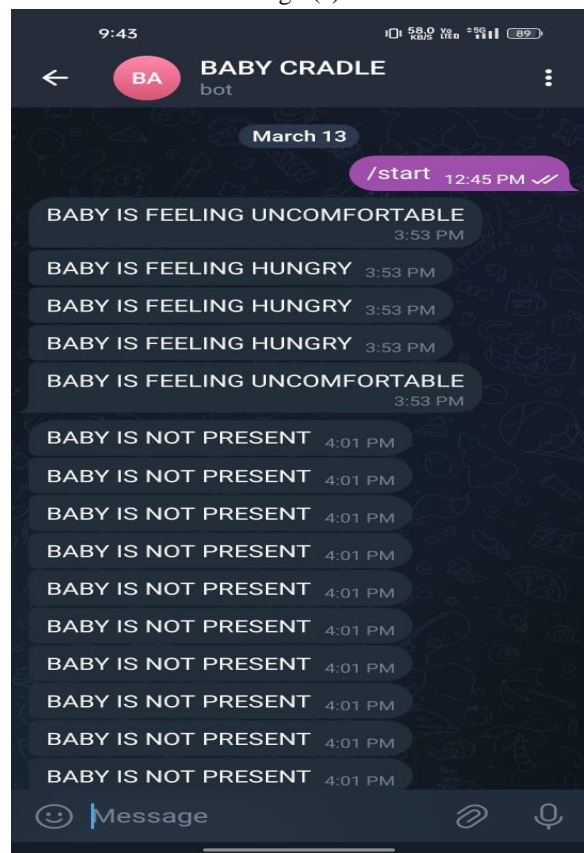

Fig:5(a)

Fig:5(b)

6. CONCLUSION AND FUTURE WORK

Monitoring a baby is a challenging task for guardians. It is almost impossible for parents to continuously monitor their babies all the time. A computational Intelligence based smart baby monitoring cradle system with emotion recognition has been designed as the best solution for working parents to monitor their babies anywhere and anytime. The memory of the Raspberry Pi used as the main controllers to connect the sensors to measure the crying condition, humidity, and ambient temperature. The system is designed to provide ease to working parents by sending instant notifications to their application when abnormal activity is detected, such as the crying of the baby. The prototype was tested by playing a crying baby ringtone on a phone and placing it near the cradle to detect crying and send the notification instantly to the parent. The system started swinging the cradle upon detecting the crying sound of the baby, and a notification was also sent to the mobile phone user. The system is capable of detecting faces and the emotions of a baby. The camera detects the face and sends a notification to parents. Moreover, we also tested the viability of the emotion by applying a machine-learning model to a video of a registered baby. The model has been trained to detect six types of emotions, but only happy, sad, and surprise emotions are notified to the parent on their application. The proposed system helps the parents to monitor their baby through online streaming via camera. There is no restriction for the parents to have the same network for mobile applications and the external camera. This enables the parents to monitor their baby in real- time.
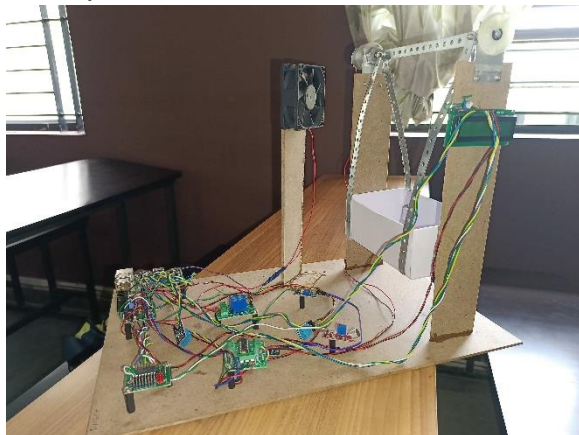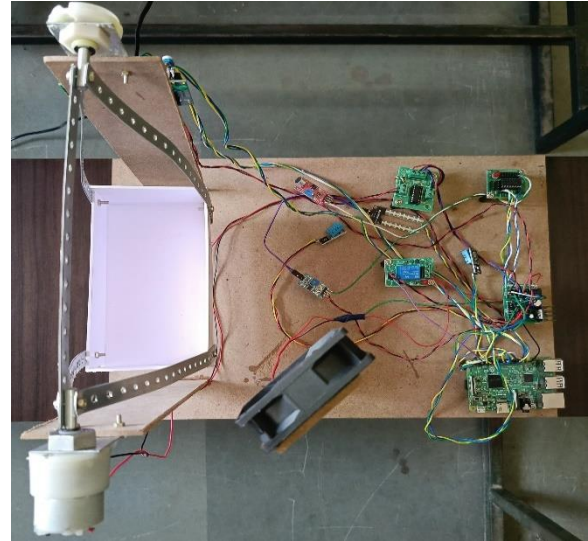

Fig:6(a)

Fig:6(b)

6.1. Future Work: In the future, the cost and complexity of the system can be reduced by connecting all the sensors to a single controller. The system's user interface also needs improvements; although Telegram provides an interactive GUI, there are some limitations in built-in applications. Furthermore, will develop our own set of dashboards for PCs, laptops, and smartphones to add more monitoring functionalities. In addition, some other possible future works to improve emotion and crying detection by implementing other machine learning algorithms to detect the actual cause of baby crying can be conducted. This paper is just detecting the baby's facial expression. Moreover, different wearable sensors can also be coupled with the system to provide accurate detection of various health conditions.

REFERENCE

[1] P. Hemalatha and S. Matilda, "Smart digital parenting using internet of things," in *2018 International Conference on Soft- Computing and Network Security (ICSNS)*, pp. 1–6, Coimbatore, India, 2018.

[2] M. Burhan, R. A. Rehman, B. Khan, and B. S. Kim, "IoT ele- ments, layered architectures and security issues: a comprehen- sive survey," *Sensors*, vol. 18, no. 9, p. 2796, 2018.

[3] L. Atzori, A. Iera, and G. Morabito, "The internet of things: a survey," *Computer Networks*, vol. 54, no. 15, pp. 2787–2805,

2010.

[4] M. T. Ubaid, M. Z. Khan, M. Rumaan, M. A. Arshed, M. U. G. Khan, and A. Darboe, "COVID-19 SOP's violations detection in terms of face mask using deep learning," in *2021 International Conference on Innovative Computing (ICIC)*, pp. 1–8, Lahore, Pakistan, 2021.

[5] M. A. Arshed, W. Qureshi, M. Rumaan, M. T. Ubaid, A.Qudoos, and M. U. G. Khan, "Comparison of machine learning classifiers for breast cancer diagnosis," in *2021 Inter- national Conference on Innovative Computing (ICIC)*, pp. 1– 6, Lahore, Pakistan, 2021.

[6] M. A. Arshed, W. Qureshi, M. U. Khan, and M. A. Jabbar, "Symptoms based Covid-19 disease diagnosis using machine learning approach," in *2021 International con- Ference on Innovative Computing (ICIC)*, Lahore, Pakistan, 2021.

[7] M. A. Arshed, H. Ghassan, M. Hussain, M. Hassan, A. Kanwal, and R. Fayyaz, "A light weight deep learning model for real world plant identification," in *2022 Second International Con- ference on Distributed Computing and High Performance Com- puting (DCHPC)*, pp. 40–45, Qom, Iran, 2022.

[8] M. Shasna, K. Mathilakam, M. M. Kabeer, U. A. Navami Krishna, N. N. Nazar, and N. Ashok, "Infant cradle monitor- ing system using IoT," *Int J Adv Res Comput Commun Eng*, vol. 8, no. 4, 2019.

[9] H. I. Shahadi, D. H. Muhsen, H. T. Haider, and A. H. Taheri- nia, "Design and implementation of a smart baby crib," *IOP Conference Series: Materials Science and Engineering*, vol. 671, no. 1, article 012050, 2020.

[10] S. Joseph, A. Kumar, and M. H. Babu, "IOT based baby mon- itoring system smart cradle," in *2021 7th International Confer- ence on Advanced Computing and Communication Systems (ICACCS)*, pp. 748–751, Coimbatore, India, 2021.

[11] "Facial expression dataset," November 2022,https://www.kaggle.com/datasets /astraszab /facial-expression-dataset-image-folders-fer 2013 ?resource=download.

[12] S. Durga, S. Itnal, K. Soujanya, C. Z. Basha, and C. Saxena, "Advanced and effective baby care monitoring smart cradle system using Internet of Things," in *2021 2nd International Conference on Smart Electronics and Communication (ICO- SEC)*, pp. 35–42, Trichy, India, 2021.

[13] S. Talukdar and S. Saha, "Intelligent Baby Monitoring System Using Blynk," in *Advances in Electronics, Communication and Computing. ETAEERE 2020. Lecture Notes in Electrical Engineering, vol 709*, P. K. Mallick, A. K. Bhoi, G. S. Chae, and K. Kalita, Eds., Springer, Singapore, 2021.

[14] M. Goyal and D. Kumar, "Automatic e-baby cradle swing based on baby cry," *International Journal of Computers and Applications*, vol. 975, p. 8887, 2013.

[15] S. P. Patil and M. R. Mhetre, "Intelligent baby monitoring sys- tem," *ITSI Transactions on Electrical and Electronics Engineer- ing*, vol. 2, no. 1, pp. 11–16, 2014.

[16] R. Palaskar, S. Pandey, A. Telang, A. Wagh, and R. Kagalkar, "An automatic monitoring and swing the baby cradle for infant care," *International Journal of Advanced Research in Computer and Communication Engineering*, vol. 4, no. 12, pp. 187–189, 2015.

[17] F. Symon, N. Hassan, H. Rashid, I. U. Ahmed, and S. M. Taslim Reza, "Design and development of a smart baby mon- itoring system based on Raspberry Pi and Pi camera," in *2017 4th International Conference on Advances in Electrical Engi- neering (ICAEE)*, pp. 117–122, Dhaka, Bangladesh, 2017.

[18] M. P. Joshi and D. C. Mehetre, "IoT based smart cradle system with an android app for baby monitoring," in *2017 Interna- tional Conference on Computing, Communication, Control and Automation (ICCUBEA)*, pp. 1–4, Pune, India, 2017.

[19] S. Mishra, "Development of RTOs based internet connected baby monitoring system," *Indian Journal of Public Health Research Development*, vol. 9, no. 2, p. 345, 2018.

[20] M. Levy, D. Bhiwapurkar, G. Viswanathan, S. Kavyashree, and P. K. Yadav, "Smart cradle for baby using FN-M16P module," *Perspectives in Communication, Embedded-systems and Signal-processing*, vol. 2, no. 10, pp. 252–254, 2019.

[21] S. Ramesh, S. Abrar, S. S. Hanidia Misbah, D. P. Bhavani, and M. H. L. Madhushree, "A Smart Baby Cradle," *Global Journal of Computer

Science and Technology, vol. 19, no. G1, pp. 1–5, 2019, Available at: https://computer research. org/index.php/computer/article/view/1815 (Accessed: 26 February 2023).

[22] D. M. Ibrahim, M. A. Hammoudeh, S. Ambreen, and S. Mohammadi, "Raspberry Pi-based smart infant monitoring system," *International Journal of Engineering Research and Technology*, vol. 12, no. 10, pp. 1723–1729, 2019.

[23] A. R. Telepatil, P. P. Patil, S. S. Yajare, and S. R. Jadhav, "Intel- ligent baby monitoring system," *International Journal of Research in Advent Technology*, vol. 7, no. 6, pp. 191–194, 2019.

[24] H. S. Gare, B. K. Shahane, K. S. Jori, and S. G. Jachak, "IOT based smart cradle system for baby monitoring," *International Research Journal of Engineering and Technology*, vol. 6, no. 10, 2019.

[25] S. Kavitha, Madhuchandra, R. R. Neela, K. Harshitha, and M. Sowndarya, "Analysis on IoT based smart cradle system with an Android application for baby monitoring," in *2019 1st International Conference on Advanced Technologies in Intelligent Control, Environment, Computing & Communica- tion Engineering (ICATIECE)*, pp. 136–139, IEEE, 2019.

[26] N. L. Pratap, K. Anuroop, P. N. Devi, A. Sandeep, and S. Nalajala, "IoT based Smart Cradle for Baby Monitoring Sys- tem," in *2021 6th International Conference on Inventive Com- putation Technologies (ICICT)*, pp. 1298–1303, Coimbatore, India, 2021.

[27] W. A. Jabbar, H. K. Shang, S. N. I. S. Hamid, A. A. Almoham- medi, R. M. Ramli, and M. A. H. Ali, "IoT-BBMS: internet of things-based baby monitoring system for smart cradle," *IEEE Access*, vol. 7, pp. 93791–93805, 2019.

[28] A. Rudyansyah, H. L. Warnars, F. L. Gaol, and T. Matsuo, "A prototype of baby monitoring use raspberry pi," in *2020 Inter- national Conference on ICT for Smart Society (ICISS)*, pp. 1–4, Bandung, Indonesia, 2020.

[29] R. Cheggou, O. Annad, and E. hadi Khoumeri, "An intelligent baby monitoring system based on raspberry PI, IoT sensors and convolutional neural network," in *2020 IEEE 21st Interna- tional Conference on Information Reuse and Integration for Data Science (IRI)*, pp. 365–371, Las Vegas, NV, USA, 2020.

[30] Y. K. Dubey and S. Damke, "Baby Monitoring system using image processing and IoT," *International Journal of Engineering and Advanced Technology*, vol. 8, no. 6, pp. 4961–4964, 2019.

[31] S. A. Alswedani and F. E. Eassa, "A smart baby cradle based on IoT," *Journal of Computer Science and Mobile Computing*, vol. 9, no. 7, pp. 64–76, 2020.

[32] S. Aiswarya Suresh, A. S. Aseema, M. Maheen, N. G. Sreekutty, and S. Sreelekshmi, "Baby monitoring smart cradle system with emotion recognition," *International Research Journal of Engineering and Technology*, vol. 7, no. 7, 2020.

[33] A. Martínez, F. A. Pujol, and H. Mora, "Application of texture descriptors to facial emotion recognition in infants," *Applied Sciences*, vol. 10, no. 3, p. 1115, 2020.

[34] H. M. Ishtiaq Salehin, Q. R. Anjum Joy, F. T. Zuhra Aparna, A. T. Ridwan, and R. Khan, "Development of an IoT based smart baby monitoring system with face recognition," in *2021 IEEE World AI IoT Congress (AIIoT)*, pp. 0292–0296, Seattle, WA, USA, 2021.

[35] S. Choi, S. Yun, and B. Ahn, "Implementation of automated baby monitoring: CCBeBe," *Sustainability*, vol. 12, no. 6, p. 2513, 2020.

[36] K. S. Alishamol, T. T. Fousiya, K. J. Babu, M. Sooryadas, and L. Mary, "System for infant cry emotion recognition using DNN," in *2020 Third International Conference on Smart Sys- tems and Inventive Technology (ICSSIT)*, pp. 867–872, Tirunel- veli, India, 2020.

[37] K. Lohekar, S. Deshmukh, S. Ambekar, N. Gole, and L. Vina, "Smart baby cradle," *International Journal of Research in Engi- neering, Science and Management*, vol. 2, no. 3, 2019.

[38] T. Khan, "An intelligent baby monitor with automatic sleeping posture detection and notification," *AI*, vol. 2, no. 2, pp. 290– 306, 2021.

[39] "Blynk IoT Plateform," November 2022, https://blynk.io.

[40] "Micmon," November 2022, https://github .com/BlackLight/ micmon.