Emotion Recognition based Smart Baby Monitoring System using Machine Learning and Raspberry PI

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Abstract - This paper proposes a novel Emotion Recognition Based Smart Baby Monitoring System utilizing a combination of machine learning techniques and hardware components such as Raspberry Pi, webcam, microphone, temperature sensor, and DC motor. The system aims to enhance traditional baby monitoring by integrating emotion recognition capabilities, allowing caregivers to remotely monitor a baby's emotional state. Through machine learning algorithms, facial expressions and vocal cues are analyzed in real-time to infer the baby's emotional status. The webcam captures facial expressions, the microphone records vocalizations, and the temperature sensor monitors environmental conditions. In response to detected emotions or temperature variations, the DC motor can activate devices like a fan or heater for comfort. This integrated system offers caregivers a comprehensive tool for ensuring the well-being and comfort of infants while providing valuable insights into their emotional state.

I. INTRODUCTION

In today's society, difficulties with childcare are a barrier to employment, particularly for mothers who work. Parents need child care, but because of their other obligations, they are not always able to look after their children and must spend time watching them. These days, when both parents work, raising a child with care is a challenging undertaking. Many families now find it difficult to watch over their kids during their regular activities. Many parents are dissatisfied with the childcare centers that are offered in various nations. Because they can't always take their kids with them at all times, working parents find it challenging to provide the care and supervision that babies require around-the-clock. When parents are busy, one option is to hire a caretaker to babysit the babies, or you may use the nursery as a backup plan. However, hiring a babysitter to watch their children is not always within the means of parents. The ideal way to reduce the distance between parents and their infants is to use an Internet of Things (IoT)-based smart baby monitoring system. The technological revolution demonstrates that the Internet of Things (IoT) is a conglomeration of several technologies. In order to gather data from the real world, the Internet of Things links billions of smart items and sensors to the network [1].The goal of these sensors and smart items is to increase automation in daily life while decreasing the need for human interaction. Additionally, a variety of smart sectors, including intelligent transportation systems, smart homes and cities, smart healthcare, and smart agriculture, are a result of these smart sensors and things. Nowadays, machine learning is also a big deal in the Internet of Things (IoT), particularly in computer vision, bioinformatics, smart homes, and agriculture. Taking into account the advancements in IoT and machine learning. In this context, an IoT-based smart real-time baby monitoring system using machine learning has been proposed. Numerous studies have been conducted, however they mostly concentrate on integrating sensors into the current designs [2–4] and [5–8]. Still, there's a lot of space for improvement in those suggested investigations. Therefore, we have suggested the concept of a smart baby monitoring system, which is a type of notification system that can identify a baby's actions in real-time and notify only registered parents of the baby's state.

II.RELATED WORK

IoT appears as a new paradigm, and methods for monitoring babies that are based on IoT are the subject of extensive study. IoT sensors have been used in a number of studies to track newborns' movements and activities and let parents keep an eye on their kids from a distance. Hina Alam ,1 Muhammad Burhan ,2 Anusha Gillani,3 Ihtisham ul Haq,1 Muhammad Asad Arshed ,1 Muhammad Shafi,4 and Saeed Ahmad 1 designed a low-cost e-baby cradle that is capable to swing only when a baby cry is detected. The Vital signs like as temperature, heart rate, and moisture are measured via Internet of Things sensors. The child's posture is also monitored using a microphone camera. Notifications regarding the infants' status will be sent to the parents via the Blynk application. Using NodeMCU and AdaFruit MQTT server, Jabbar et al. created a low-cost Internet of Things-based solution for real-time infant monitoring in [15].

The IFTTT mobile application may be used by the system to inform the user when it detects changes in the baby's temperature, moisture content, and crying. Another similarstudy based on GSM has been carried out by Levy et al. [8] that focuses on the monitoring cry, nonrespiratory, 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 [9], 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 [10] 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 Firebase cloud to send notifications to the parent’s android application. Several similar studies on infant monitoring systems have been conducted in [2, 11] and [12]. 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 [14], 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 [15] incorporatesIoT 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.

These proposed systems can be improved by implementing face and emotion detection features. Cheggou et al. [15] 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 [4]; 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 reason for a baby’s cry.

In [22] 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. [9]. 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 [9], 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. [13] 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 [20]. Al-ishamol et al. [21] 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 [6, 7] and [21] 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, 14]. 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, therefore, propose a system that makes use of all the necessary sensors and emotion recognition techniques to make a smart baby monitoring system. I 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.

IV. PROPOSED WORK

To determine the shortcomings of the current systems, a thorough examination of the literature is done in the preceding section.In order to get around the shortcomings in the current systems, a smart baby cradle system that combines the ideas of machine learning and IoT with the baby monitoring system is presented in this study. Four components comprise our method: selection of system components, design, implementation, and methodology.

4.1. Waterfall Methodology

The waterfall approach was the natural choice for this project due to the structure of the assignment and the diversity of participants. The waterfall approach involves a set of steps that are followed in a certain order, beginning with planning and analysis and continuing with execution, testing, and final product assessment [7]. Parents were interviewed for qualitative research in order to better understand the project's needs and expectations before any development began. This project was perfect for combining qualitative and quantitative methods since it required extensive specification preparation before any work could begin. Overall, the waterfall approach proved to be a useful framework for this project as it was imperative to fully understand the problem before beginning any development. A specification was initially approved by all parties concerned, and this specification was developed into a design idea. After then, work on implementing the system began, and it continued until all of the elements that had been decided upon were completed to a high standard.

4.2. System Component Selection

In this section, the hardware and software components that we have used to design and implement the proposed system are discussed.

4.2.1. Hardware Components

In this work, a Raspberry P is used to process the data from sensors. The Raspberry Pi OS is used as the main connecting link between the camera, mic sensors, Temperature and DCmotor. The hardware components included the following:

(i) Raspberry Pi 4
(ii) Camera
(iii) Condenser mic
(iv) DHT 11 temperature sensor
(v) 12VDC motor
(vi) Baby cradle

4.2.2. 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

4.2.3. Communication Platforms

The Communication Platforms include the following:

(i) Blynk Server: Blynk Server is an IoT-based server that is responsible for forwarding messagesbetween Blynk mobile application and numerous microcontroller boards and SBCs. The Blynk server is used to connect the Raspberry Pi, and the application
(ii) Blynk Application

4.3. System Design and Architecture

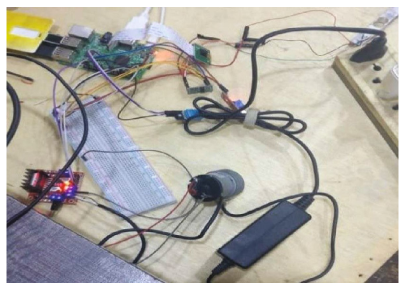
The specifics of our system's architecture and design will be covered in this part. Guardians must cradle their infants themselves when necessary, despite the fact that there are a plethora of manual cradle designs on the market that run without a power source. As a result, we suggest an automated system with all the sensors required to keep an eye on the infant in real time from a distance.

4.3.1. Cradle Design

The baby cradle system is intended to ensure a comfortable and restful sleep for the infant. The infant is kept safe from tumbling from the cradle thanks to its limits and rectangular design. Furthermore, there is a DC motor attached that can be turned on by the user and is used to swing the cradle whenever the cry sound is detected. The cradle was put together with the use of glue, screws, and nuts to ensure that every component was held in place and that swinging the cradle was smooth. The cradle envisioned in this work is modest for a typical newborn, but we may use the monitoring system to a larger cradle by utilizing the same sensors.

4.3.2. Architectural Details.

The control system of the smart cradle is equipped with a Raspberry Pi with the camera, a Dc motor, a condenser mic, and a DHT11 sensor for



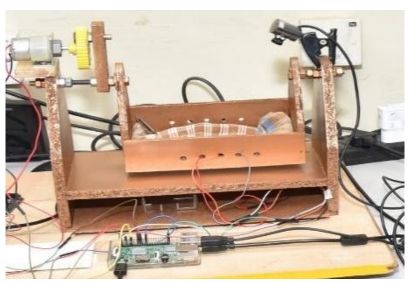


Figure 1: System design and connection of the hardware components.

reading vital parameters to control and monitor the current status of the baby. The complete hardware setup is shown in Figure 1. The controller is linked together with the help of the Blynk

4.3.3. System Monitoring Features.

Our work is aimed at developing a smart baby monitoring system, which provides the following key features:

(i) Cry detection: the mic connected to the cradle continuouslydetects the baby's crying sound and sendsa signal to the Raspberry Pi whenever a crying sound is detected. A notification is sent to the parent's Blynk application to alert them that the baby is crying

(ii) Swing cradle: Raspberry pi 4 switches the relay that iscoupled to a DC motor and thus associated withthe cradle for swinging purposes. Parents can control the cradle from swinging using the application

(iii) Live streaming: the user can remotely monitor thereal-time conditions of the baby through the mobileapplication. 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 sensormeasures the surrounding air and records the sensor values in the Raspberry pi 4 and uploads them tothe Blynk server at the same time
(v) Face and emotion detection: in this work, a machinelearning model is employed for infant facial andemotion recognition. A notification is sent to theparent's Blynk application to notify them aboutthe current emotion
(vi) Mobile application: the parents can observe the normaldata collected from the sensor attached to thecradle, such as ambient temperature and humidityand live video of the baby, whereas the abnormalconditions are conveyed to the parents using Blynknotifications to take appropriate action.

5. 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 module. The overall methodology adopted in this research is shown in Figure 3 in the form of a flowchart.

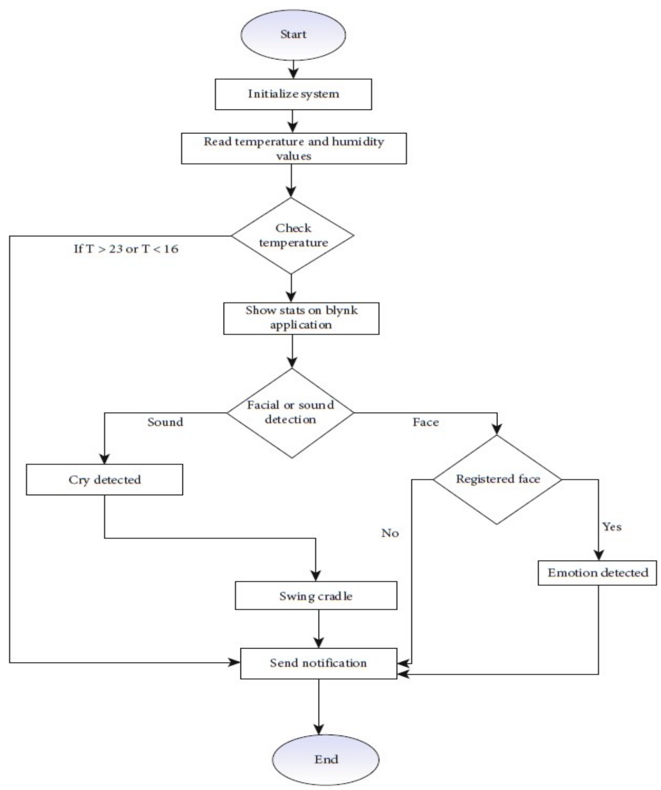


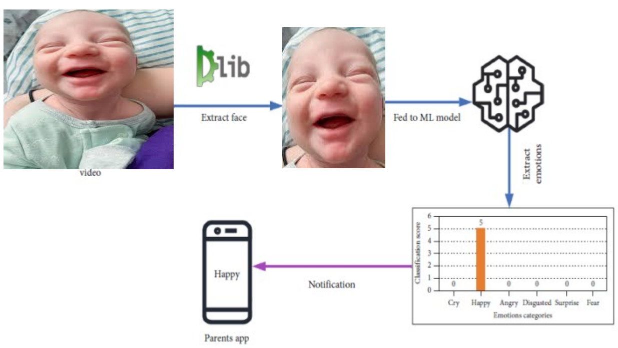
Figure 3: Flowchart

5.1. Connection of Controllers with the Sensors

A 5V power connection is supplied for powering the Raspberry Pi. We use Python as the programming language to implement and configure the Raspberry Pi after installing the Raspbian OS on an SD card. After powering up the PI, the OS initializes the Python script. The general-purpose input/output (GPIO) port will then activate to operate. The OS will check the GPIO states. Consequently, Pi collects information regarding the baby's cry level and emotion from the feedback from the camera. Similarly, will receive information from the DC motor and temperature sensor. All the data collected from the controllers will then be uploaded to the server, and then the server will forward the real-time information of the child to the parent's application. The user can control the baby system through the application. Parents who are far from their children need to have a quick notification whenever the baby is crying. In our proposed system, we take into our consideration this feature. A mic is used to detect the crying of the baby and provide the signal to the Raspberry Pi which in turn runs a Micmon script continuously to check the baby's crying level. If the sound is detected, it sends notifications to the user's Blynk application and automatically activates the DC motor for swinging the cradle. The parents can also control the motor using the application. If the user turned the motor on, the DC motor automatically starts swinging the cradle. A 12V relay is used for controlling the current. Micmon [21] is an ML-powered library to detect sounds in an audio stream, either from a file or from an audio input. For cry detection, we have generated our dataset by visiting children's hospitals and recording the crying sound of different babies. After recording the audio, we label the audio as a positive or negative sound. In the next phase, the system collects the data to analyze the baby's sounds based on the labels. For continuously measuring the real-time surrounding humidity change and temperature, the DHT11 sensor is attached to the raspberry pi 4 controller, which sends the values to the Blynk server. If the temperature degree is higher than 23C or less than 16C, the GPIO pins will be activated and a notification is sent to the parents about the irregular temperature level. For live streaming, a camera is used which is connected to a Raspberry Pi. We have created a server and assigned the IP address of the server to the Blynk application. There is no restriction for the parents to have the same network for the cradle and a mobile application. Using this application, parents can see a live video of their baby at any time and any place.

5.2. Face Detection and Emotion Recognition

The most crucial component of our technology is the machine learning approach we employ to automatically identify the baby's emotion from live stream data. The baby's face can be accurately captured by the web camera because of the way it is configured. At device registration, the user will log in and upload a photo of the infant. The user profile folder on the system contains these images. A live webcam stream is utilized to identify the baby's face using the Viola-Jones algorithm. The system will notify a user application with the message "unknown



face" if the photo taken by the camera during the live broadcast does not match the one that is saved in the system. This study proposes a unique method for recognizing facial emotions from video frames. Human facial expressions reveal details about an individual's emotional state. A person's facial expressions reveal information about their feelings. Moreover, these expressions result from modifications to certain face features including the lips, eyes,and eyebrows. Additionally, identifying the expressions leads to the detection of fundamental emotions, including fear, happiness, sorrow, rage, contempt, surprise, and many others extra. However, analyzing the photos and identifying the variations in face characteristics constitute the most popular method of deriving emotions from facial expressions. The general working technique of the suggested work is shown in Algorithm 1. A Kaggle dataset [11] was utilized by us. in order to teach our machine learning model how to recognize the baby's feelings. These photos have been categorized into six pre-established groups. These classes are divided into categories such as surprise, fear, grief, rage, and happiness. This module has been split up into three stages, which are shown in Figure 4. Initially, the video stream is captured using OpenCV, and the baby's picture is identified. These photos are taken, resized, and then grayscaled. The face has been extracted from the picture using Dlib. Our classifier receives the collected picture data in the second step. The collected face was subjected to emotion identification and categorization using the support vector machine (SVM). Ultimately, the identified face expressions are categorized into suitable emotional states. Only the parent's application notifies of emotions like surprise, happiness, and sadness.

5.3. Mobile Application

A mobile application running on the iOS or Android operating system is necessary to operate sensors using a phone. Thus, a program called "Blynk" was employed for this objective. We require an authentication key in order to establish a connection between controllers and the Blynk application. The registered email address receives the authentication token from the Blynk application, which synchronizes it with the Blynk server. Because it has several graphic interfaces and offers an easy-to-use interface with straightforward widgets, we used the Blynk program to create the dashboard. Additionally, the data collected by the used sensors is updated online and retrieved via the Blynk server and mobile application.

(a) Blynk mobile application interface

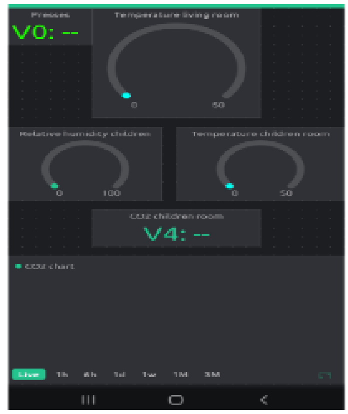


Figure 5: Blynk mobile application usage.

6. Results

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 Blynk server and Blynk mobile application. Figure 5(a) shows the main screen of our user's Blynk application with buttons to swing the cradle and to check the temperature and live stream of the baby. The values uploaded by the microcontrollers connected to the baby monitoring system to the user's application via the Blynk server are shown in Figure 5(b). The real-time humidity and temperature of the baby's surroundings were determined, and a notification was sent to the user's application if the measured temperature was not within 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. Our proposed system is intended to develop a smart baby monitoring system with emotion detection using the ML technique. For experimentation, we played a YouTube video of a baby, and different baby emotions were recorded. The captured video frame is taken as an input image, 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, as shown in Figures 5(c) and 5(d). These emotions were notified to the user application.

VII. CONCLUSION AND FUTURE WORK

Monitoring a newborn is a difficult duty for parents. Parents struggle to constantly supervise their children. Our IoT-based smart baby monitoring cradle system with emotion detection is ideal for working parents who want to keep an eye on their child at all times. The technology alerts working parents to anomalous activity, such as a baby crying, through an app notification. To test the prototype, a wailing baby ringtone was played on a phone and placed near the cradle, triggering an immediate notice to the parents. When the infant cries, the system swings the cradle and sends a notification to the user's mobile phone. The algorithm can identify emotions in recorded newborn faces and find unfamiliar faces. The prototype was tested using a baby video from YouTube. The camera detects faces and alerts parents with "unknown face detected" notifications. We assessed the emotion's feasibility using a machine-learning model on a video of a registered newborn. The algorithm detects six types of emotions, but only happy, sad, and surprise emotions are informed to parents through the app. The suggested solution allows parents to monitor their newborn through internet streaming via webcam. Parents may use the same network for both mobile applications and external cameras. Parents may monitor their infant in real-time by setting up the key supplied by the Blynk program.

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