Arab American University

Faculty of Engineering

Computer Systems Engineering

SENIOR PROJECT (II)

SMART CRIB FOR INFANTS (SCFI)

2025

Students Statement

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Supervised by: Prof. Hazem Khanfar

Computer Systems Engineering Dept.
Submitted in partial fulfillment of the requirements of B.Sc. Degree in Computer Systems Engineering

2025

Supervisor Certification

This to certify that the work presented in this senior year project manuscript was carried out under my supervision, which is entitled:

“**SMART CRIB FOR INFANTS (SCFI)**”

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I hereby that the aforementioned students have successfully finished their senior year project and by submitting this report they have fulfilled in partial the requirements of B.Sc. Degree in Computer Systems Engineering.

I also, hereby that I have read, reviewed and corrected the technical content of this report and I believe that it is adequate in scope, quality and content and it is in alignment with the ABET requirements and the department guidelines.

Prof. Hazem Khanfar,

ACKNOWLEDGMENT

First and foremost, we express our heartfelt gratitude to God for guiding us towards success. We acknowledge our deep appreciation to our loving parents for their unwavering support and prayers. We are also grateful to our supervisor, Prof. Hazem Khanfar, who was always ready to listen and provide valuable advice throughout this project.

We extend our gratitude to everyone who has taught us and to our friends and families. Thank you all for your support.

Lastly, we would like to express our sincere appreciation and thanks to ourselves for our dedicated and steady commitment to the success of this project.

ABSTRACT

With the development of life aspects and the increase in the percentage of workers in various fields, a problem has emerged that parents suffer from monitoring their infants continuously while they are in their crib, in addition to their inability to determine the reason for their crying and give them the appropriate solution. In this project, we present a solution to this problem using a prototype of a smart crib for infants supported by artificial intelligence, which provides many features that aim to facilitate the care and continuous monitoring of the infant in his crib.

The model consists of several integrated systems where the crib contains a surveillance camera that can identify the infant using artificial intelligence. It is connected via an application on the parent's phone, enabling them to see the infant at any time. In addition to the temperature and humidity sensor that gives continuous room temperature and humidity readings and displays them in the application. A microphone is also used to receive the sound and using artificial intelligence, the infant's voice is identified and distinguished if the sound is crying or another sound, and the causes of crying are determined, accordingly the system rock the crib and plays music and toys automatically. After that, a notification containing the result of the reason for crying is sent to the parent's phone. Of course, the system will always remain in the event of crying.

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LIST OF SYMBOLS AND ABBREVIATIONS

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₪	ILS
LIST OF ABBREVIATIONS	
SCFI	Smart Crib For Infants
IOT	Internet Of Things
WIFI	Wireless Fidelity
AWS	Amazon Web Services
DC	Direct Current
MP3	Mpeg Audio Layer-3
ARM	Acorn RISC Machine
IOS	iPhone Operating System
UI	User Interface
AI	Artificial Intelligence
UML	Unified Modeling Language
RAM	Random Access Memory
USB	Universal Serial Bus
PCs	Personal Computers
DHT11	Temperature And Humidity Sensor
USB-C	Universal Serial Bus Type-C
IC	Integrated Circuit
YOLO	You Only Look Once
v11	Version 11
CNN	Convolutional Neural Network
Pi	Python Interpreter
OS	Open System
SD	Secure Digital
SSH	Secure Shell

VNC	Virtual Network Computing
GUI	Graphical User Interface
iOS	iPhone Operating System
GHz	Giga Hertz
GB	Giga Byte
°C	Celsius
W	Watt
V	Volt
A	Ampere
NoSQL	Not Only Structured Query Language
JSON	JavaScript Object
HTTP	Hypertext Transfer Protocol

1. CHAPTER 1: INTRODUCTION

1.1 PROBLEM STATEMENT AND PURPOSE

As a parent, supporting your child becomes crucial and sometimes essential in today's highly dynamic world. With over 141,000 babies born in Palestine by the end of 2022 [1]. The demand for effective childcare solutions is higher than ever. Regular cribs do not provide real-time monitoring, making it difficult for parents to balance their work and routine while keeping an eye on their children. This project provides the solution in the form of a smart crib and an easy-to-use app. Using IoT and AI technology, the crib can monitor the baby in the crib, the temperature and humidity of the room, identify the baby's crying and its cause using AI, and can be controlled remotely. These transmission features check on the parents' health and ensure better sleep for their children.

1.2 PROJECT AND DESIGN OBJECTIVES

We are developing a product that can be called a "smart crib" connected with a smartphone application. With this, we would like to help parents in their lives by facilitating their continuous monitoring of their child while allocating more time to other aspects of life. Our primary goals are to develop a safe product for infants that can be used all the time without affecting them and is easy for parents to use. We aim to include accurate sensors that help parents know the child's condition without touching the child. Developing an easy-to-use application interface for parents, regardless of their level of technology development, to easily control their child's bed remotely.

1.3 INTENDED OUTCOMES AND DELIVERABLE

In this project, we have developed a prototype of an AI-powered smart bed connected with sensors, a camera, a microphone, a speaker, and toys for the baby. The product is also connected to a mobile app to receive notifications and control the crib remotely. The intended outcomes and deliverables of our project are outlined below:

- Smart baby crib:
    - Deliverable: Smart baby crib equipped with sensors, camera, microphone and motors to monitor and soothe the baby.
    - Outcome: Facilitates parents' care of the baby, ensuring safety and comfort while providing continuous monitoring
- Mobile application:

   - Deliverable: Easy-to-use application created using the flutter and supports parents in monitoring the crib and external control of it.

   - Outcome: Enables parents to receive updates on the baby's condition including direct monitoring, reason for crying and room temperature readings. In addition to manual crib control options such as rocking the crib, playing music and toys

- AI-powered object detection:

   - Deliverable: A pre-trained model based on the Yolo system to ensure the presence of the child in the crib.

   - Outcome: Detecting the presence of the child to operate the child-related effects such as voice analysis and other resulting commands.

- AI-powered cry detection and analyzing:

   - Deliverable: A pre-trained model to analyze the child's voice and identify the causes of crying.

   - Outcome: Helping parents identify the child's needs and address them quickly, which reduces stress and response time becomes fast.

- Seamless Connectivity and Data Management:

   - Deliverable: Integration between the server and Firebase to manage and process data and facilitate data transfer between all necessary project resources.

   - Outcome: Ensuring real-time data processing and secure communication between hardware and software components in the system.

- Temperature and humidity monitoring:

   - Deliverable: Integrating a temperature sensor to provide real-time room temperature and humidity readings and sending them to the phone application Mobile.

   - Outcome: Help parents maintain a comfortable environment for the baby.
- Automatic crib functions:

- Deliverable: Rocking the baby when crying, playing music and interactive baby toys that are controlled manually or automatically.

- Outcome: Help parents calm the baby when crying, providing a comprehensive care experience.

- Documentation and training materials:
  - Deliverable: Comprehensive documentation in detail about the smart crib system and instructions on how to operate and handle it.
  - Outcome: Support users in the effective use of the system and maximizing its benefits.

1.4 SUMMARY OF REPORT STRUCTURE:

Chapter one included the objectives and introduction ,Chapter two provides background information ,Chapter three explains the methods and materials used , Chapter four result and Discussions, Chapter five covered project management and Chapter Six went into detail about the engineering impact of the solution. The proposed conclusions and proposals were discussed in the seventh and final chapter.

2. CHAPTER 2: BACKGROUND

2.1 OVERVIEW

Many parents may not be able to spend all their time watching their babies due to their busy schedules or sleeping at night, but babies need to be monitored 24 hours a day. This makes monitoring more difficult, which can be stressful for the family during the process of putting the baby to sleep and staying up late. A suitable solution must be found to ensure comfortable sleep for the babies and comfort for the parents.

Traditional methods of childcare require a lot of manual intervention, which can be time-consuming and stressful for them. Recent developments in the described systems and smart technologies offer a solution by automating many of these tasks. The described systems integrate hardware and software to perform specific functions, and when applied to childcare, they can significantly reduce the burden on parents. As technology and machine language evolve and enter all areas of life.

With this in mind, we present the smart baby crib project that seamlessly integrates with the mobile application to provide unparalleled peace of mind for parents. The innovative crib is equipped with machine learning technology using object detection to check whether the baby is in the crib or not, and it also allows it to receive the baby's voice and analyze it using artificial intelligence, a trained model to analyze the sound and provide a report on the reason for crying, and start the rocking process that simulates the parents carrying the baby, also play a baby toys in addition to the ability to play soothing music from built-in speakers, which will encourage the baby to relax. The crib is connected to the parents' phone wirelessly through the application, which in turn sends notifications to the parent. The application allows parents to fully control the crib remotely, so they can rock the crib, play baby toys and music, and watch the baby directly through the camera, in addition to displaying a report on the room temperature and the reason for crying. This application help revolutionize child care technology, as it combines advanced features and intuitive design to redefine comfort, safety and well-being for parents.

2.2 RELATED WORK

With the development of technology and its entry into the world of child care. Several projects have been developed using different strategies. These projects focus on reduce the problems that parents suffer in monitoring their children. These projects facilitate the process of caring for children. In this section, we present some of these systems. Each system presents some solutions from different points of view. Each system focuses on separate topics.

2.2.1 SMART CRIB

The general idea of the smart crib project is to ensure safe monitoring of the infant inside his crib. Figure 2.1 shows the project's function. it consists of several sensors that work together to monitor the child's vital signs in a contactless manner. The temperature sensor senses the child's temperature and links the readings with the phone application, in addition to the noise sensor uses an accelerometer, which senses movement around the child and inside the crib, and through it is determined whether the child is awake or not, and also the 4x weight sensor. Which monitors the child's growth over the days. As for the heartbeat, it is monitored through a pulse sensor is a heart rate sensor that monitors the heartbeat and sends the readings to the phone application. If any danger occurs with these readings, notifications are sent to the application, which in turn informs the parents of the possible danger.

The application enables parents to monitor their child by directly opening the camera installed above the child. The application connects with used parts using a WIFI transceiver. It was programmed using AWS mobile, Android Studio, and GitHub [2].

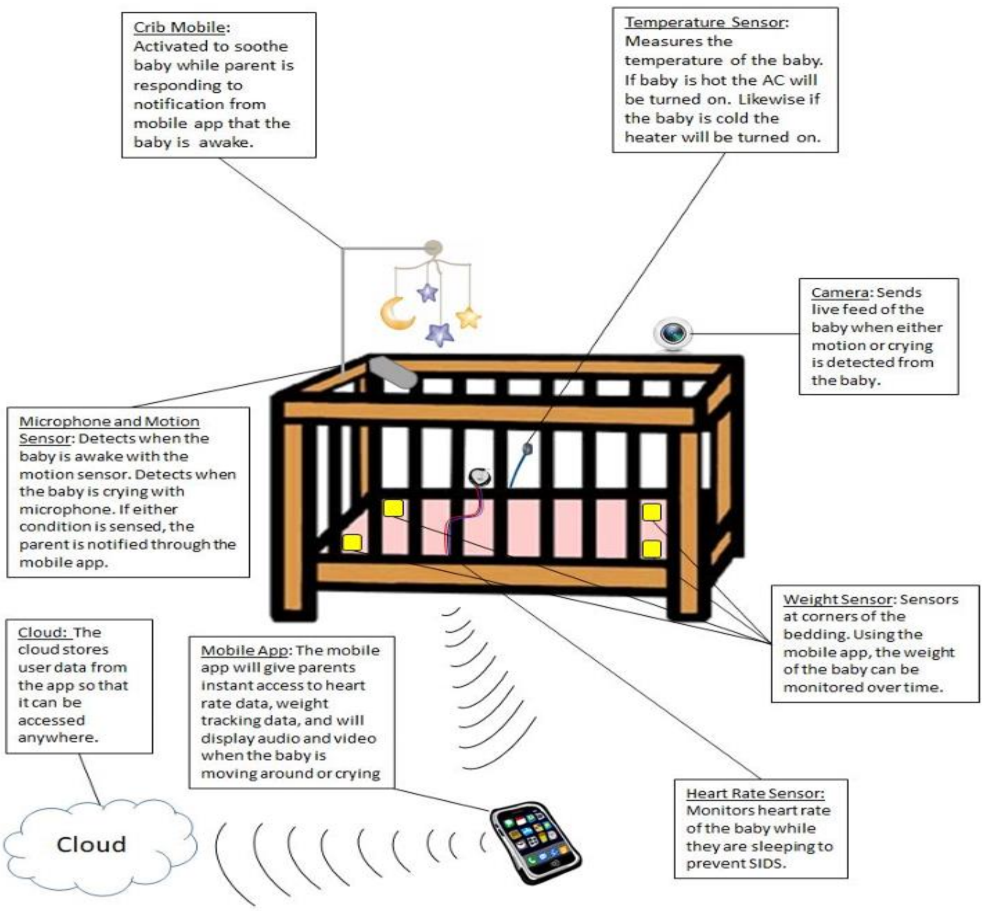


Figure 2. 1 Smart Crib General Description

2.2.2 SMART BABY CRIB

The idea of this project revolves around providing comfortable sleep for children through a smart crib as shown in Figure 2.2 The crib operates in two modes, manual and automatic. In manual mode, the baby's crib swing is controlled through the phone application through the DC Motor and H-Bridge L298N. And start playing music through MP3-Player.

In automatic mode, when the baby starts crying, the crying is detected using high frequency through the sound sensor (KY-37). The crib sways and music are played until the baby stops crying and sends a message to the mobile phone. To request immediate attendance and follow up on the child’s condition [3].

Figure 2. 2 The prototype system for the SMART BABY CRIB

2.2.3 AUTOMATIC BABY CRADLE

This project is a smart crib for children as shown in Figure 2.3. It contains several features, the most important of which is recognizing the child's crying so that when the child cries, the crib starts rocking automatically for five minutes. During this time, a soothing sound is played to calm the child, the room temperature and the humidity of the child's towel are measured, and a text message is sent to the mother to alert her. Of course, this project is beneficial for struggling families that work as a whole, and it also helps nurses in hospitals or nannies in nurseries [4].

Figure 2. 3 The prototype system for the AUTOMATIC BABY CRADLE

Table 2.1 shows similarities and differences between our project and the previous project mentioned in the related work section.

Table 2.1 Comparison Table Between Projects

	Similarities	**Differences**
SMART CRIB	1. Using a mobile application. 2. Using a camera. 3. Using a temperature sensor. 4. Using a microphone.	1. Using AI to detect the infant's sound. 2. Using AI to detect and track the infant. 3. Rocking the crib. 4. Turn on the music. 5. Turn on the crib toys.
SMART BABY CRIB	1. Using a mobile application. 2. Rocking the crib. 3. Turn on the music.	**1.** Using AI to detect the infant's sound. **2.** Using AI to detect and track the infant. **3.** Using a camera. **4.** Using a microphone. **5.** Using a temperature sensor. **6.** Turn on the crib toys.
AUTOMATIC BABY CRADLE	1. Using a temperature sensor. 2. Using a microphone. 3. Rocking the crib. 4. Turn on the music. 5. Turn on the crib toys.	1. Using AI to detect the infant's sound. 2. Using AI to detect and track the infant. 3. Using a camera. 4. Using a mobile application.

The three smart baby crib projects analyzed exhibit a set of common functions. They were intended to improve childcare by integrating technology. However, each project is limited to one or two features in a traditional way. The first project (“Smart Crib”) measures the baby’s temperature by touching the baby’s body and displays crying alerts, while our project expands the functionality by analyzing infant sounds using AI and includes a vibration feature to soothe the baby and play music and games in case of crying, and our project provides AI tracking and exploration of the baby in the crib. The second project (“Smart Baby Crib”) and the third project (“Automated Baby Cradle”) share features such as crib shaking and music playback, but they lack AI-based sound analysis and AI-based camera monitoring.

CHAPTER 3: METHODS AND MATERIALS

3.1 SYSTEM DESIGN AND COMPONENTS

3.1.1 SYSTEM DESIGN:

In this section, Figure 3.1 shows a schematic diagram of the system architecture and explains how it works. In addition, we review all the hardware components that were used in our system.

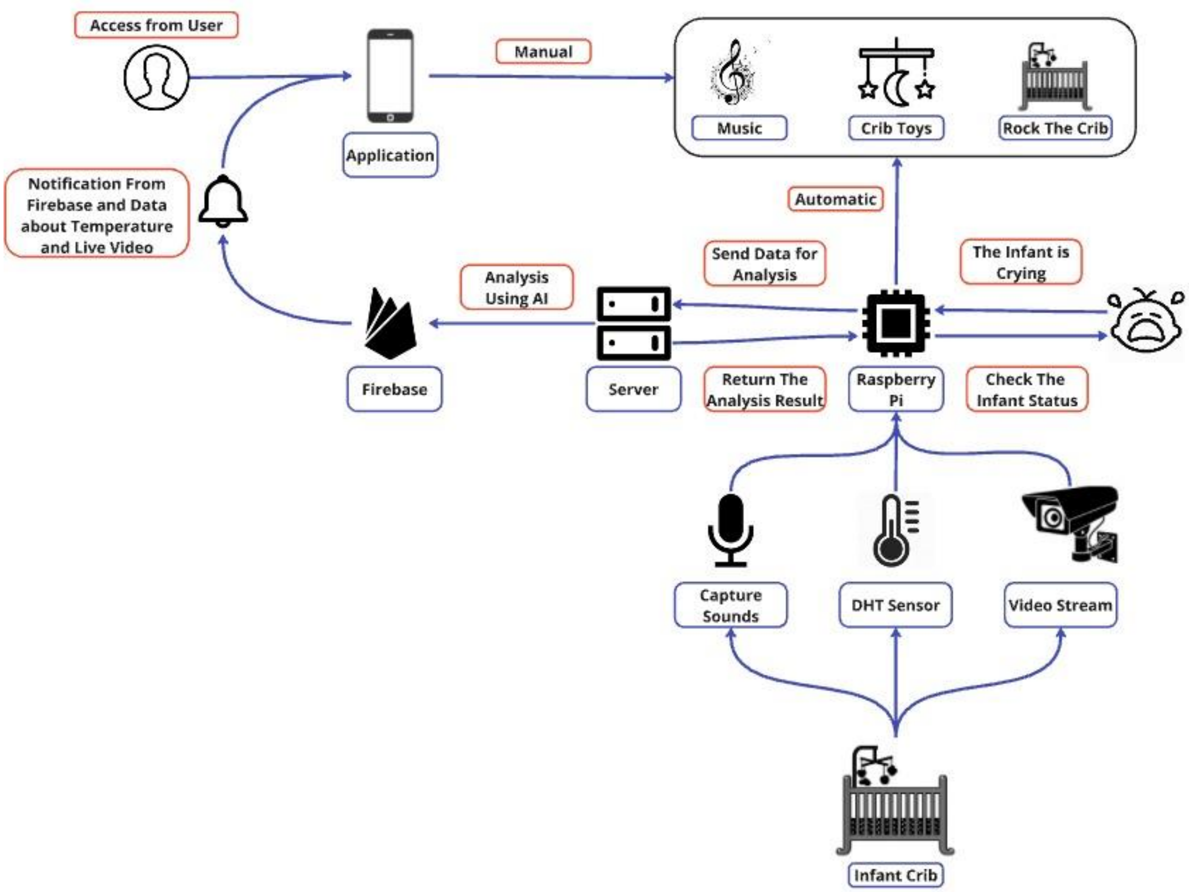


Figure 3. 1 Smart Crib for Infants system architecture Block Diagram

These points provide a summary of the block diagram:

- The Raspberry pi starts sending live video from the camera to the server to process them using an AI-trained model to identify whether there is a child in the crib or not and send the result to the Raspberry pi.

- If the result is that the child is in the crib, the Raspberry pi turns on the microphone, records an audio and sends it to the server for processing.

- The data is processed inside the server using AI to determine whether the sound is crying or not and sends a notification about the reason for the crying to the application, in addition to sending a signal to the Raspberry Pi.

- The Raspberry Pi plays music on the speakers, rocks the crib and plays children's toys.

- When parents open the application, they can watch a live video of the child with the room temperature and humidity and a report on the reason for the child's crying, and they can also rock the crib and play music and children's toys manually through the application.

3.1.2 HARDWARE COMPONENTS

In this section, the main hardware component of our project will be shown.

3.1.2.1 Raspberry Pi 4

The Raspberry Pi 4 Model B which shown in Figure 3.2 is the latest and most advanced Raspberry Pi, working as a small, powerful single-board computer designed to perform a lot of computing tasks like word processing, gaming, internet browsing, and high-definition video playback. It is equipped with a 1.5GHz quad-core ARM Cortex-A72 processor, available in configurations of 2GB, 4GB, or 8GB of RAM, and equipped with dual-band Wi-Fi, Bluetooth 5.0, Gigabit Ethernet and USB 3.0, it delivers desktop-like performance rivaling entry-level PCs. the Raspberry Pi 4 delivers exceptional performance for personal, educational, and IoT projects, blending flexibility with cutting-edge features [5].

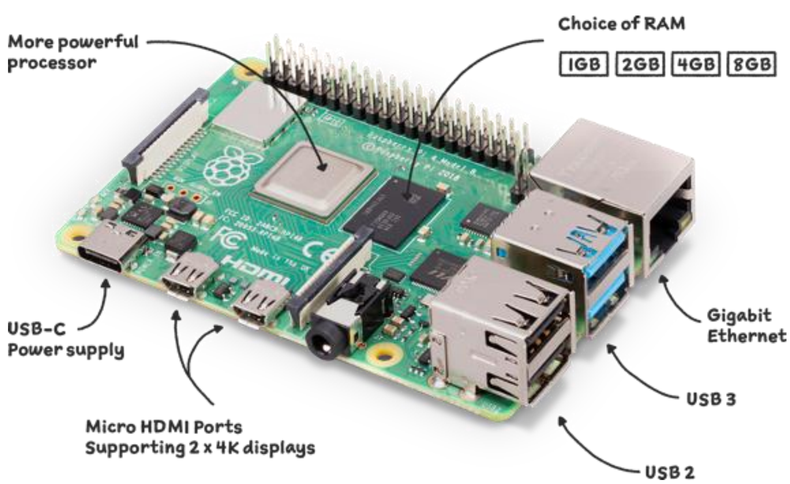


Figure 3. 2 RASPBERRY PI 4

3.1.2.2 Microphone:

A device called a microphone, as shown in Figure 3.3, it works to convert sound waves into electronic signals for recording or playback through a speaker.

The YOUMI Mini USB 2.0 Microphone use in our project is a compact, high-quality option designed for convenience and versatility. it requires no drivers to operate on Windows 10 or earlier. Despite its small size, the YOUMI Mini USB Microphone delivers powerful performance, making it a great choice for both professional and personal use.

Figure 3. 3 Microphone

3.1.2.3 USB Camera.

USB camera also known as web camera is a digital camera that connects to the computer via Universal Serial Bus port as shown in Figure 3.4. This type of camera is designed to capture video and images. The design of this type of camera helps us to place it in suitable positions for the bed and capture video in high quality [6].

Figure 3. 4 USB Camera

3.1.2.4 DHT11 Temperature-Humidity Sensor

This is a digital temperature and humidity module as shown in Figure 3.5 with built-in DHT11 sensor. It can be used to detect temperature and humidity, through a standard single wire interface. It has a temperature range of 0°C - 50°C with an accuracy of ±2°C and a humidity range of 20% - 90% with an accuracy of ±5%. Compact and energy-efficient, the DHT11 is perfect for our project because we requiring real-time environmental data [7].

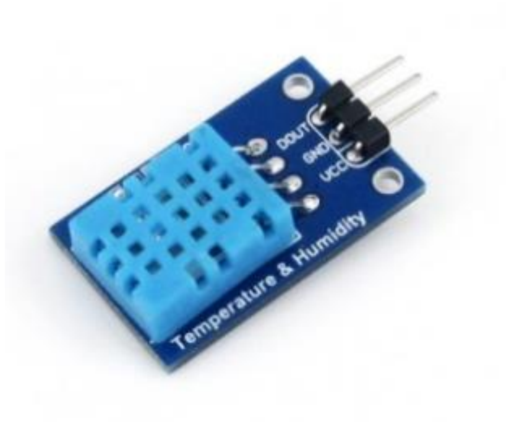


Figure 3. 5 DHT11 Temperature-Humidity

3.1.2.5 Speaker Module:

The speaker module as shown in Figure 3.6 is a small and compact module that can be used to play MP3 audio files. This module can play pre-loaded music or sounds to soothe the baby. Which can be controlled by Raspberry Pi 4.

Figure 3. 6 Speaker Module

3.1.2.6 DC Motor

Is an electrical motor see in Figure 3.7 that uses direct current (DC) to produce mechanical force. The most common types rely on magnetic forces produced by currents in the coils. A DC motor's speed can be controlled over a wide range, using either a variable supply voltage or by changing the strength of current in its field windings. It will be convenient to use it to play children's toys [8].

Figure 3. 7 DC Motor

3.1.2.7 Power supply unit via USB:

The Raspberry Pi 15W USB-C Power Supply as shown Figure 3.8 is designed to power the Raspberry Pi 4. This reliable, high-quality power supply comes with a USB cable and provides 5.1V/3.0A DC output power through the USB-C port to power the Raspberry Pi 4. [9].

Figure 3. 8 Power supply unit via USB

3.1.2.8 Children's toys:

They are rotating toys as shown in Figure 3.9 that are hung above the child's crib and we will control it using DC motors.

Figure 3. 9 Children's toys

3.1.2.9 Baby crib:

A wooden crib with a comfortable design, as shown in Figure 3.10 , that allows the electronic components of the system to be integrated with the crib in a proper way that allows all components to work properly. In addition to a small cabinet that allows the components to be protected.

Figure 3. 10 Baby crib

3.1.2.10 Servo motor:

A servo motor as shown in the Figure 3.11 is a motor that rotates with great precision. It is equipped with a control circuit that provides real-time feedback about the position of its shaft we use it in our project to rock a baby's crib when he cries with regular movements and a specific speed [10].

Figure 3. 11 servo motor

3.1.2.11 Breadboard:

A breadboard is a rectangular plastic board with a series of small holes as shown in Figure 3.2.11. These holes allow us to easily insert electronic components to create a prototype of an electronic circuit. We have collected all the connections for the electronic parts through the breadboard [11].

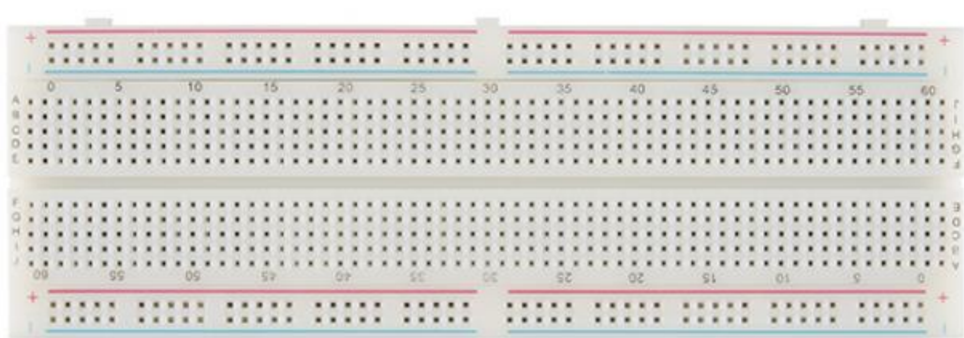


Figure 3. 12 Breadboard

3.1.2.12 Wires:

The wires shown in Figures 3.13, 3.14, and 3.15 are used for connections in our project, including female-to-female jumper wires, male-to-male jumper wires, and female-to-male jumper wires.

Figure 3. 13 Female to Male jumper wires

Figure 3. 14 Female to Female Jumper Wires

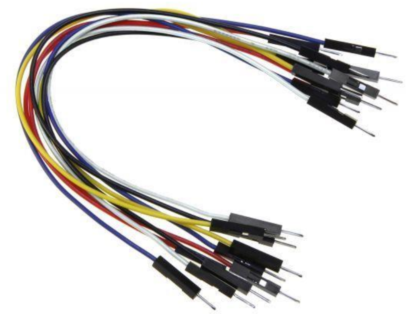


Figure 3. 15 male to male Jumper Wires

3.1.2.13 L298N Motor Driver Module

The L298N motor driver as shown in figure 3.16 is a high-power motor driver module for driving DC motors. It is built around the L298N dual H-Bridge motor driver IC, which allows control of two motors simultaneously. The module supports operating voltages from 5V to 35V. The L298N is commonly used in robotics, smart cars, and automation systems, where precise motor control is essential [12].

Figure 3. 16 The L298N motor driver

3.1.3 CONNECTING THE CIRCUIT:

After determining the components of the project. Figure 3.17 shows the circuit design with the component, and how the electronic components are connected to each other and to the Raspberry Pi.

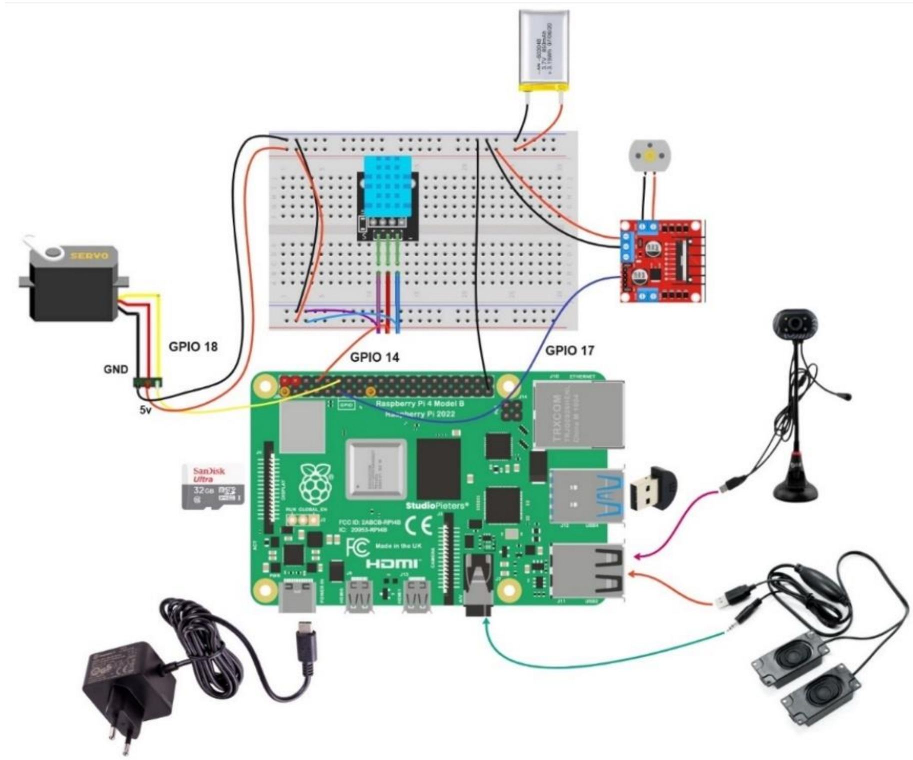


Figure 3. 17 Circuit Design

3.1.4 SOFTWARE COMPONENTS:

- **Python to Control the Raspberry Pi:**

  Python, an interactive, interpreted, object-oriented programming language, derives its popularity from its simplistic design philosophy and easy syntax. It is the most popular programming language utilized to software the Raspberry Pi because it is relatively easy to learn and there are many libraries available. The “Pi” in Raspberry Pi refers to “Python Interpreter,” which implies that this is the designated language for that platform [13] [14].

- **Raspberry Pi OS & Imager:**

  Raspberry Pi requires an operating system to work. The operating system for raspberry Pi is formerly known as Raspbian specifically optimized for Raspberry Pi devices as shown in Figure 3.18. It offers simple usability and comes with programming, multimedia, and general computing tools. Raspberry Pi Imager is the quickest way to set up Raspberry Pi OS or any other compatible operating system onto an SD card. The user can simply select the operating system and write it to the SD card so that the Raspberry Pi can be ready [15].

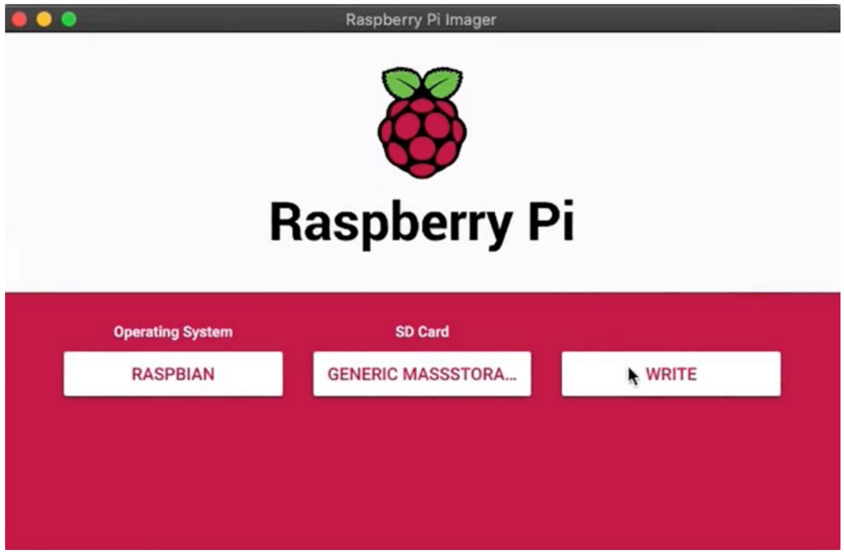


Figure 3. 18 Raspberry Pi Imager

- **PUTTY:**

  Is a free and lightweight SSH client for Windows and other platforms. It allows users to establish secure connections to remote devices like Raspberry Pi. Its ease of use and reliability make it a popular choice for remote device access [16].

- **VNC (Virtual Network Computing):**

  The virtual network computing protocol allows graphical access to the Raspberry Pi from other devices as shown in Figure 3.19. Real VNC is included in Raspberry Pi OS and allows users to view and control the Pi desktop across the network. VNC is especially useful with GUI-type applications; this provides an efficient and effective way for remote management and development [17].

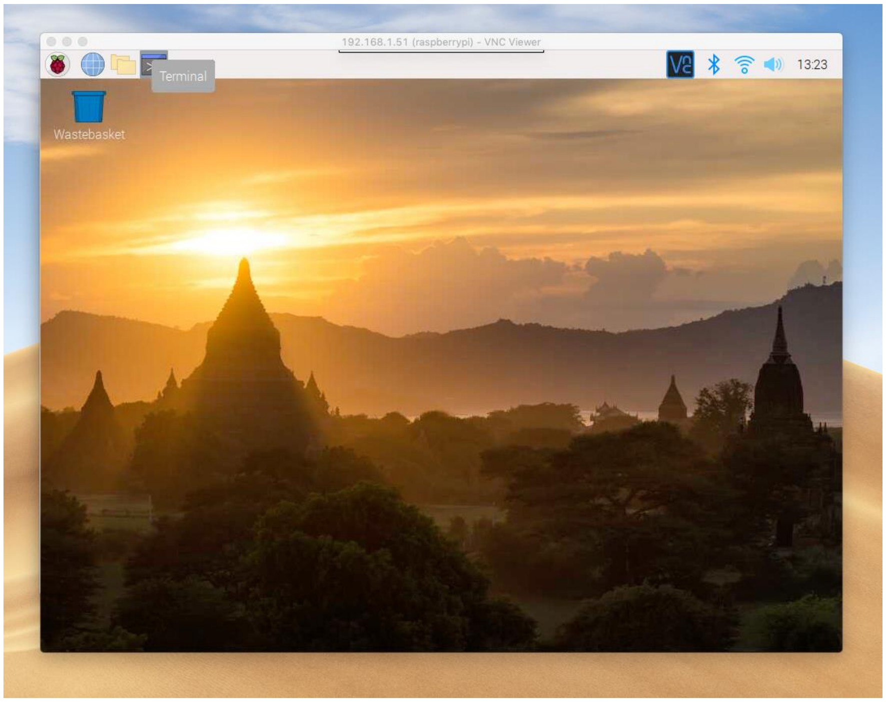


Figure 3. 19 Real VNC

- **YOLO v11: Real-Time object detection:**

  YOLO v11 is an advanced version of the YOLO (You Only Look Once) series designed for real-time object detection. The YOLO algorithm takes an input image and utilize a simple deep convolutional neural network to identify objects in the image. the image is divided into an S×S grid, that grid cell is responsible for detecting an object if the object's center falls within that cell as shown in Figure 3.20. Each grid cell predicts B bounding boxes and their associated confidence scores. These confidence scores indicate how confident the model is that the box contains an object and the accuracy of the box's predicted dimensions [18].

Figure 3. 20 YOLO v11: Real-Time object detection

- **CNN Model for Deep Learning:**

  A Convolutional Neural Network (CNN) is a specialized deep learning model as shown in Figure 3.4. 4. It's designed to analyze and learn visual features from large amounts of data. Work by processing large amounts of data in a grid format and then extracting important granular features for classification and detection. In our project, we used it in Sound Detection because it is considered the best algorithm and gives the best accuracy rate based on the experience of many algorithms [19].

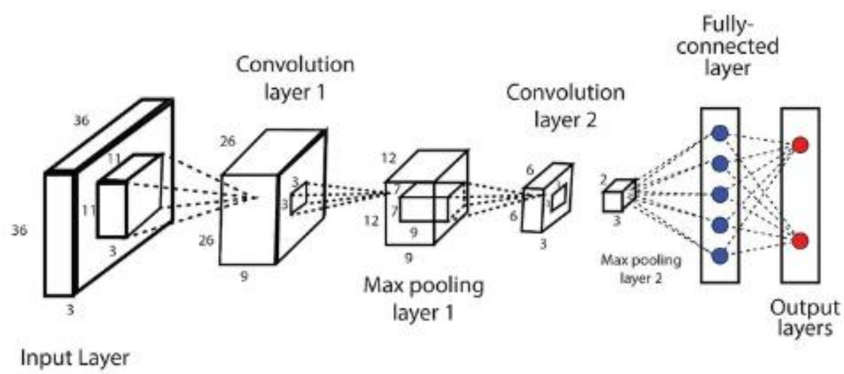


Figure 3. 21 CNN model for Deep Learning

- **Flutter:**

  Flutter is an open-source framework, developed by Google. Its single codebase allows developers to build cross-platform applications. It has the ability to create high-performance, high-fidelity iOS and Android smartphone applications, with easy implementation of touch-sensitive user interfaces through powerful animation and graphics libraries. Flutter is built on the Dart programming language, which provides a fast development process and quick loading to enable quick code changes. It is an easy-to-use language, and offers an expressive and flexible user interface based on Google's Material Design guidelines, and native performance on iOS and Android [20] [21].

The following images show some of the application interfaces written with flutter that were designed according to the previous requirements mentioned.

Our mobile application included one type of users and it is a parent so we have the same application home interface for all users. The user has his own profile that view the crib and their status. Also enables him to control it.

The mobile application opens with a welcome message on the homepage, followed by the application's icon and buttons for Sign up and log in, as shown in the Figure 3.22.

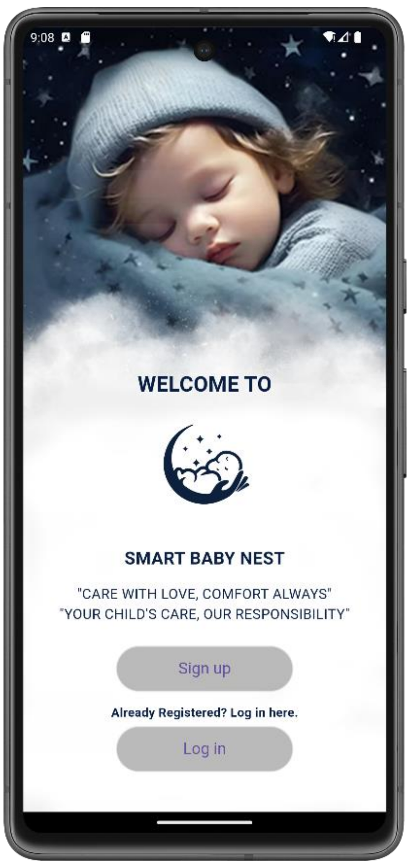


Figure 3. 22 Welcome interface

When the user clicks on the Sign-Up button, a screen will appear for him to create a new account asking him for the following information as shown in Figure 3.23.

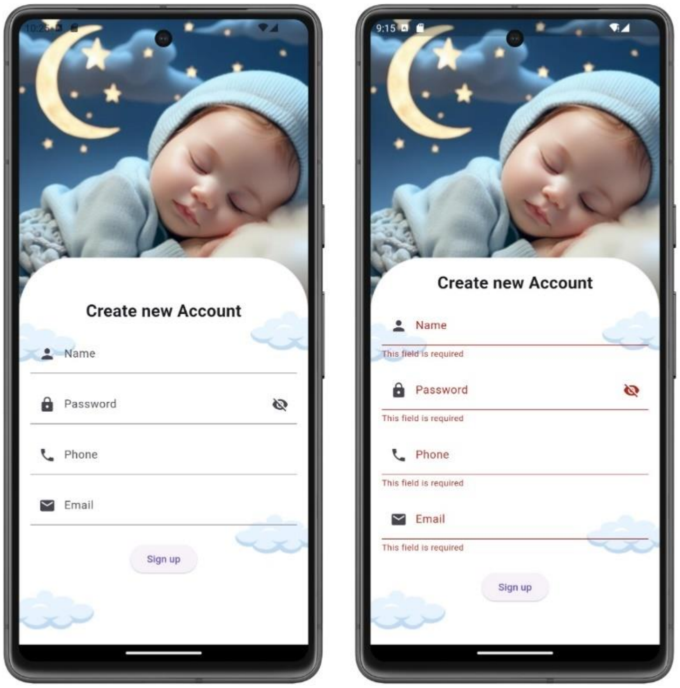


Figure 3. 23 Sign up interface

If the user has an existing account, he clicks on the Login button and the following screen appears as shown in Figure 3.24.

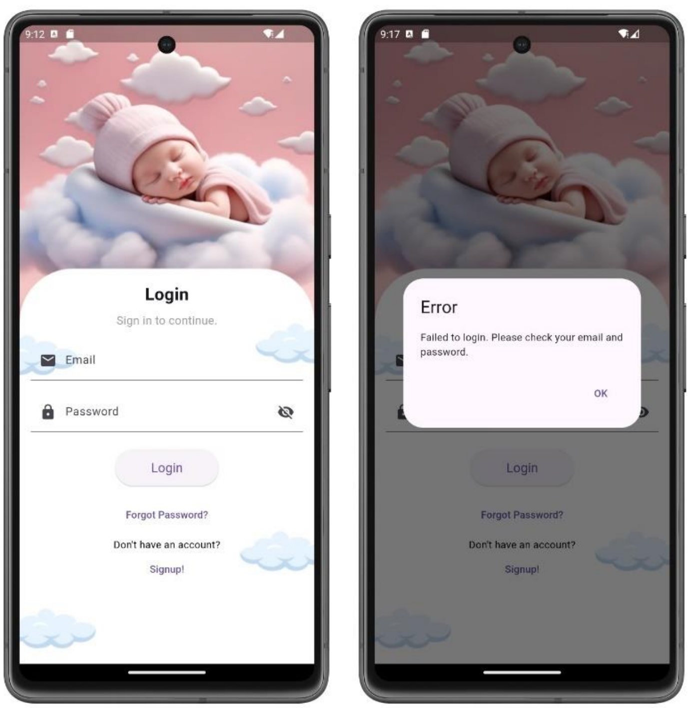


Figure 3. 24 Login interface

When the user logs in, he will move to the main interface that displays a live streaming of the child and the temperature and humidity of the room, in addition to buttons such as the possibility of manual control and buttons to navigate to notifications, settings, and the report, as shown in Figure 3.25.

The user has profile page that displays some of the functions that he can perform Such as changing the password, language, application information, and the logout feature as shown in the Figure 3.26.

After creating the account, the user logs in and clicks on the confirm email button to receive an confirmation massage to the email that entered on the sign up page, as shown in the Figure 3.27

Figure 3. 25 Main screen

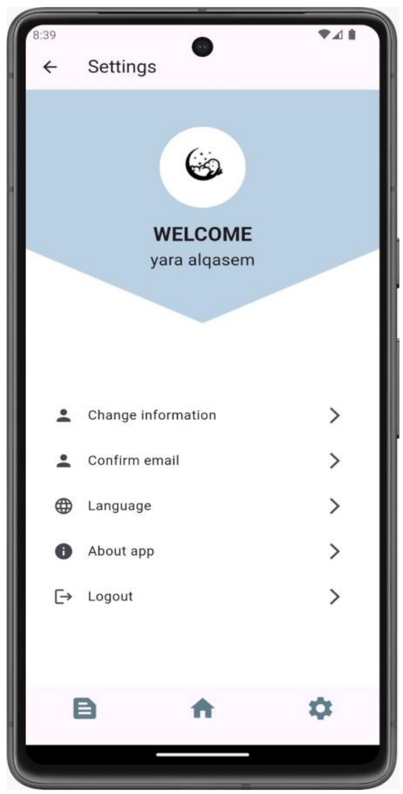


Figure 3. 26 User profile

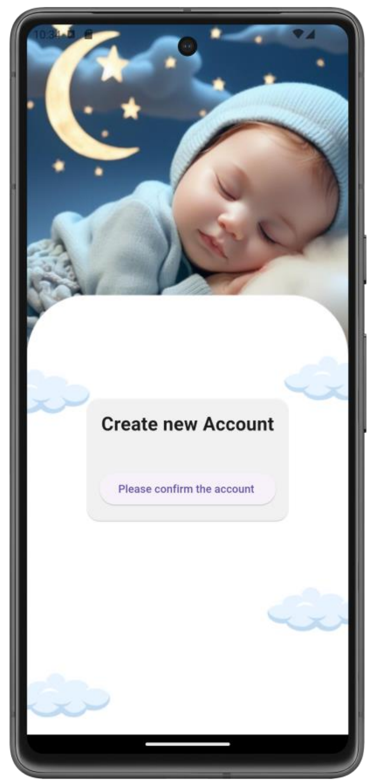


Figure 3. 27 confirm email

The Drawer in main interface displays manual control features to shaking the crib and playing music and toys as shown in the Figure 3.28.

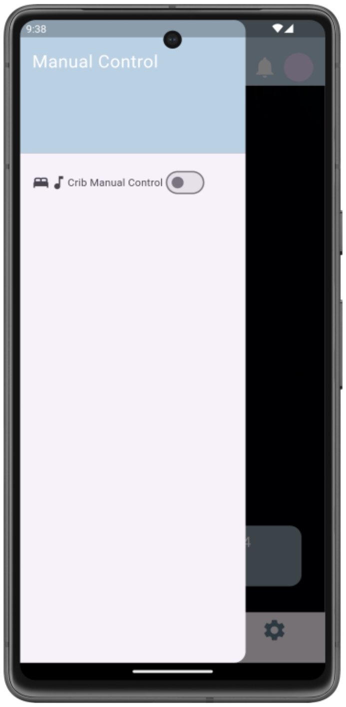


Figure 3. 28 Manual user control

From the main interface, the user can access the received notifications, which appear as in the Figure 3.29.

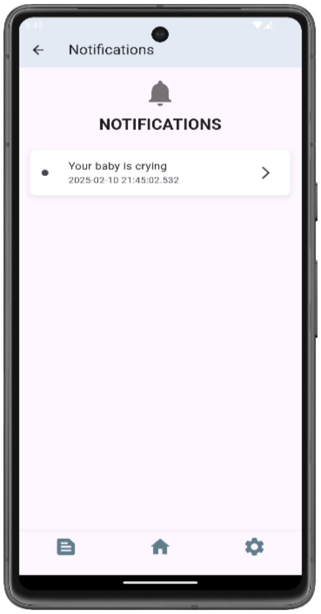


Figure 3. 29 Notifications screen

The report interface that contains a report on crying reasons along with some advice as shown in Figure 3.30.

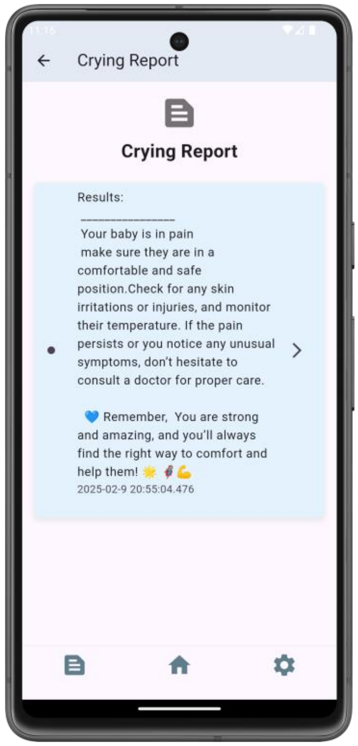


Figure 3. 30 Baby crying report screen

- **Firebase:**
    - **Firebase Realtime Database:**

      It is a NoSQL database, hosted in the cloud. Data is stored in JSON format and synced in real time with every connected client. Clients share a single virtual copy of the Realtime Database and automatically receive the latest news from the latest data. Firebase Realtime Database uses data instead of typical HTTP requests. Every time the data changes, any connected device receives that update within milliseconds. It reads and syncs data such as temperature and humidity [22].

    - **Cloud Firestore:**

      Cloud Firestore as shown in figure 3.31 is a cloud-hosted NoSQL database, documents are stored in document containers that are used to organize data and create queries. It uses Firebase Authentication, which securely stores user data in the cloud and delivers a personalized experience across all user devices. It supports authentication using passwords, phone numbers, and popular federated identity providers like Google, Facebook, Twitter, and more [23].

Identifier	Providers	Created ↓	Signed In	User UID
aseel111@gmail.com		Feb 2, 2025	Feb 2, 2025	ZOlDm7EaUcQFTq89EoenH37...
abraraaup@gmail.com		Jan 24, 2025	Jan 25, 2025	5GL0FZm0Q3af7Q7mzDFriuf...
aseel123@gmail.com		Jan 24, 2025	Jan 24, 2025	XbSs24Mb1iNRk7OEbDgBAU7...
abrar.hammo99@gmail...		Dec 9, 2024	Dec 9, 2024	XQ0XcxVGUPSYYj9n6CjPDVx...
smartcrib26@gmail.com		Dec 9, 2024	Dec 23, 2024	TJDNRRKK2eewOggkzkKyGM...
aseelmajdy123@gmail....		Dec 9, 2024	Feb 4, 2025	rb9iNaDEzxSjFP7wyC6kzrSiim...
aseelalqasem582@gm...		Dec 9, 2024	Dec 9, 2024	tebzbMMZr7W3P5nOEuKglt6...
abrar2222@gmail.com		Dec 4, 2024	Dec 4, 2024	73W0WUXYx4eEuPBHIhXud9r...

Figure 3. 31 Cloud Firestore and Authentication

3.2 DESIGN SPECIFICATIONS AND CONSTRAINTS

3.2.1 SPECIFICATIONS:

3.2.1.1 FUNCTIONAL REQUIREMENTS:

1. Temperature and Humidity monitoring & reporting:
   - The system shall monitor room temperature and humidity with a temperature & humidity sensor.
   - Temperature and humidity data will be reported to the mobile app for monitoring in real-time by the system.
2. Object detection:
   - The system shall to keep monitoring the crib by camera and detect using machine learning algorithm if the baby on the crib to start recording or not.
3. Sound detection and notification:
   - The system shall Keep recording sound when the baby in the crib.
   - Use of AI to detect and classify different types of babies crying with the system.

- When the baby starts crying, the system shall communicate this event from the cloud to the mobile application.

4. Live video streaming:

- The system shall stream live video from camera in the crib to mobile application.
- The video streaming shall provide real-time monitoring of the baby and its surroundings.

5. Crib rocking control:

- The system shall gently rock the crib when the baby cries.
- The system shall allow crib rocking control via the mobile application.

6. Music playback control:

- The system shall play music through the speaker when the baby cries.
- The system shall allow music playback control via the mobile application.

7. Playing children's toys:

- The system shall play toys when the baby cries.
- The system shall allow toys control via the mobile application

8. Raspberry pi functionality:

- The Raspberry pi shall process sensor data for temperature and humidity monitoring.
- The Raspberry pi shall perform object detection for start record the sound.
- The Raspberry pi shall perform audio analysis for cry detection.
- The Raspberry pi shall facilitate communication with the mobile application for real-time updates and control.

9. Phone application functionality:

- The system shall allow the application to see information such as room temperature and humidity, live video of a child.
- The system shall allow the user to control the system through the application, such as rock the crib, playing music playing toys.

3.2.1.2 NON-FUNCTIONAL REQUIREMENTS:

4. Reliability:
   - The system shall respond to user commands and data coming from the sensors immediately, which ensures high-accuracy control and monitoring of the children's crib in a timely manner.
   - The system shall provide a good, reliable communication channel must be provided between the sensors, Raspberry and Firebase to ensure smooth data transfer and control.

5. Performance:
   - User requests and control panel operations shall execute quickly, reducing waiting time and ensuring real-time speed.
   - Information algorithms must detect whether the child is in the crib using object detection, and trigger the recorder, allowing accurate detection of the sound and its causes in a timely manner.

6. Accuracy:
   - The system shall accurately detect and analyze data it receives and control appropriate response.
   - The system shall maintain data integrity during the transmission and storage process in order to ensure reliability of the information obtained from the sensors.

7. Affordability:
   - The total system cost shall be appropriate for the community compared with existing products in the market.

8. Usability:
   - Mobile application interfaces shall design to be user-friendly allowing users with different technical competencies using mobile applications easily.

9. Compatibility:
   - The phone application shall support all smartphone devices and operating systems and work on them smoothly.

10. Security and safety:

- Personal data collected by the crib, such as video and audio recordings, shall be kept confidential and secure.
- Access to and control of crib data is limited to permitted individuals only and communication between the mobile application and the crib controller shall be encrypted to ensure the privacy and security of user interactions, allowing only authorized users to access and control the crib features.

3.3 DESIGN ALTERNATIVE

In the Alternatives section, we explain the modifications made to certain components within our project, as well as introducing the new component that was integrated.

3.3.1 USE OBJECT DETECTION

We thought about using continuous audio analysis using AI, but in some cases the baby might be crying but not in the bed, in which case the system would work but without proper logic. So, we used AI to analyze the image and make sure the baby was in the bed before analyzing the audio to ensure proper logic for the system.

3.3.2 USE LOCAL WEB SERVER

We thought of using the Raspberry Pi as a processor to process data using artificial intelligence, but because of the large load on it and the continuous processing process that generates heat for the Raspberry, we turned to using a web server to perform the processing, analysis, and decision-making process for the Raspberry Pi.

3.4 SYSTEM ANALYSIS AND OPTIMIZATION

3.4.1 FLOW CHART:

This flow chart shows the main process of our system as shown in Figure 3.32

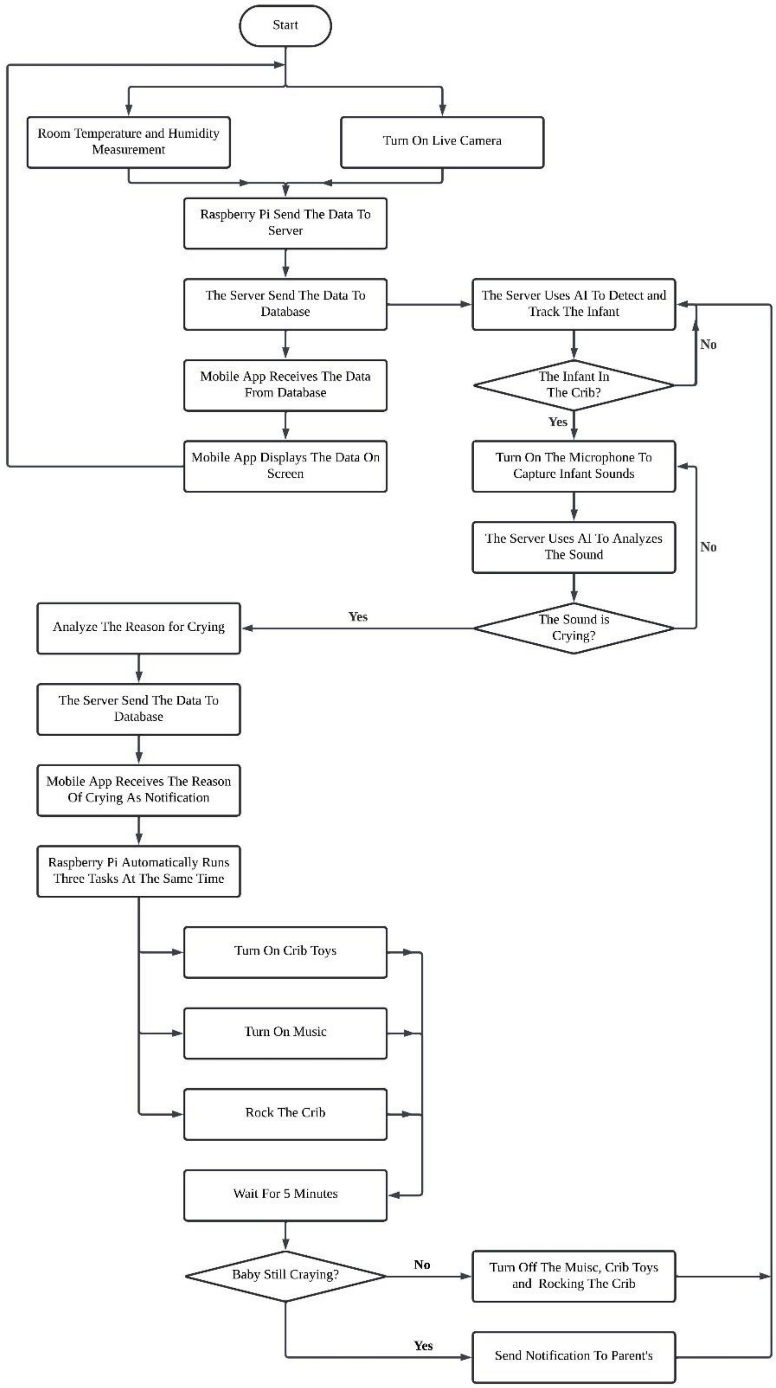


Figure 3. 32 Flow chart for Smart Crib for Infants

3.4.2 USE CASE

The use case diagram is the most important part of the UML that illustrates the actors of our system and the relationships between the use cases. The Figure 3.33, Figure 3.34, Figure 3.35 and Figure 3.36 show the use cases for our project.

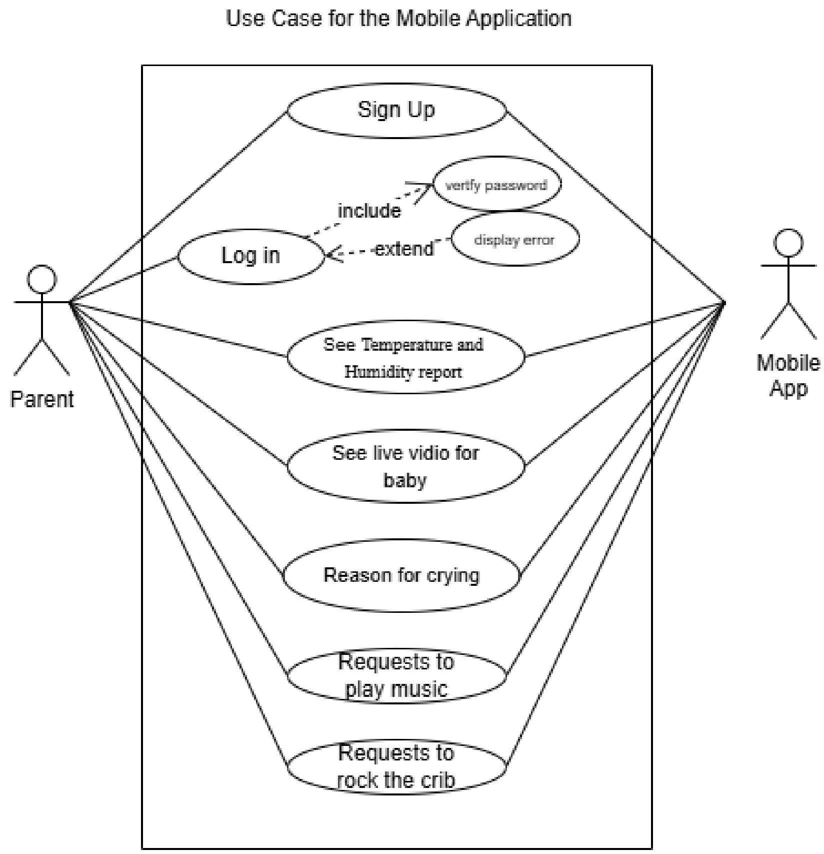


Figure 3. 33 Mobile application use case

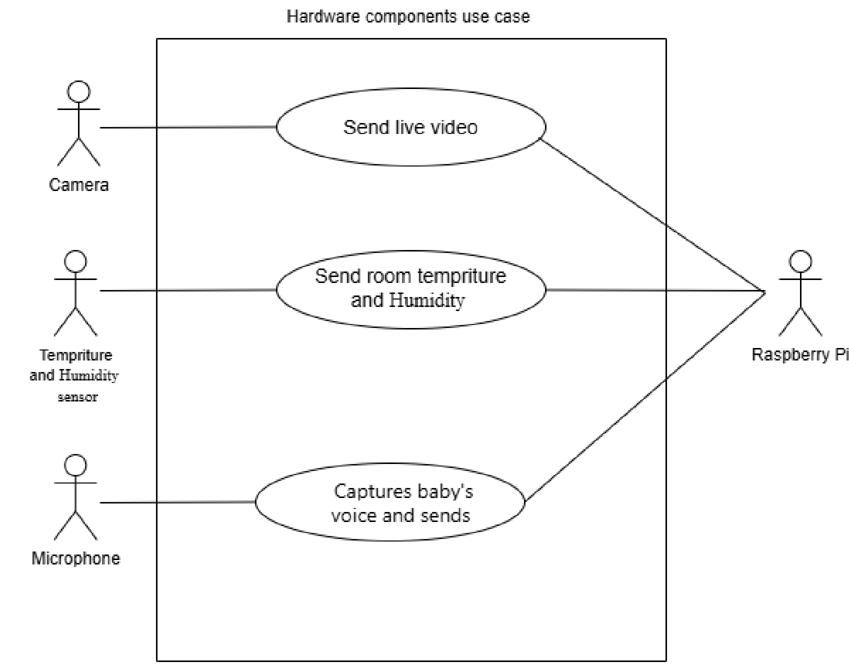


Figure 3. 34 Hardware components use case

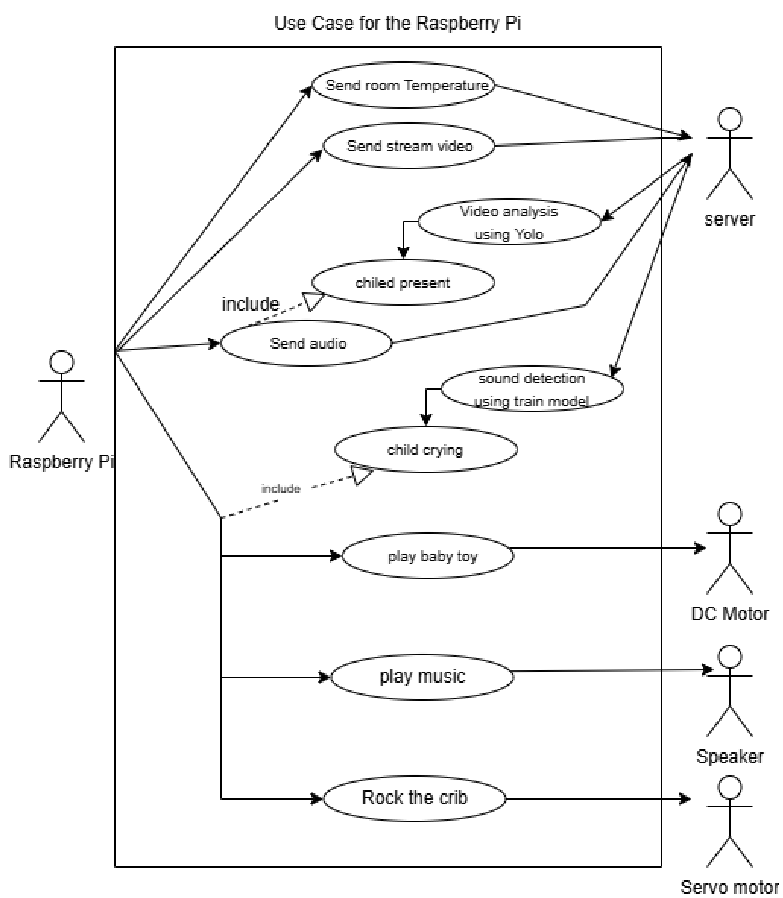


Figure 3. 35 Raspberry Pi use case

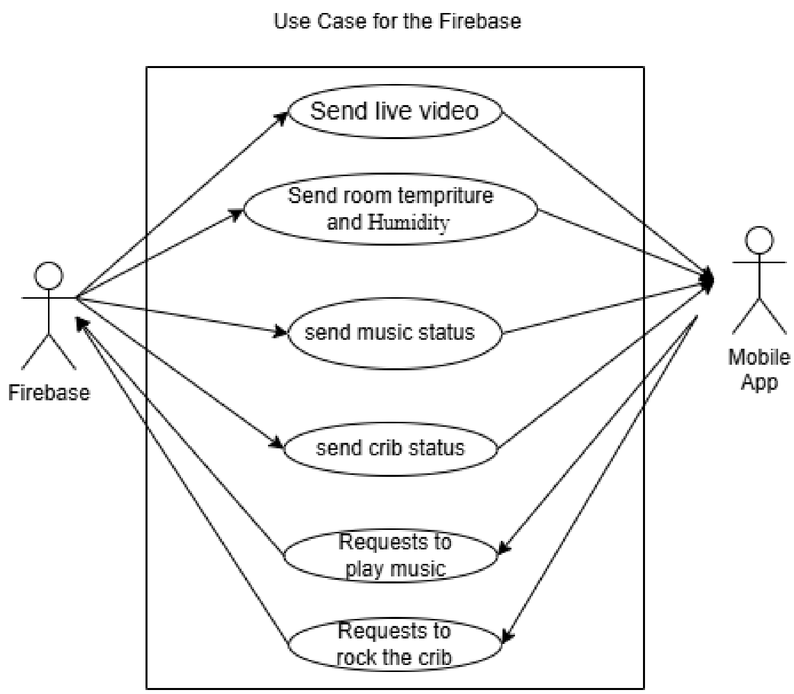


Figure 3. 36 Firebase use case

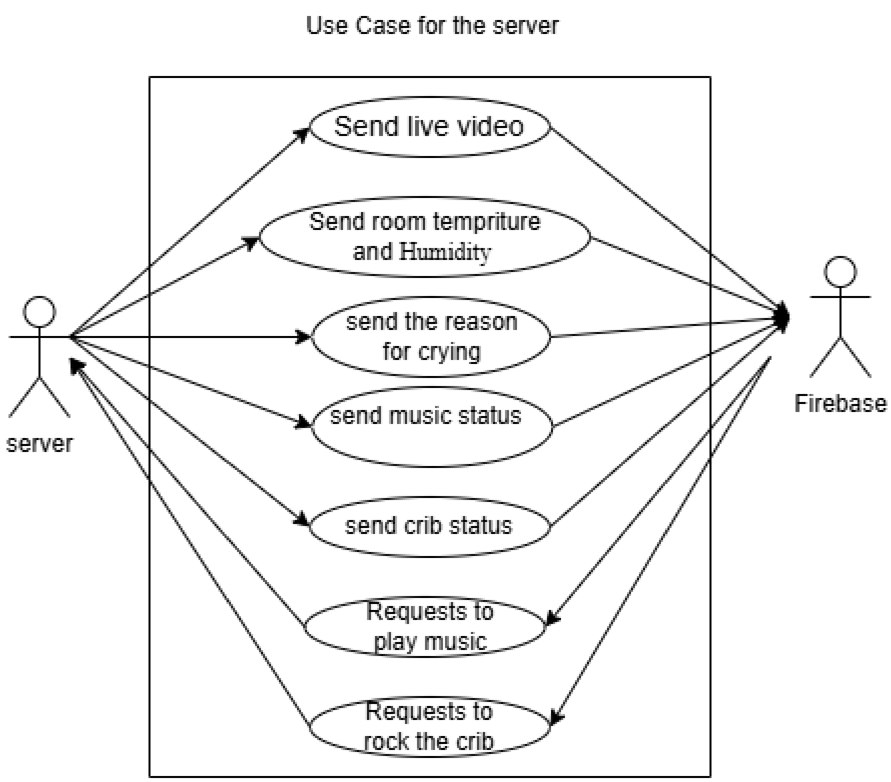


Figure 3. 37 Server use case

3.4.3 USE CASE TABLES:

Use Case 1: Sign Up

Table 3. 1 Sign up use case table

Actor(s)	Parent, Mobile Application ,Firebase
Type	Primary
Description	The parent creates a new account by entering an email, name, password, and phone number. The system verifies the email's is unique in the Firebase database before create account .A confirmation email is sent, and upon confirmation, the account is successfully created.
Pre-condition	The user must not have an existing account.
Post-condition	Account created and successfully confirmed.

Use Case 2: Log In

Table 3. 2 Login use case table

Actor(s)	Parent, Mobile Application
Type	Primary
Description	The parent enters their email and password
Pre-condition	The user must have a registered account.
Post-condition	Logged in successfully

Use Case 3: monitoring baby via the mobile application

Table 3. 3 Turn on Camera via the mobile application

Actor(s)	Parent, Mobile Application, Firebase
Type	Primary
Description	The parent watches a live video of the child in his crib via the mobile application coming from Firebase.
Pre-condition	The user must be logged into the mobile application.
Post-condition	The camera is working and the live video is being streamed. The stream is reaching the firebase properly.

Use Case 4: Manual control via the mobile application

Table 3. 4 Manual control via the mobile application

Actor(s)	Parent, Mobile Application, Firebase
Type	Primary
Description	The parent sends a request via the mobile app to Firebase to manual control for the crib.
Pre-condition	The user must be logged into the mobile application.
Post-condition	Music is playing through speaker, the crib is rocking gently and toys are playing through DC motor

Use Case 5: Send Live Video

Table 3. 5 Send Live Video

Actor(s)	Camera, Raspberry pi, server, Firebase ,Mobile Application
Type	Primary
Description	The camera captures live video and sends it to the Raspberry Pi which sends it as frames to the server which sends these frames to the Firebase which then transmits them to the mobile application for real-time monitoring.
Pre-condition	The camera and Raspberry pi must be properly connected and functional.
Post-condition	Live video is available on the mobile application

Use Case 6: Send Room Temperature and humidity

Table 3. 6 Send Room Temperature and humidity

Actor(s)	Temperature and Humidity Sensor, Raspberry pi , server, Firebase , Mobile Application
Type	Primary
Description	The temperature and humidity sensor reads the room conditions and sends the data to the Raspberry P which in turn sends the readings to the server which sends them to the Firebase which then transmits them to the mobile app.
Pre-condition	The temperature and humidity sensor and Raspberry pi must be properly connected and functional.
Post-condition	Room temperature and humidity data is available on the mobile application.

Use Case 7: Object Detection

Table 3. 7 Object detection

Actor(s)	Camera, Raspberry Pi, Server, Firebase, Mobile Application
Type	Primary
Description	The camera continuously sends video of the baby's crib to the Raspberry Pi. The Raspberry Pi sends the frames to the server, which analyzes them using the trained YOLO model to detect whether the baby is in the crib. If the baby is detected, the server notifies the Raspberry Pi.
Pre-condition	The camera must be connected and working. The server must have an object detection model, and the Raspberry Pi must be configured to process and transmit data.
Post-condition	Identify if the baby in the crib .

Use Case 8: Capture Baby's Voice and Send Reason Why Crying

Table 3. 8 Capture Baby's Voice and Send Reason Why Crying

Actor(s)	Microphone, Raspberry Pi, Server, Firebase, Mobile Application
Type	Primary
Description	When a baby is detected in the crib, the Raspberry Pi records a 10-second audio sample and sends it to the server. The server analyzes the audio to determine if the baby is crying using a trained model. If crying is detected, another model determines the cause and sends the information to Firebase, which displays it on the mobile app.
Pre-condition	The microphone must be connected and functional. The AI system must be trained to analyze crying and determine the reason..
Post-condition	The reason for crying is available on the mobile application

Use Case 9: Send Notifications

Table 3. 9 Send Notifications

Actor(s)	Raspberry Pi, Server, Firebase, Mobile Application
Type	Primary
Description	When the system detects events such as baby crying or temperature changes, the server sends a message to Firebase which in turn sends notifications to the mobile app.
Pre-condition	Specific events must be detected by the system.
Post-condition	Notification sent to the mobile application

Use Case 10: Play Music Automatically When Baby Cries

Table 3. 10 Play Music Automatically When Baby Cries

Actor(s)	Microphone, Raspberry Pi, Server ,Speaker
Type	Primary
Description	When the trained model detects that the baby is crying, the server sends a message to the Raspberry Pi that the baby is crying and the Raspberry Pi automatically plays music through the speaker to calm the baby.
Pre-condition	The microphone, Raspberry Pi, and speaker must be properly connected and functional. The system must detect the baby's crying.
Post-condition	Music is playing through the speaker automatically when the baby cries

Use Case 11: Rock the crib Automatically When Baby Cries

Table 3. 11 Rock the crib Automatically When Baby Cries

Actor(s)	Motor, Raspberry Pi, Microphone, Server
Type	Primary
Description	When the trained model detects that the baby is crying, the server sends a message to the Raspberry Pi that the baby is crying and the Raspberry Pi activates a servo motor to rock the crib automatically.
Pre-condition	The microphone, Raspberry pi, and motors must be properly connected and functional. The system must be able to detect the baby's crying.
Post-condition	Crib rocking through motor automatically when the baby cries

Use Case 12: Play baby toy Automatically When Baby Cries

Table 3. 12 Play toys Automatically When Baby Cries

Actor(s)	Microphone, Raspberry Pi, Server , DC motor
Type	Primary
Description	When the trained model detects that the baby is crying, the server sends a message to the Raspberry Pi that the baby is crying and the Raspberry Pi automatically plays toys through the DC motor to calm the baby.
Pre-condition	The microphone, Raspberry Pi, and DC motor must be properly connected and functional. The system must detect the baby's crying.
Post-condition	toys is playing automatically when the baby cries

3.4.4 SEQUENCE DIAGRAMS:

Detection Process Sequence Diagram:

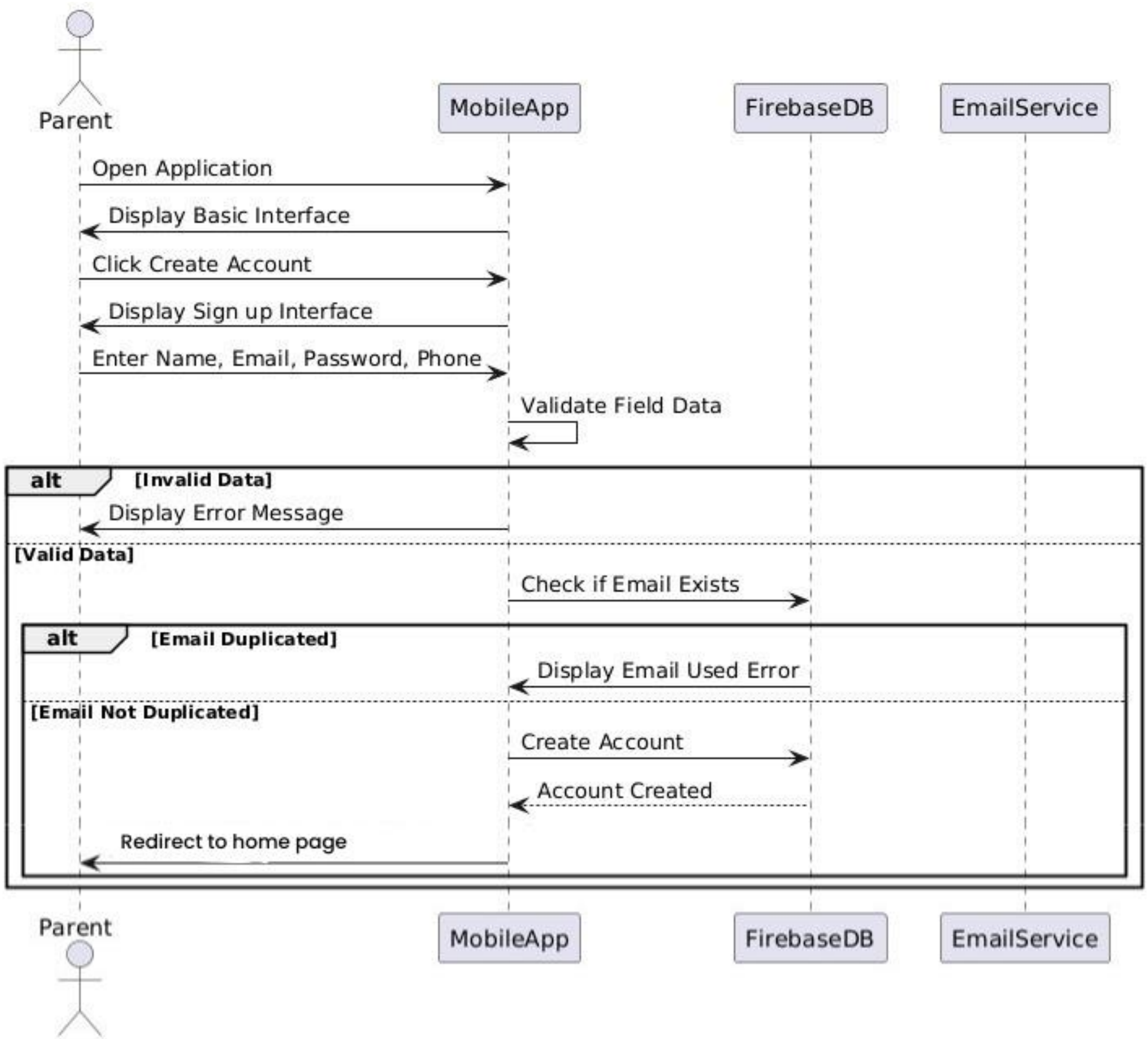


Figure 3. 38 sign up Sequence Diagram

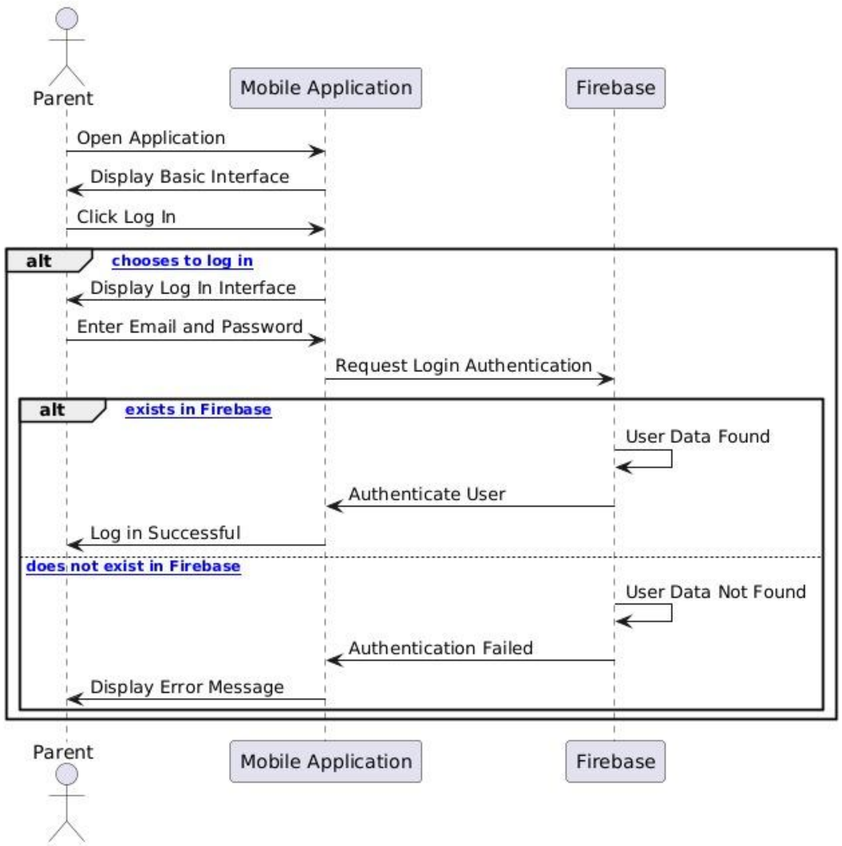


Figure 3. 39 Login Sequence Diagram

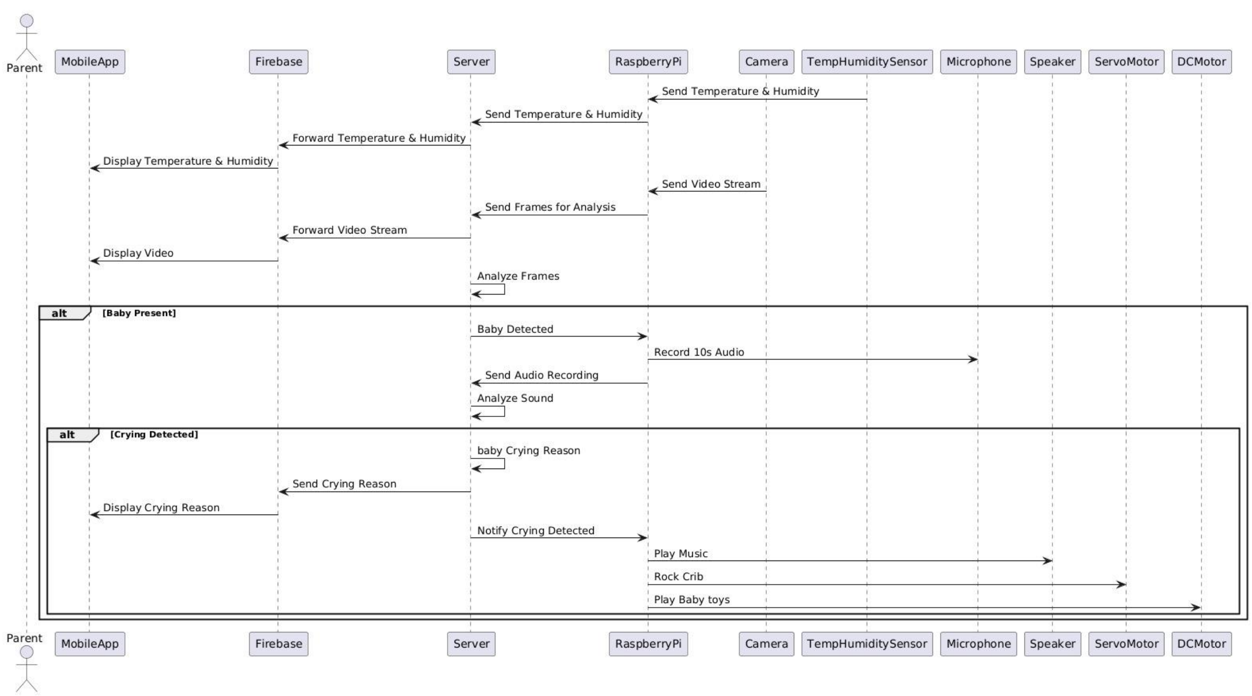


Figure 3. 40 Automatic crib functions Sequence Diagram

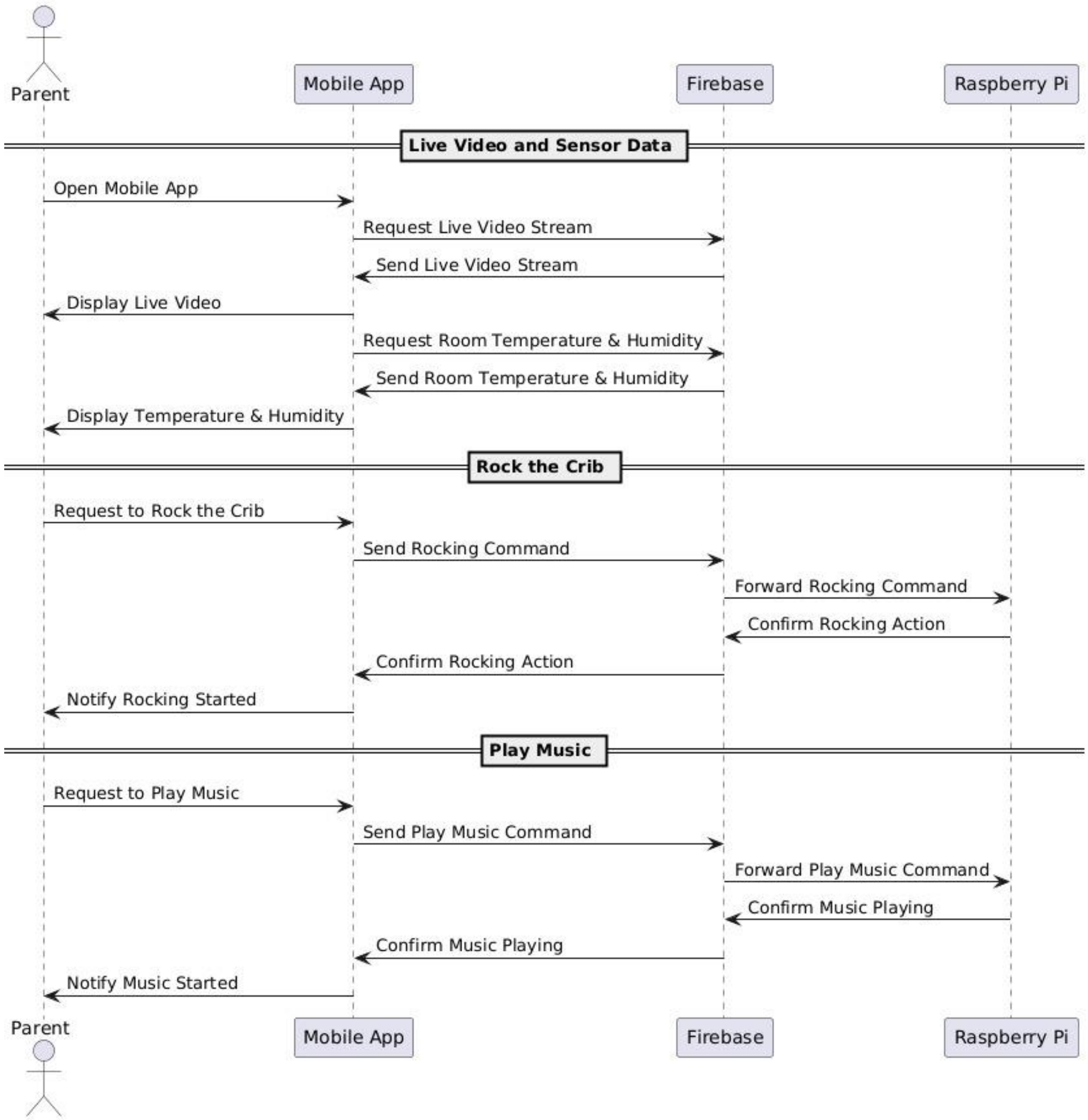


Figure 3. 41 Manual control

CHAPTER 4: RESULTS AND DISCUSSIONS

4.1 RESULTS

4.1.1 HARDWARE RESULT

- **Baby Crib Prototype**:

After successfully implementing the smart baby crib, we got a crib supported by a temperature and humidity sensor for the room and a camera that continuously monitors the baby as shown in Figure 4.1, as the Raspberry Pi sends the readings to the server, which in turn processes them and sends them to Firebase to display them on the mobile phone application. The server analyzes the image and confirms the presence of a baby, then the crying sound is analyzed using artificial intelligence for audio clips recorded via the microphone. If the baby is actually crying, the server sends commands to the Raspberry Pi to rock the crib and play music and toys in addition to sending data to Firebase, which in turn sends notifications to the mobile phone application to alert the parents of the child's crying with a report on the reasons for the crying.

Figure 4. 1 Baby Crib Prototype

As shown in the Figure 4.2, this is the final connection of the system hardware components.

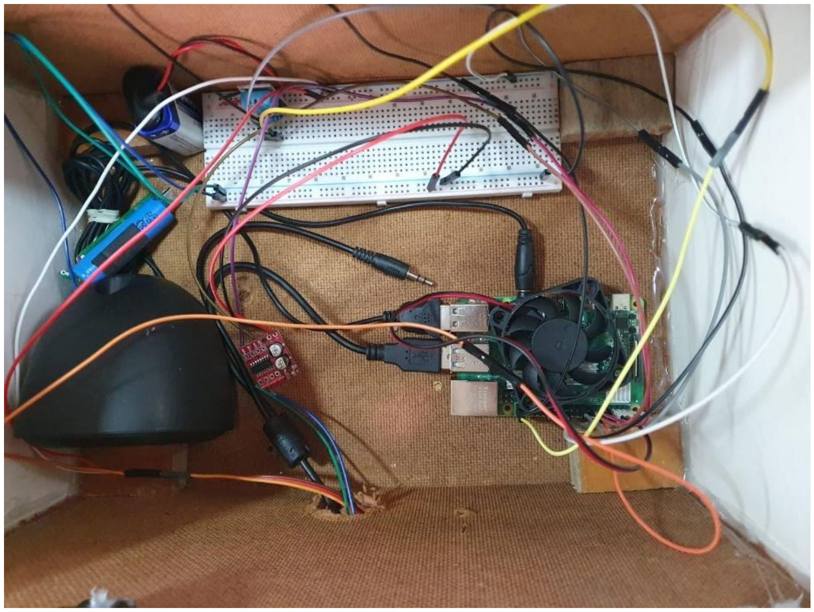


Figure 4. 2 Connection of the system components

4.1.2 SOFTWARE RESULT

- **Dataset and Augmentation:**

  In order to start analyzing the audio, we merged more than one dataset and expanded the merged dataset to get nine classes but it is not balanced as shown in Figure 4.3, so we increased the sounds to reduce overfitting and underfitting to get better accuracy and we got nine classes divided in a balanced way as shown in the Figure 4.4.

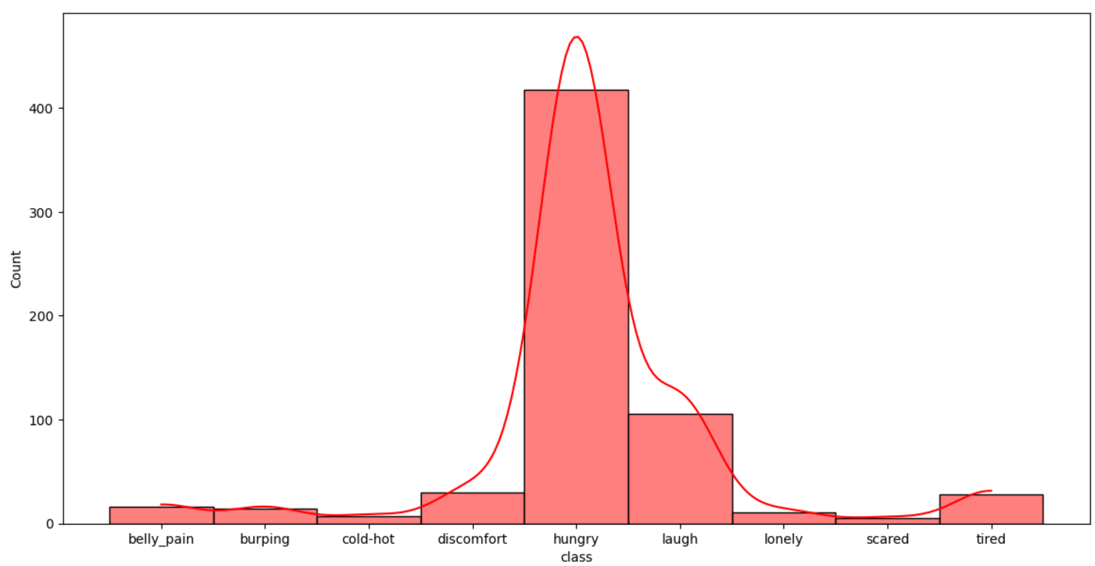


Figure 4. 3 Before Augmentation

```
for folder in glob('aug-seniorDataset1/*'):
    temp_df = pd.DataFrame({f'{folder}': glob(f'{folder}/*')})
    df = pd.concat([df, temp_df], axis= 1)

df.columns.str.replace("\\", ' ')
```

```
Index(['seniorDataset belly_pain', 'seniorDataset burping',
       'seniorDataset cold-hot', 'seniorDataset discomfort',
       'seniorDataset hungry', 'seniorDataset laugh', 'seniorDataset lonely',
       'seniorDataset scared', 'seniorDataset tired',
       'aug-seniorDataset1 belly_pain', 'aug-seniorDataset1 burping',
       'aug-seniorDataset1 cold-hot', 'aug-seniorDataset1 discomfort',
       'aug-seniorDataset1 hungry', 'aug-seniorDataset1 laugh',
       'aug-seniorDataset1 lonely', 'aug-seniorDataset1 scared',
       'aug-seniorDataset1 tired'],
      dtype='object')
```

Figure 4. 4 After Augmentation

- **Cry detection model:**

We built a model to recognize and analyze sounds that can distinguish crying from other sounds, then trained it on 80%, epochs =50 and tested it on 20% as shown in Figure 4.5 and Figure 4.6. The accuracy we got was 97.7% as shown in Figure 4.7.

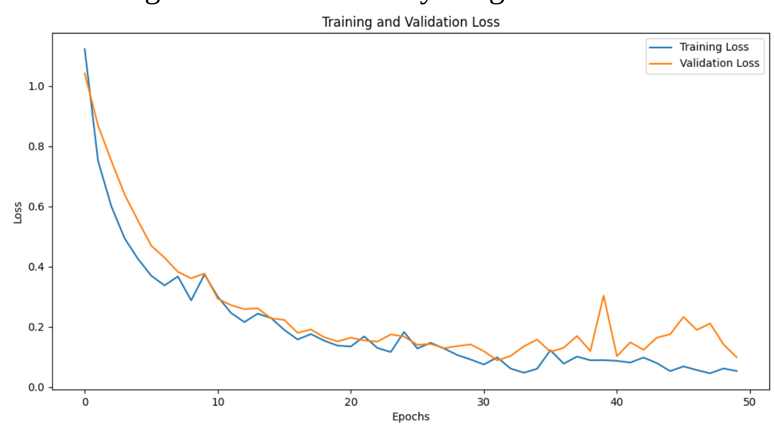


Figure 4. 5 Training and Validation Loss

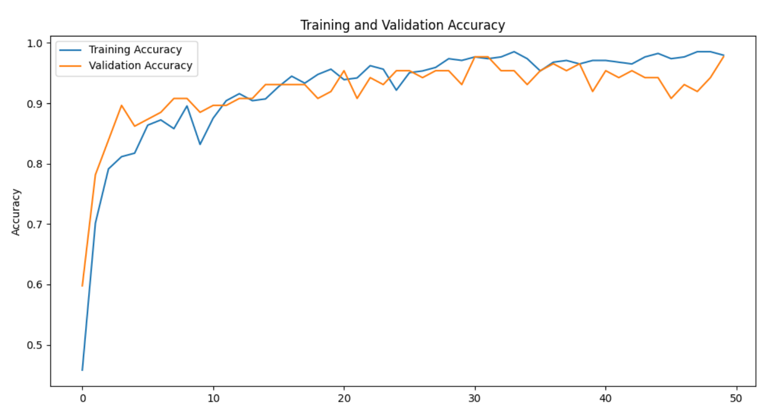
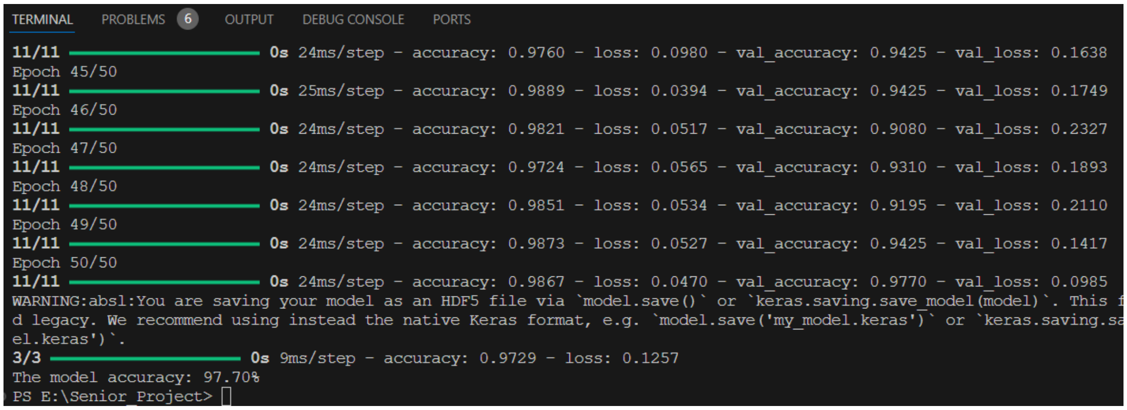


Figure 4. 6 Training and Validation Accuracy



```
TERMINAL   PROBLEMS 6   OUTPUT   DEBUG CONSOLE   PORTS
11/11 ━━━━━━━━━━━━━━━━━━━━ 0s 24ms/step - accuracy: 0.9760 - loss: 0.0980 - val_accuracy: 0.9425 - val_loss: 0.1638
Epoch 45/50
11/11 ━━━━━━━━━━━━━━━━━━━━ 0s 25ms/step - accuracy: 0.9889 - loss: 0.0394 - val_accuracy: 0.9425 - val_loss: 0.1749
Epoch 46/50
11/11 ━━━━━━━━━━━━━━━━━━━━ 0s 24ms/step - accuracy: 0.9821 - loss: 0.0517 - val_accuracy: 0.9080 - val_loss: 0.2327
Epoch 47/50
11/11 ━━━━━━━━━━━━━━━━━━━━ 0s 24ms/step - accuracy: 0.9724 - loss: 0.0565 - val_accuracy: 0.9310 - val_loss: 0.1893
Epoch 48/50
11/11 ━━━━━━━━━━━━━━━━━━━━ 0s 24ms/step - accuracy: 0.9851 - loss: 0.0534 - val_accuracy: 0.9195 - val_loss: 0.2110
Epoch 49/50
11/11 ━━━━━━━━━━━━━━━━━━━━ 0s 24ms/step - accuracy: 0.9873 - loss: 0.0527 - val_accuracy: 0.9425 - val_loss: 0.1417
Epoch 50/50
11/11 ━━━━━━━━━━━━━━━━━━━━ 0s 24ms/step - accuracy: 0.9867 - loss: 0.0470 - val_accuracy: 0.9770 - val_loss: 0.0985
WARNING:absl:You are saving your model as an HDF5 file via `model.save()` or `keras.saving.save_model(model)`. This f
d legacy. We recommend using instead the native Keras format, e.g. `model.save('my_model.keras')` or `keras.saving.sa
el.keras')`.
3/3 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - accuracy: 0.9729 - loss: 0.1257
The model accuracy: 97.70%
PS E:\Senior_Project>
```

Figure 4. 7 Accuracy for cry detection model

- **Cry reasons detection model:**

  We built a model to recognize and analyze crying causes so that it could distinguish between each crying sound and classify it into one of the nine causes mentioned, then we trained it on 80%, age = 50 years, and tested it on 20% as shown in Figure 4.8 and Figure 4.9. The accuracy we obtained was 87.16% as shown in Figure 4.10.

Figure 4. 8 Training and Validation Loss

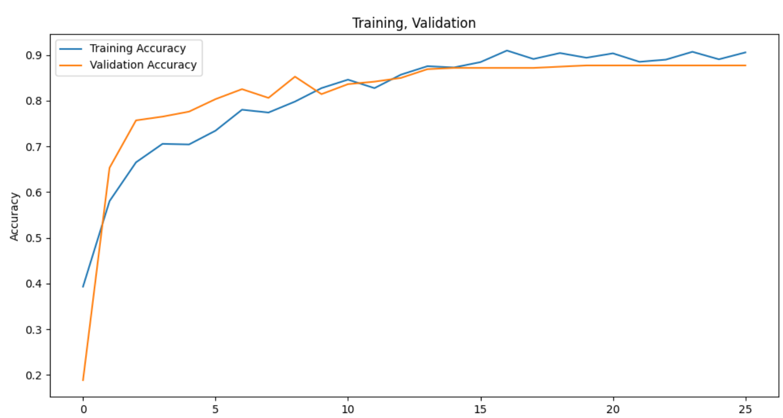


Figure 4. 9 Training and Validation Accuracy

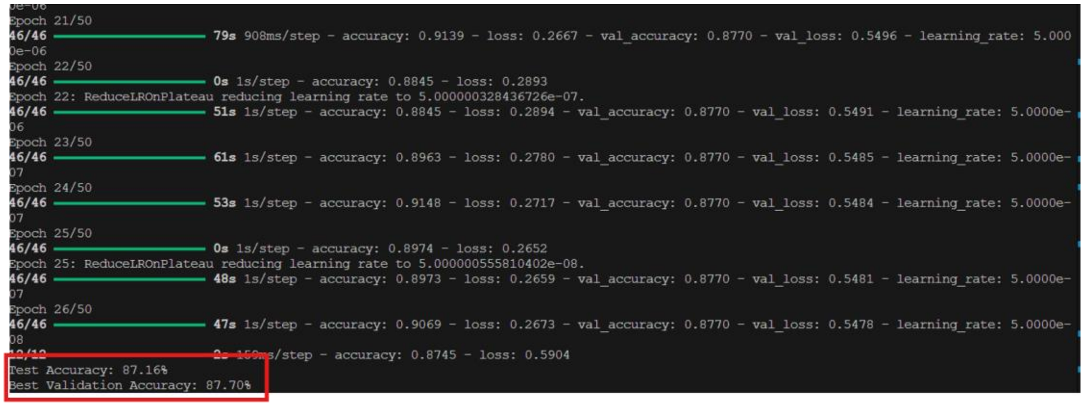


Figure 4. 10 Accuracy for Cry reasons detection model

- **Object detection using YOLOv11:**

We have integrated Object Detection using YOLOv11 in our project with the previous models to ensure the correct work sequence as the system does not work until it is sure that the baby is in the crib as shown in the Figure 4.11.

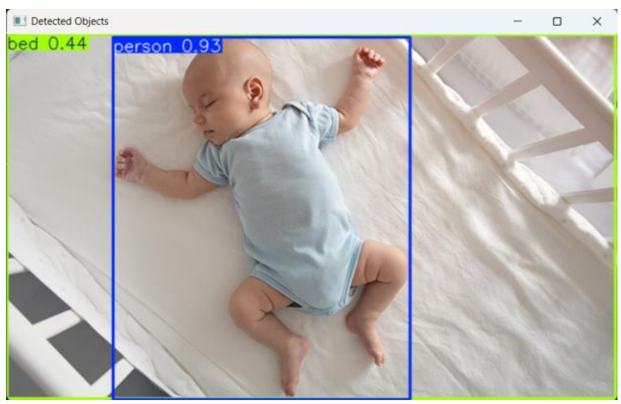


Figure 4. 11 Object detection using YOLOv11

- **Firestore Database:**

To ensure security and privacy, authentication has been activated through the use of Firestore Database from Firebase, through which accounts are created as shown in Figure 4.12.

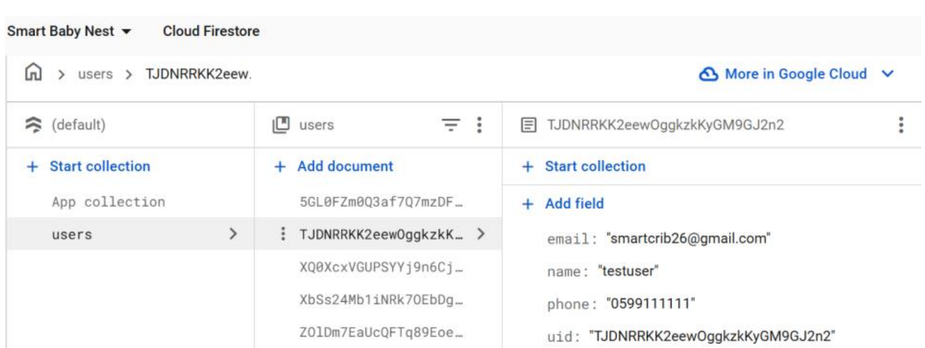


Figure 4. 12 Firestore Database for user authentication

- **Realtime Database:**

To ensure real-time data synchronization between the hardware and the mobile app, we used Realtime Database from Firebase to store crying status and it's reasons, temperature and humidity sensor readings, Raspberry Pi IP and manual control status to control it from mobile application as shown in Figure 4.13.

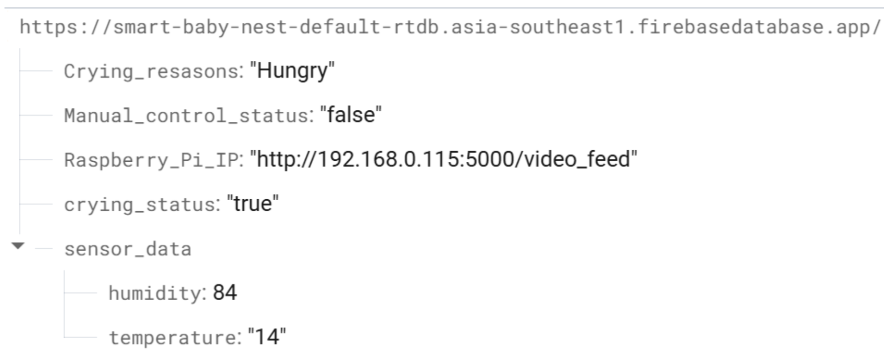


Figure 4. 13 Realtime Database

- **Web Server:**

Because our system consists of several processes on inputs, outputs and processing operations using artificial intelligence for sound and image, and to ensure the acceleration of work, we used a web server to receive and process readings and then send the results and commands through it as shown in Figure 4.14.

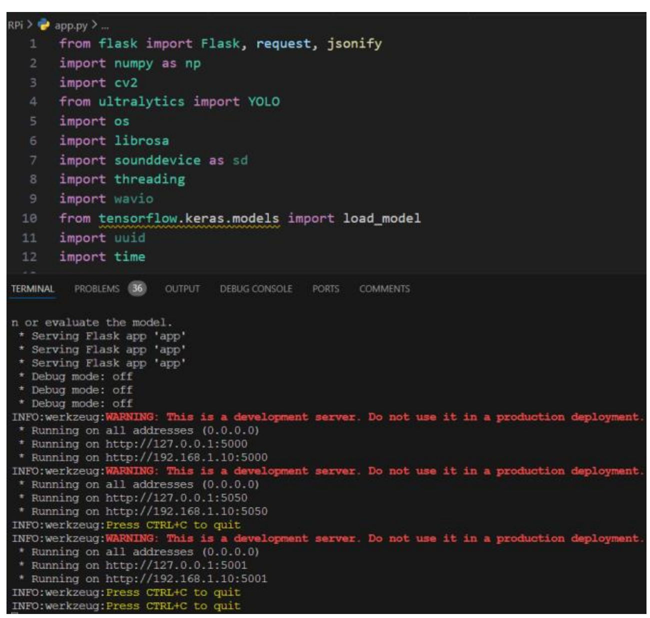


Figure 4. 14 Web Server

4.2 DISCUSSION

In this section, three system cases and their workflow are presented as shown.

- **Case 1: User account:**

  To ensure security and privacy in the system, the use of Firebase authentication and Firestore database have been included within the Flutter application to create accounts and log in to them as follows:

  - **Sign up:**

    This screen is used to register a new account. The user enters the name, active email, phone number and password as shown in Figure 4.15. All the data entered must be in accordance with the controls, otherwise an error will appear below the field containing the incorrect information as shown in Figure 4.16. After verifying the data in the correct form, it is verified via Firebase that the entered email does not actually have an account, otherwise a message will appear as shown in Figure 4.17. After the registration process is successful, the user data is stored in the firestore as shown in the Figure 4.18.

Figure 4. 15 Create account

Figure 4. 16 Error in Sign up

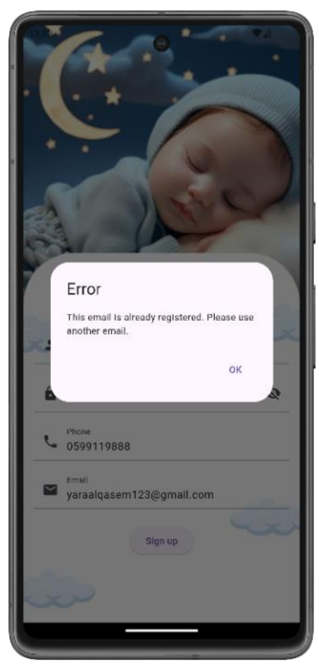


Figure 4. 17 The user has account

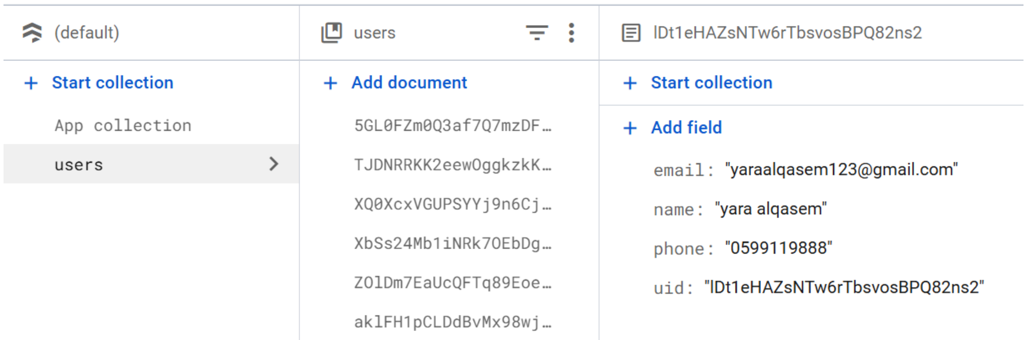


Figure 4. 18 Store user data in Firestore

After creating the account, the user is directed to an interface to confirm his account via email. When he clicks on the button, the confirmation email will arrive, as in the Figure 4.19 and Figure 4.20.

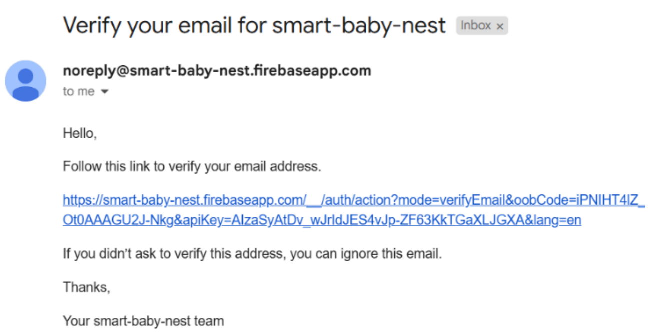


Figure 4. 19 Verify account

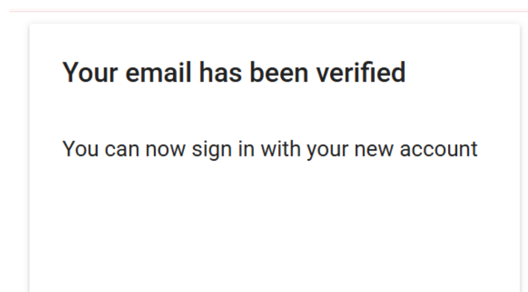


Figure 4. 20 Account verified massage

- **Log-in:**

After creating the account, you log in by entering the user's email and password as shown in Figure 4.21. If there is any error in the data, an alert message appears as shown in Figure 4.22.

Figure 4. 21 Success Login

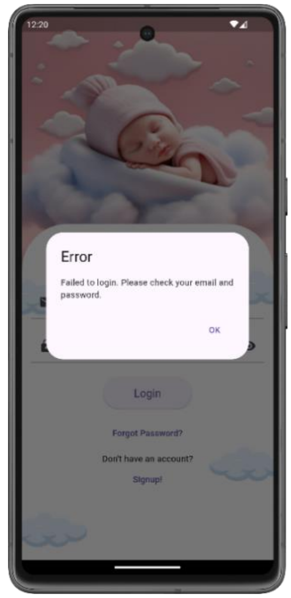


Figure 4. 22 Error in Login

- **Forget Password:**

If the user forgets the password, he uses "Forgot Password" which takes him to the interface as in Figure 4.23, which asks the user to enter his email to update the password. After verifying the validity of the email, a green sign appears to the user to alert him to send a message to his email as in Figure 4.24.

Figure 4. 23 reset password interface

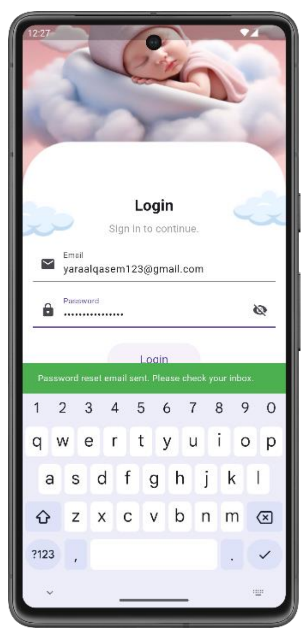


Figure 4. 24 send email successfully

Through the email received by the user as in Figure 4. 25, the user can enter the password through the interface as in Figure 4. 26 then re-login using the new password.

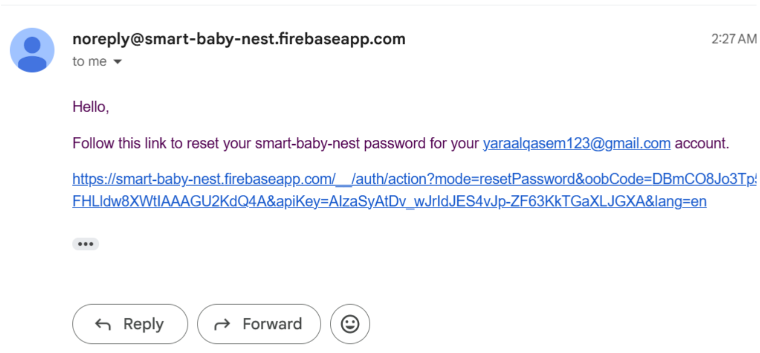


Figure 4. 25 Reset password email

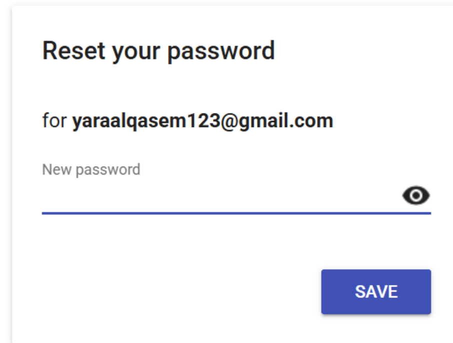


Figure 4. 26 reset password

- **Case 2: Automatic control.**

  The camera is in a continuous state of live streaming the baby and the frame coming from the Raspberry Pi is processed in the server using YOLOv11 artificial intelligence continuously. If the baby is present as in Figure 4.27, audio is recorded via the microphone for 10 seconds, which is examined using artificial intelligence in server to see if it is crying or not and If it is crying, it uses the second model to find out the reason for the crying as in Figure 4.28. Accordingly, the server sends commands to the Raspberry Pi to turn on the crib rocking feature and play toys and music. In addition to sending the temperature, humidity, crying statues, Raspberry Pi IP readings and the result of crying to Firebase as in Figure 4.29 which in turn sends notification, crying report and readings to the Flutter application and displays them inside it as in Figure 4.30, Figure 4.31 and Figure 4.32.

Figure 4. 27 Object Detection

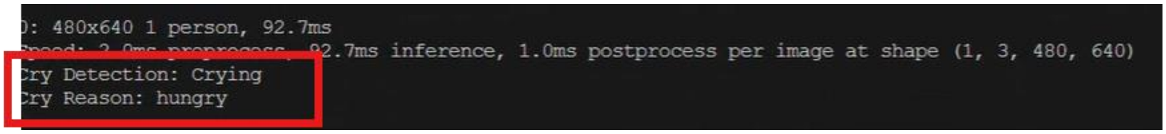


Figure 4. 28 Model 1 and 2 result

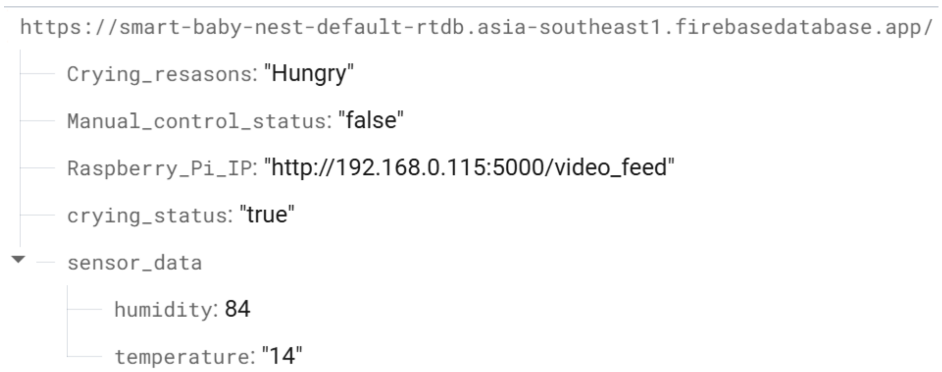


Figure 4. 29 The readings in Realtime database

Figure 4. 30 main interface with data

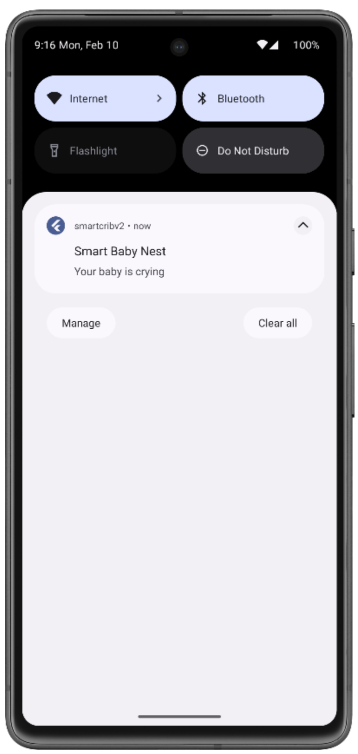


Figure 4. 31 Notification

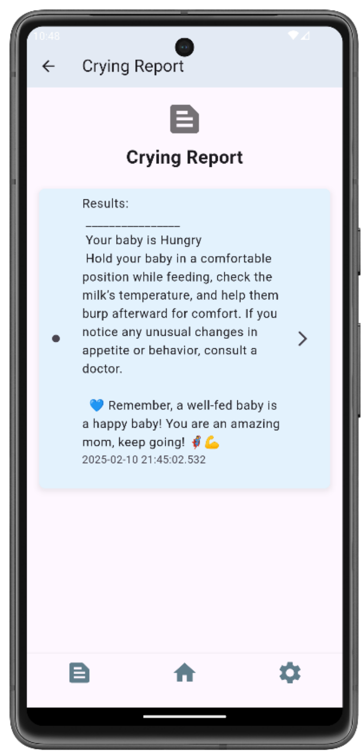


Figure 4. 32 Crying report

- **Case 2: Manual control:**

Through the mobile application, the baby continues to be monitored through live streaming. The user can benefit from the feature of rocking the crib, playing music, and controlling it manually through the interface as shown in Figure 4. 34. When any feature is activated, its status changes on the Firebase as shown in Figure 4. 35, which is read by the server, and then it gives a command to the Raspberry Pi to run the selected command.

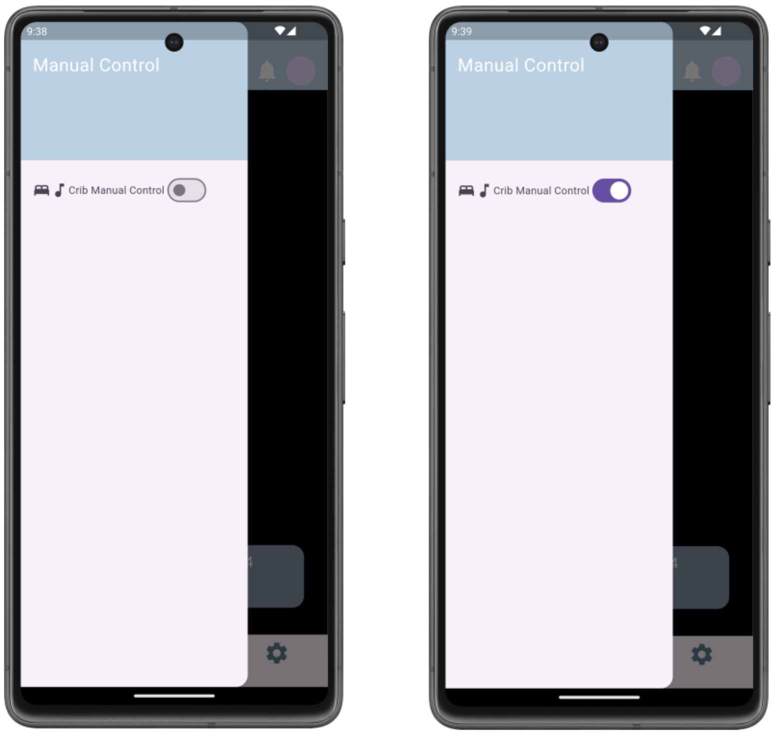


Figure 4. 33 Manual control

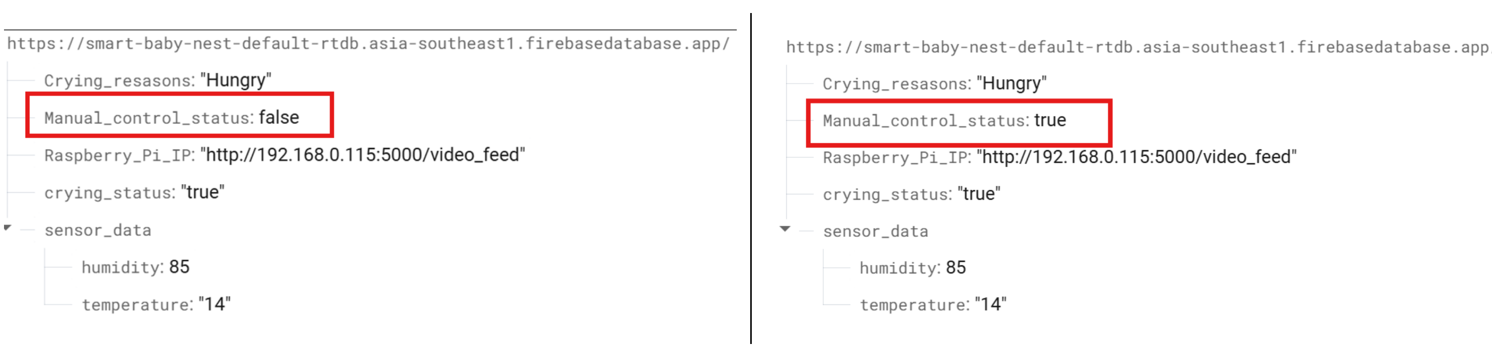


Figure 4. 34 Components status in Realtime database

CHAPTER 5: PROJECT MANAGEMENT

In this chapter we have built the project schedule scheduling, as shown Figure 5.1 and gantt chart as shown Figure 5.2 all tasks completed main tasks and subtasks as well estimating the time of each task, how many days it will take and scheduling the date for each of the tasks.

5.1 TASKS, SCHEDULE AND MILESTONES:

Task Mode	Task Name	Duration	Start	Finish	Predeces	Resource Names
	1 Smart Crib For Infants	**227 days**	**Wed 4/10/24**	**Thu 2/20/25**		
	1.1 Initiating	**8 days**	**Wed 4/10/24**	**Fri 4/19/24**		
	1.1.1 Define the Project Idea and Its Objectives	3 days	Wed 4/10/24	Fri 4/12/24		Abrar,Aseel,Mohammad
	1.1.2 Select Project Manager	4 days	Sun 4/14/24	Wed 4/17/24		
	1.1.3 Project Kick-Off Meeting	3 hrs	Thu 4/18/24	Thu 4/18/24		
	1.2 Planning	**14 days**	**Mon 4/15/24**	**Thu 5/2/24**		
	1.2.1 Determine the Requerment	5 hrs	Mon 4/15/24	Mon 4/15/24	3	Abrar,Aseel,Mohammad
	1.2.2 Make Project Proposal	1 day	Mon 4/15/24	Tue 4/16/24	7	Abrar,Aseel,Mohammad
	1.2.3 Submit Project Proposal	0 days	Tue 4/16/24	Tue 4/16/24	8	Abrar,Aseel,Mohammad
	1.2.4 Develop Project Plan WBS	2 days	Tue 4/16/24	Thu 4/18/24	9	Abrar,Aseel,Mohammad
	1.2.5 Project Kick-Off Meeting	3 hrs	Thu 5/2/24	Thu 5/2/24		
	1.3 Executing	**47 days**	**Thu 5/2/24**	**Fri 7/5/24**		
	1.3.1 Project Description	6 days	Thu 5/2/24	Fri 5/10/24	11	Abrar,Aseel,Mohammad
	1.3.2 Project Background	**6 days**	**Fri 5/10/24**	**Fri 5/17/24**		
	1.3.2.1 Overview	2 days	Fri 5/10/24	Tue 5/14/24	13	Abrar,Aseel,Mohammad
	1.3.2.2 Comparison Between Projects	2 days	Tue 5/14/24	Thu 5/16/24	15	
	1.3.3 Methods and Materials	**35 days**	**Sat 5/18/24**	**Thu 7/4/24**		
	1.3.3.1 Determine System Design and Components	8 days	Sat 5/18/24	Tue 5/28/24		Aseel
	1.3.3.2 Design Specifications And Constraints	4 days	Wed 5/29/24	Mon 6/3/24	18	Aseel
	1.3.3.3 System Analysis And Optimization	**18 days**	**Tue 6/4/24**	**Thu 6/27/24**		
	1.3.3.3.1 Flow Chart	6 days	Tue 6/4/24	Tue 6/11/24	19	Mohammad
	1.3.3.3.2 Use Case Diagrams	6 days	Wed 6/12/24	Wed 6/19/24	21	Abrar
	1.3.3.3.3 Sequence Diagrams	6 days	Thu 6/20/24	Thu 6/27/24	22	Abrar,Aseel,Mohammad
	1.3.3.4 System Block Diagram	4 days	Fri 6/28/24	Wed 7/3/24	23	Mohammad
	1.4 Submit Report	0 days	Sun 7/14/24	Sun 7/14/24		

Task Mode	**Task Name**	Duration	Start	Finish	Predeces	Resource Names
	1.5 Integration and testing	**67 days**	**Fri 11/1/24**	**Sat 2/1/25**		
	1.5.1 Develop the Flutter Application Ui	22 days	Fri 11/1/24	Sat 11/30/24		Aseel
	1.5.2 Build and Train the Sound Model	7 days	Fri 11/1/24	Mon 11/11/24		Abrar
	1.5.3 Build and Train The Crying Model	15 days	Sun 11/10/24	Thu 11/28/24		Mohammad
	1.5.4 Testing The YOLOv11 Model	8 days	Thu 11/28/24	Mon 12/9/24		Abrar
	1.5.5 Setup The Rasbperry Pi	4 days	Thu 11/28/24	Tue 12/3/24		Aseel,Mohammad
	1.5.6 Build The Firebase	7 days	Mon 12/2/24	Tue 12/10/24	27	Aseel,Abrar
	1.5.7 Design The Crib	7 days	Tue 12/10/24	Wed 12/18/24		Mohammad
	1.5.8 Connect and Program The Hardware Components on The Crib	14 days	Thu 12/19/24	Tue 1/7/25	33	Mohammad,Aseel,Abrar
	1.5.9 Connect The Raspberry Pi With Server and Firebase	14 days	Wed 1/8/25	Mon 1/27/25	34	Abrar,Aseel
	1.5.10 Test The System	40 days	Tue 12/10/24	Sat 2/1/25	30	Mohammad,Aseel,Abrar
	1.5.11 Update The Senior #1 Document	47 days	Sun 12/1/24	Sat 2/1/25		Mohammad,Aseel,Abrar
	1.6 Closing The Project	**14 days**	**Mon 2/3/25**	**Thu 2/20/25**		
	1.6.1 Create Senior #2 Presntation	5 days	Mon 2/3/25	Fri 2/7/25	37	Mohammad,Aseel,Abrar
	1.6.2 Submit Project	1 day	Mon 2/10/25	Mon 2/10/25	39	
	1.6.3 Project Discussion Training	10 days	Sat 2/8/25	Thu 2/20/25		Mohammad,Aseel,Abrar

Figure 5. 1 TASKS, SCHEDULE AND MILESTONES

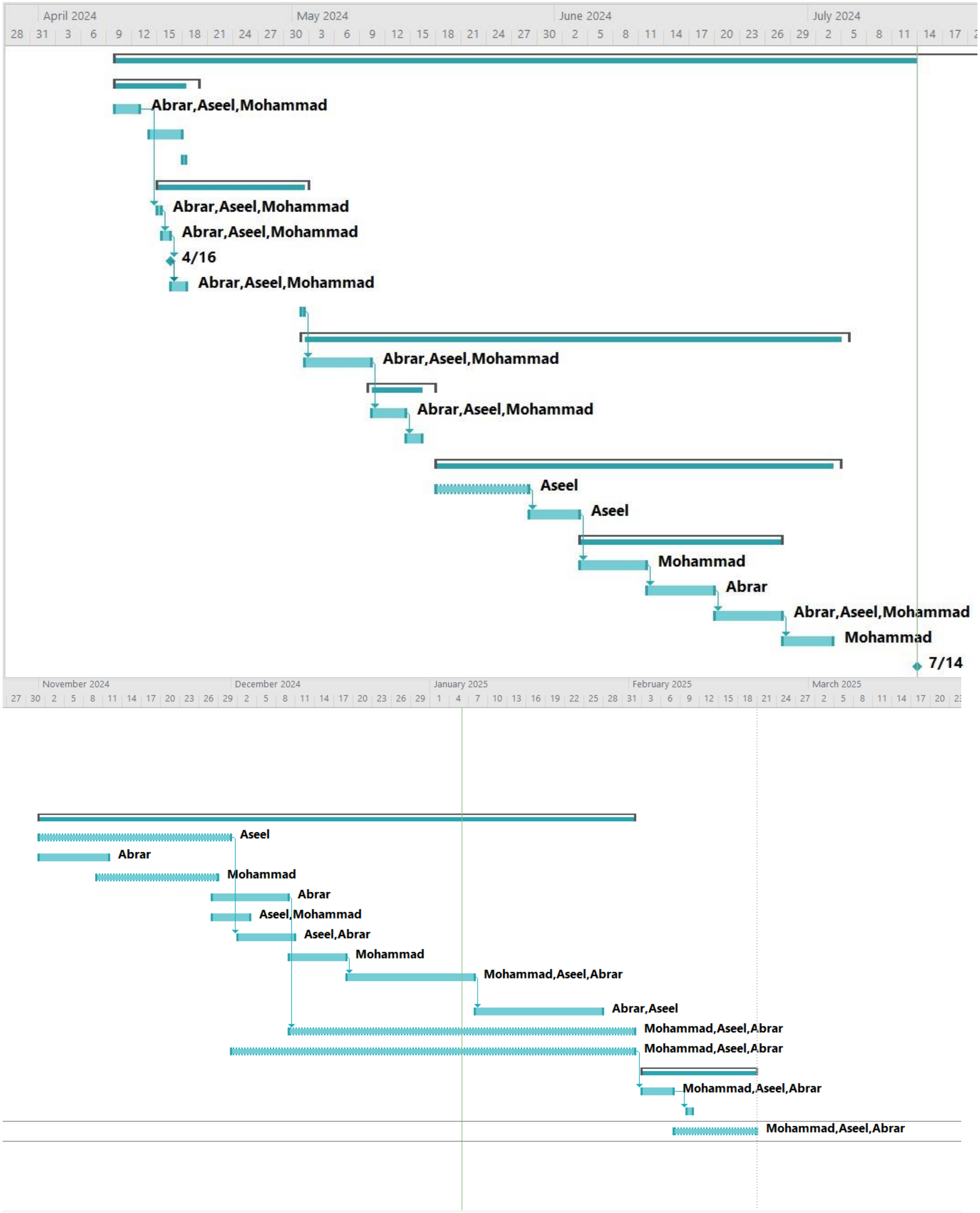


Figure 5. 2 Gantt chart

5. 2 RESOURCES AND COST MANAGEMENT

The table below shows the number of units and the cost of each one:

Table 5. 1 Resources and cost management

Item	#Units	Unit Cost	Subtotals
Raspberry Pi 4 Model B	1	**400 ₪**	**400 ₪**
L298N Motor Driver Module	1	**22 ₪**	**22 ₪**
Microphone	1	**25 ₪**	**25 ₪**
USB Camera	1	**50 ₪**	**50 ₪**
DC Motor	1	**10 ₪**	**10 ₪**
Servo Motor	1	**65 ₪**	**65 ₪**
Children Toys	1	**10 ₪**	**10 ₪**
Baby Crib	1	**60 ₪**	**60 ₪**
Breadboard	1	**20 ₪**	**20 ₪**
Wires	40	**1 ₪**	**40 ₪**
Speaker	1	**20 ₪**	**20 ₪**
Battery	2	**9 ₪**	**18 ₪**
Total Cost	730 ₪		

5.3 LESSONS LEARNED

In terms of managing the project, those are the main lessons our team has learned:

- Clear Communication
- Team Collaboration
- Documentation and Knowledge Management
- Continuous Improvement
- Organizing and respecting time

CHAPTER 6: IMPACT OF THE ENGINEERING SOLUTION

The Smart Crib for Infants system can influence almost any aspect, including, but not limited to, the global, societal, and economic pillars. This chapter analyzes the intricate implications of the engineering remedy.

6.1 ECONOMICAL, SOCIETAL AND GLOBAL

Economic impacts:

- Promoting local innovation:
  - Supports the technology sector in Palestine, which contributes to opening up job opportunities in the fields of programming, design, and maintenance.
  - Encourages investment in innovative fields that meet the needs of the Palestinian market.

- Reducing costs for parents:
  - Thanks to the integration of the camera, gaming microphone, and sensors into one product, our project reduces the need to purchase separate devices, which saves additional costs for parents.

- Opportunities for expanding the Palestinian market:
  - The project paves the way for entering regional and global markets, which supports the Palestinian economy and highlights its technological capabilities.

Societal and Global impacts:

- Reducing the burden on parents:
  - The smart bed allows them to perform daily tasks as if they were without children.
  - It also allows parents to feel comfortable by providing continuous and clear monitoring of their infant.

- Level of care and responsiveness:
  - It allows them to make a great effort by meeting their initial requests when they hear crying or laughing sounds to meet such needs.
  - In turn, the bed ensures strengthening family ties by providing effective responses directed towards the child.

- Protecting technological awareness:
  - It encourages the adoption of smart solutions to enhance the quality of daily life among Palestinian family members by instilling behavioral culture and technology.
- Achieving safety:
  - It protects the child from any risks of care leakage and lack of attention to him by providing an environment that provides him with monitoring and at the same time provides him with immediate responses to the child's needs.

6.2 ENVIRONMENTAL AND ETHICAL:

Environmental Impact:

- Energy Efficiency:
  - The smart crib is designed with low-energy characteristics in mind, so it automatically contributes to the absolute conservation of environmental resources to a higher level.
  - Based on a new need, rechargeable batteries or other new resources can be used to reduce the usual electricity consumption.

- Electronic Waste Reduction:
  - By using one of the cameras, vibration, and sound analysis combinations, the project will provide the possibility of using all these devices and reducing the production of electronic waste.
  - The design focus on quality and maintenance reduces the environmental impact in a way that helps increase the life of the product.

Ethical impact:

- Privacy protection:
  - The project has taken it upon itself to protect audio-visual installations from any infringement using password encryption systems with the possibility of not forgetting.
  - Control of use by obligation does not include storing any data about the user or opening their family and the goal is to provide comfort for the family and their connection.

- Enhancing the quality of life:
    - The level of family comfort is followed by an increase in the quality of life from the continuous care of children by the parents, which makes the rest of the performance comfortable for the child.
    - It works to reduce the daily stress on families and the impact of this on their psychological and social health is good.

- Making technology available to all:
    - The product is designed at reasonable prices compared to competing products, making it easy for all segments of society to buy and use.
    - It helps provide advanced services that help narrow the technological gap between the branches of society.

CHAPTER 7: CONCLUSIONS AND RECOMMENDATIONS

7.1 SUMMARY OF ACHIEVEMENTS OF THE PROJECT OBJECTIVES:

We have succeeded in building a smart baby crib connected to artificial intelligence that monitors the child and when the child is in the crib, it takes the sound and sends it to the server to analyze the sound and know if it is crying or not. If it detects that it is a crying sound, it analyzes the reason for the crying and rocks the crib, and plays music for the child to calm him down.

As mentioned in the objectives, we have built an easy-to-use mobile application connected to Firebase through which the mother can monitor her child or know the room temperature. She can also receive notifications about the reason for crying. The mother can also manually control the crib by rocking it when needed or playing music for her child.

7.2 NEW SKILLS AND EXPERIENCES LEARNT:

- The skills learnt:
  - Time management skills.
  - The skills of deep searching.
  - Report writing skills.
  - Team working skills.
  - Better Communication Skills.
  - Smart Planning.

- The Experience gained:
  - Connecting hardware components.
  - Programming Raspberry Pi.
  - Reading from sensors.
  - Handling with the Raspberry Pi OS.
  - Problem-solving.
  - Flutter Programming.
  - Firebase connection.
  - Using Python with Machine Learning to train an Audio Analysis Model.
  - How to test the model.
  - How to make a wooden crib.
  - How to connect Raspberry Pi to the server.
  - Connect the Server with firebase.

7. 3 RECOMMEND ACTIONS FOR FUTURE WORK

- Replace the regular microphone with a microphone with a sound isolation feature to get better accuracy.
- Use a camera with a higher resolution.
- Replace the servo motor with a wiper motor.
- Deal with a better server.
- Improving the data set to get better accuracy.

REFERENCES

[1] P. C. B. o. Statistics, "Palestinian Central Bureau of Statistics," 14 1 2024. [Online]. Available: https://www.pcbs.gov.ps/statisticsIndicatorsTables.aspx?lang=ar&table_id=2259. [Accessed 1 4 2024].

[2] U. o. C. Florida, "University of Central Florida," 5 3 2018. [Online]. Available: chrome-extension://kdpelmjpfafjppnhbloffcjpeomlnpah/https://www.ece.ucf.edu/seniordesign/sp2018su2018/g07/docs/G7_Initial%20Project.pdf. [Accessed 2 4 2024].

[3] H. I. Shahadi, "Design and Implementation of a Smart Baby Crib," IOP Conf. Series: Materials Science and Engineering, 2020.

[4] A. n. n. university, "an najah national university," 2015. [Online]. Available: https://eng-old.najah.edu/ar/news/7116. [Accessed 2 4 2024].

[5] r. pi, "raspberry pi," 2025. [Online]. Available: https://www.raspberrypi.com/documentation. [Accessed 2 8 2024].

[6] Yealink, "Yealink," 2023. [Online]. Available: https://www.yealink.com/en/onepage/what-is-usb-camera. [Accessed 1 5 2024].

[7] Waveshare, "Waveshare," [Online]. Available: https://www.waveshare.com/wiki/DHT11_Temperature-Humidity_Sensor. [Accessed 1 5 2024].

[8] Byjus, "Byjus," 2024. [Online]. Available: https://byjus.com/physics/dc-motor/. [Accessed 1 5 2024].

[9] R. pi, "Raspberry pi," [Online]. Available: https://www.raspberrypi.com/products/type-c-power-supply/. [Accessed 1 5 2024].

[10] Arduino, "Arduino," 2024. [Online]. Available: https://docs.arduino.cc/learn/electronics/servo-motors/. [Accessed 1 5 2024].

[11] S. Buddies, "Science Buddies," [Online]. Available: https://www.sciencebuddies.org/science-fair-projects/references/how-to-use-a-

breadboard#what-breadboard. [Accessed 1 5 2024].

[12] Components101, "Components101," 2023. [Online]. Available: https://components101.com/modules/l293n-motor-driver-module. [Accessed 1 5 2024].

[13] B. A. Fette, " The Software-Defined Radio as a Platform for Cognitive Radio," in *Cognitive Radio Technology*, 2009.

[14] E. IITH, "Medium," 23 10 2023. [Online]. Available: https://medium.com/@elektronica/getting-started-with-raspberry-pi-a9a1cf8e4414. [Accessed 3 10 2024].

[15] Raspberrypi, "Raspberrypi," [Online]. Available: https://www.raspberrypi.com/software/. [Accessed 12 10 2024].

[16] putty, "putty," [Online]. Available: https://www.putty.org/. [Accessed 23 10 2024].

[17] realvnc, "Realvnc," [Online]. Available: https://www.realvnc.com/en/blog/raspberry-pi-vnc/?lai_vid=xA9MQzXAEUQO&lai_sr=20-24&lai_sl=l. [Accessed 10 10 2024].

[18] V. labs, "V7 labs," [Online]. Available: https://www.v7labs.com/blog/yolo-object-detection. [Accessed 1 11 2024].

[19] GeeksforGeeks, "GeeksforGeeks," 2024. [Online]. Available: https://www.geeksforgeeks.org/convolutional-neural-network-cnn-in-machine-learning/. [Accessed 2 11 2024].

[20] Flutter, "Flutter," [Online]. Available: https://flutter.dev/. [Accessed 3 6 2024].

[21] Adservio, "Adservio," [Online]. Available: https://www.adservio.fr/post/what-is-flutter-and-what-are-its-advantages. [Accessed 3 6 2024].

[22] Firebase, "Firebase," [Online]. Available: https://firebase.google.com/docs/database. [Accessed 21 10 2024].

[23] Firebase, "Firebase," [Online]. Available: https://firebase.google.com/docs/firestore. [Accessed 21 10 2024].

[24] wikipedia, "wikipedia," wikipedia, [Online]. Available: https://en.wikipedia.org/wiki/ESP32. [Accessed 14 6 2024].

[25] "circuitdigest," [Online]. Available: https://circuitdigest.com/microcontroller-projects/interface-ky038-sound-sensor-with-esp32. [Accessed 10 6 2024].

[26] "arducam," [Online]. Available: https://www.arducam.com/product/arducam_ov7670_camera_module_vga_mini_ccm_compact_camera_modules_m0030/. [Accessed 10 6 2024].

[27] "analog," [Online]. Available: https://www.analog.com/media/en/technical-documentation/data-sheets/ds18b20.pdf. [Accessed 10 6 2024].

[28] "az-delivery," [Online]. Available: https://www.az-delivery.de/en/products/mp3-player-modul. [Accessed 14 6 2024].

[29] "wikipedia," [Online]. Available: https://en.wikipedia.org/wiki/DC_motor . [Accessed 14 6 2024].

[30] "circuitdigest," [Online]. Available: https://circuitdigest.com/microcontroller-projects/interfacing-sim800l-module-with-esp32. [Accessed 10 6 2024].

[31] H. I. Shahadi, "Design and Implementation of a Smart Baby Crib," p. 15, 1 2020.

[32] D. H. M. ,. H. T. H. Haider Ismael Shahad, "Design and Implementation of a Smart Baby Crib," p. 15, 1 2020.

[33] "Palestinian Central Bureau of Statistics," 14 1 2024. [Online]. Available: https://www.pcbs.gov.ps/statisticsIndicatorsTables.aspx?lang=ar&table_id=2259. [Accessed 1 4 2024].

[34] "Design and Implementation of a Smart Baby Crib," 2020.

[35] www.espressif.com, "espressif," [Online]. Available: https://www.espressif.com/en/products/socs/esp32. [Accessed 1 5 2024].

[36] arduino.cc, "arduino cc," 4 3 2024. [Online]. Available: chrome-extension://kdpelmjpfafjppnhbloffcjpeomlnpah/https://docs.arduino.cc/resources/datasheets/A000066-datasheet.pdf. [Accessed 1 5 2024].

[37] Joy-IT, "KY-038 Microphone sound sensor module," 16 6 2017. [Online]. Available: https://semiconductors.es/KY-038.html. [Accessed 1 5 2024].

[38] www.arducam.com, "Arducam," [Online]. Available: https://www.arducam.com/product/arducam_ov7670_camera_module_vga_mini_ccm_compact_camera_modules_m0030/. [Accessed 1 5 2024].

[39] alldatasheet, "alldatasheet," [Online]. Available: https://pdf1.alldatasheet.com/datasheet-pdf/view/58557/DALLAS/DS18B20.html. [Accessed 1 5 2024].

[40] picaxe, "picaxe," [Online]. Available: chrome-extension://kdpelmjpfafjppnhbloffcjpeomlnpah/https://picaxe.com/docs/spe033.pdf. [Accessed 1 5 2024].

[41] moog, "moog," [Online]. Available: chrome-extension://kdpelmjpfafjppnhbloffcjpeomlnpah/https://www.moog.com/content/dam/moog/literature/MCG/moc23series.pdf. [Accessed 1 5 2024].

[42] alldatasheet, "alldatasheet," [Online]. Available: https://www.alldatasheet.com/datasheet-pdf/pdf/22440/STMICROELECTRONICS/L298N.html. [Accessed 1 5 2024].

[43] "panchbhaya," [Online]. Available: chrome-extension://kdpelmjpfafjppnhbloffcjpeomlnpah/https://panchbhaya.weebly.com/uploads/1/3/7/0/13701351/phys11_11_7.pdf. [Accessed 1 5 2024].

[44] "makerselectronics," [Online]. Available: https://makerselectronics.com/product/sim800l-gprs-gsm-module-for-esp. [Accessed 1 5 2024].

[45] "firebase," [Online]. Available: https://firebase.google.com/. [Accessed 3 5 2024].

[46] D. android., "developer android.," [Online]. Available: https://developer.android.com/distribute/console. [Accessed 22 10 2024].