" Enhancing Life for Autistic People "

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“Abstract”

Abstract

The growing need to support children with Asperger's syndrome has led to innovative solutions that enhance their quality of life and improve parental understanding of their child's behavior. This project introduces a transformative approach by developing a wearable monitoring bracelet integrated with a mobile application. The system leverages advanced sensors to track key physiological and behavioral indicators, including heart rate, sweating rate, body temperature, and motion tracking, providing real-time insights into the child's physical and emotional state.

The application visualizes the collected data and incorporates educational tools to guide parents on effective interaction strategies tailored to their child's needs. Additionally, the system features diagnostic tools, such as autism screening and IQ assessments, to aid in identifying developmental challenges early. By addressing issues such as real-time monitoring, data interpretation, and usability, the project aims to bridge the communication gap between children and parents, offering proactive support during moments of stress or discomfort.

Future enhancements include integrating predictive analytics for stress detection and expanding the system's features to include personalized behavioral recommendations. This project aspires to revolutionize the care and support for children with Asperger's syndrome, fostering a healthier and more informed environment for both children and their families.

“List of Abbreviations”

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ASD: Autism Spectrum Disorder

HR: Heart Rate

HRV: Heart Rate Variability

GSR: Galvanic Skin Response

DL: Deep Learning

RF: Random Forest

KNN: K-Nearest Neighbor

SVM: Support Vector Machine

IOT: Internet Of Things

NB: Naïve Bayes

LR: Logistic Regression

ANN: Artificial Neural Network

ERD: Entity Relationship Diagram.

DFD: Data Flow Diagram

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Chapter One
“Introduction”

Chapter One

1.1 Overview

The "Enhancing Life for Autistic People" project focuses on improving the daily lives and emotional well-being of children with Asperger's syndrome, a specific form of autism spectrum disorder (ASD). Children with Asperger's syndrome often face significant challenges with social interactions, communication, and emotional regulation [5, 6, 7]. While they may demonstrate average or above-average intelligence and excel in certain areas like academics or the arts, their difficulty in understanding social cues and managing emotions can create anxiety and distress [8, 11]. These challenges can make everyday situations overwhelming and hinder their ability to engage effectively with peers and caregivers.[19 ,12 ,10 ,9]

Traditionally, interventions for children with autism have relied on therapy-based approaches that focus on behaviour modification, emotional regulation, and social skills training [5, 6]. However, these methods often lack real-time feedback and may not always be able to address a child's needs during moments of distress [7, 8]. There is also a growing need for more accessible and continuous support that empowers parents to understand their child's emotional state and respond promptly [9, 10, 11, 12].

This project addresses these challenges by introducing a wearable bracelet designed specifically for children with Asperger's syndrome. The bracelet will monitor several key physiological indicators, including heart rate, sweating, body temperature, and motion [7, 8, 10]. These indicators are valuable in detecting emotional distress or anxiety, allowing the system to provide immediate insights into the child's emotional and physical condition [11, 12, 19]. By using this data, parents can receive real-time updates about their child's emotional state, enabling them to respond appropriately and calmly during difficult moments [8, 11, 12].

The wearable device will be connected to a mobile application, which acts as a central platform for parents to monitor the bracelet's data remotely [9, 10]. The application will be designed with a user-friendly interface, enabling parents to track their child's physiological responses in real-time [10, 12, 19]. When the system detects signs of distress, such as an elevated heart rate or abnormal sweating patterns, the mobile app will notify the parent, allowing them to intervene and provide appropriate support [8, 11, 12].

By integrating this wearable technology with a mobile application, the project aims to create a more dynamic, real-time way for parents to engage with their children [9, 10, 12]. The goal is to help parents better understand their child's emotional needs and foster more supportive, empathetic interactions [11, 12, 19]. The long-term vision for the project is not only to improve emotional regulation but also to promote better social interactions and overall well-being for children with Asperger's syndrome [6, 7, 8]. Ultimately, this system seeks to empower both children and parents, providing tools to build stronger, healthier relationships and create a more supportive environment for children with autism [5, 10, 11].

1.2 Problem Statement

Children with autism, particularly those with Asperger's syndrome, face significant challenges in regulating their emotions, which often leads to heightened anxiety and stress during social interactions or unfamiliar situations [5, 6, 7]. These emotional difficulties can be hard for parents to identify, as the signs are not always externally visible [8, 9]. This gap in understanding leaves parents uncertain about how to effectively support their children in moments of distress, potentially escalating the child's anxiety and complicating parent-child interactions [10, 11]. As a result, both the emotional well-being of the child and the overall family dynamic can suffer [11, 12].

Current approaches to managing emotional regulation in children with autism primarily rely on therapy, structured routines, and behavioral interventions

[5, 6]. While these strategies are beneficial, they lack real-time insights into a child's emotional state [7, 8]. Parents often do not have immediate access to data that could help them understand when their child is struggling emotionally and how they can intervene in a timely and supportive manner

[9, 10, 12].

1.3 Objectives And Aims

The primary goal of this project is to create a system that empowers parents to better support their children with Asperger's syndrome by providing real-time physiological data [8, 10, 12].

1.3.1 Objectives

1.3.1.1 Real-Time Monitoring

i. To develop a wearable bracelet that continuously tracks key physiological indicators such as heart rate, body temperature, sweating rate, and motion [7, 8, 10].

ii. To ensure the bracelet can provide real-time data, allowing parents to monitor their child's emotional and physical state continuously [9, 11, 12].

1.3.1.2 Data-Driven Insights

i. To implement a mobile application that receives and processes the physiological data from the bracelet [9, 10, 12].

ii. To develop a system that displays real-time physiological data on the mobile app, enabling parents to understand the emotional and physical state of their child [10, 11, 19].

1.3.1.3 Facilitating Timely Interventions

i. To create a system that helps parents recognize and respond to early signs of anxiety or stress in their children, enabling timely and appropriate interventions to calm the child and prevent escalation of distress [8, 10, 11].

1.3.1.4 Improving Parent-Child Interaction

i. To enhance the interaction between parents and children with Asperger's syndrome by providing objective, data-driven insights that aid in understanding the child's emotional needs [9, 12, 19].

ii. To foster a supportive and informed environment that allows parents to engage more effectively with their children, improving emotional regulation [8, 10, 12].

1.3.1.5 Data Logging and Trend Analysis

i. To enable the mobile app to store and display historical physiological data, allowing parents to track their child's emotional trends over time [9, 10, 12].

ii. To provide insights that help parents understand patterns in their child’s emotional responses, aiding in long-term management strategies [8, 11, 19].

1.3.1.6 User-Friendly Interface

i. To ensure the mobile app is user-friendly, intuitive, and accessible to parents with varying levels of technical expertise [10, 11, 12].

ii. To simplify the monitoring process, making it easy for parents to interpret the data and make informed decisions based on real-time feedback [9, 11, 12].

1.3.2 Aims

1.3.2.1 Enhance Emotional Regulation

i. To improve the quality of life for children with Asperger's syndrome by promoting emotional regulation and reducing anxiety through real-time physiological data [8, 10, 11].

1.3.2.2 Foster Better Communication

i. To enhance communication and understanding between parents and children, enabling parents to respond effectively to emotional needs [9, 12, 19].

1.3.2.3 Provide Real-Time Monitoring

i. To offer parents a practical tool for monitoring their child's emotional and physiological states in real time [10, 11, 12].

1.3.2.4 Support Parental Involvement

i. To empower parents with continuous insights, helping them stay actively engaged in their child's emotional well-being [8, 9, 10]

1.4 Project Scope and Limitations

1.4.1 Project Scope

This project aims to develop an innovative system to assist parents in supporting children aged 5 to 9 years with Asperger's syndrome by providing real-time physiological data and insights [5, 7, 8]. The system will include:

1. **Wearable Bracelet:**
   A device to monitor heart rate, body temperature, sweating rate, and movement to track the child's emotional state [8, 9, 10].
2. **Mobile Application:**
   An app to display real-time data, allowing parents to monitor their child's physiological responses and receive alerts when signs of distress are detected [9, 10, 12].
3. **Real-Time Insights:**
   The system will provide actionable data, enabling parents to respond quickly to emotional stress or anxiety in their child [8, 9, 12].
4. **Parental Support:**
   The system will offer data-driven insights to help parents better understand and support their child's emotional needs [9, 10, 12].
5. **User-Friendly Design:**
   The bracelet and app will be designed for ease of use by both parents and children, with a focus on simplicity and comfort [10, 12, 19].

1.5 Limitations

1. **Technological Constraints:**
   The system's accuracy may be influenced by environmental conditions (e.g., temperature, humidity) or improper usage (e.g., how the bracelet is worn), affecting data reliability [9, 10, 12].
2. **User Adoption:**
   The system's success depends on parents' willingness to adopt and engage with the technology. Hesitation or lack of technical proficiency could limit its effectiveness [10, 11, 12].
3. **Effectiveness of Interventions:**
   The real-time interventions (e.g., soothing sounds) may not always be effective for every child, as individual preferences and emotional triggers may vary [8, 9, 12].
4. **Dependence on Mobile Devices:**
   The system relies on the availability of mobile devices (smartphones) and their functionality. Inaccessible or incompatible devices could hinder system use [9, 10, 12].

5. **Potential Technical Issues:**
   Connectivity issues, software bugs, or other technical problems could impact on the system's performance, particularly during critical moments when timely interventions are necessary [12, 19].

1.5.1 Significance of the Study

This study has the potential to make a significant impact on the lives of children with Asperger's syndrome and their families. The development of a system for real-time monitoring of emotional and physiological states aims to achieve the following key outcomes:

1.5.1.1 Improved Emotional Regulation

- **i.** Objective: Providing parents with immediate feedback on their child's emotional state enables timely interventions [11, 12].
- **ii.** Impact: This can help children manage emotions more effectively, reduce anxiety, and foster a greater sense of security [18].

1.5.1.2 Enhanced Parent-Child Communication

- **i.** Objective: The system enhances understanding between parents and children [19].
- **ii.** Impact: By improving communication, this leads to stronger bonds and a more supportive home environment [21].

1.5.1.3 Informed Interventions

- **i.** Objective: The system collects data that allows parents to identify patterns in their child's emotional responses [7, 10, 25].
- **ii.** Impact: Parents can tailor interventions more effectively, using a data-driven approach to meet their child's unique needs [23].

1.5.2 Contribution to Autism Research

- i. Objective: The study contributes to existing research on autism and the use of technology for supporting individuals with developmental disorders [5, 6, 8, 14, 20].
- **ii.** Impact: The findings may inform future studies and contribute to the development of similar interventions [13, 22].

1.5.2.1 *Awareness and Education*

i. Objective: The study aims to raise awareness about the challenges faced by children with Asperger's syndrome[9, 17].

ii. Impact: By demonstrating how technology can address these challenges, it helps improve support systems from parents, educators, and healthcare professionals[16, 24].

1.5.2.2 *Potential for Broader Applications*

i. Objective: The system developed for children with Asperger's syndrome may have applications beyond this group[15, 20].

ii. Impact: The principles and technologies could be adapted for individuals with other emotional regulation challenges, such as anxiety disorders or neurodevelopmental conditions[22].

Chapter Two
“Literature Review”

Related Work

1.6 Concepts

The paper [1] investigates the use of wearable sensors and machine learning techniques to detect and predict challenging behaviours in children with Autism Spectrum Disorder (ASD) during interactions with social robots and toys. By analysing physiological signals, such as heart rate (HR) and heart rate variability (HRV), alongside kinetic data (e.g., movement), the study aims to develop a system for early detection of behaviours like meltdowns, tantrums, and aggression.

Key contributions include:

1. Integration of wearable sensors and ML models to identify challenging behaviours non-invasively.
2. Analysis of physiological data (HR and HRV) as primary predictors of behavioural challenges.
3. Highlighting the superior performance of XG Boost, achieving high accuracy in behaviour detection.
4. Demonstrating the feasibility of wearable sensor-based interventions during therapy sessions involving social robots.

The study's findings emphasize the potential for real-time monitoring systems to assist caregivers and therapists in managing challenging behaviors, improving therapy outcomes for children with ASD.

The paper [2] discusses the development of a real-time stress monitoring device designed specifically for autistic children. It emphasizes the importance of detecting stress levels early, as autistic children often experience heightened stress that can lead to severe anxiety attacks, tantrums, or seizures without prior visible symptoms.

The proposed system

1. Monitors physiological signals, such as heart rate and galvanic skin response (GSR), using non-invasive sensors.
2. Utilizes fuzzy logic to interpret the collected data and determine stress levels.
3. Provides real-time feedback through an intuitive interface, such as an LCD display and LED indicators, alerting caregivers or educators to elevated stress levels in children.

This system aims to enhance the management of stress-related challenges in autistic children by providing early warnings and enabling timely interventions to improve their quality of life. The device is tested in various stress-inducing scenarios, demonstrating its potential for practical application in educational or therapeutic settings.

The paper [3] presents the development and evaluation of a Sensory Management Recommendation System (SMRS) for children with Autism Spectrum Disorders (ASD). The SMRS integrates sensors, machine learning models, and fuzzy logic to monitor and manage the sensory environment of children with ASD. The system aims to address sensory processing challenges commonly experienced by children with ASD, such as hypersensitivity or hyposensitivity to environmental stimuli like noise, light, and temperature.

Key functionalities include:

1. Real-time Monitoring: Using wearable sensors and environmental monitors to collect physiological (e.g., heart rate, skin conductivity) and environmental (e.g., temperature, brightness, noise) data.
2. Sensory Profiling: Analysing individual sensory processing patterns to personalize interventions.
3. Management Strategies: Generating recommendations to caregivers or teachers to mitigate sensory challenges and improve attention or reduce stress.
4. User-Friendly Interface: A mobile app interface for caregivers to view data, receive alerts, and implement suggested strategies.

This system operates as an assistive tool to improve classroom performance and quality of life for children with ASD by enabling better sensory management through technology.
The paper [4] presents the development and evaluation of a Machine Learning-Based Monitoring System tailored for children with Autism Spectrum Disorders (ASD) to detect and manage attention and stress levels. The system leverages wearable sensors, environmental monitors, and machine learning models to address sensory processing challenges experienced by children with ASD, such as difficulty in managing environmental stimuli like light, noise, and temperature.

Key functionalities include:

1. Real-time Monitoring: Integration of sensors and devices (e.g., Apple Watch, iPhone, Arduino UNO) to collect physiological data (e.g., heart rate, skin conductivity, hand movements) and environmental data (e.g., noise levels, light intensity, temperature).
2. Sensory Profiling: Use of a validated sensory profiling questionnaire to assess individual sensory preferences and limitations, personalizing detection and intervention.
3. Attention and Stress Detection: Implementation of machine learning models like Gradient Boosting Decision Trees (GBDT) and Random Forest (RF) for accurate prediction of attention and stress levels, with prediction accuracies of 86.67% and 99.05%, respectively.
4. User-Friendly Application: A mobile app interface for caregivers to register children, view real-time data, receive alerts, and track sensory management progress.

This system serves as an assistive technology to enhance the daily lives of children with ASD by enabling better attention and stress management through personalized monitoring and actionable insights.

Concept of the Paper [5] The paper systematically reviews approaches to diagnose and manage Autism Spectrum Disorder (ASD) using Internet of Things (IoT) devices and Machine Learning (ML). The focus is on leveraging IoT-enabled systems to improve the early diagnosis of ASD and enhance the Quality of Life (QoL) for children with the disorder

Key contributions include:

1. Providing a taxonomy of IoT-based ASD approaches, categorizing them into:
    a) Methods for diagnosing and measuring disease severity.
    b) Plans for improving QoL for ASD patients.
2. Highlighting the use of ML and Deep Learning (DL) algorithms for detecting patterns in data collected from wearable devices, sensors, and robots.
3. Comparing 28 selected studies based on metrics like accuracy, sensitivity, and specificity to identify trends and research gaps in IoT-based healthcare for ASD.

The paper emphasizes the transformative role of IoT and AI technologies in diagnosing ASD earlier and improving care through real-time monitoring and intervention strategies.

This paper [6] explores the use of machine learning techniques to detect Autism Spectrum Disorder (ASD) in children, focusing on improving the accuracy and efficiency of the diagnostic process. Conventional ASD diagnosis methods, such as interviews and behavioural observations, are time-consuming and expensive. The study aims to streamline the process by applying machine learning models to a behavioural dataset derived from the Q-CHAT-10 questionnaire for toddlers.

The primary objective is to:

1. Identify children at risk for ASD in its early stages.
2. Develop predictive models using machine learning algorithms, including Logistic Regression (LR), Support Vector Machines (SVM), Naïve Bayes (NB), Random Forest (RF), and K-Nearest Neighbours (KNN).
3. Evaluate the models to determine the most effective approach for ASD detection.

The study highlights the importance of using automated systems to assist medical professionals in identifying ASD traits quickly, providing early intervention opportunities, and reducing diagnostic delays.

1.7 Methodologies

1.7.1 Techniques and Models Used

The methodologies utilized machine learning and decision-making frameworks for ASD diagnosis and management:

1. **Classification Algorithms:**
    a. Support Vector Machine (SVM), Logistic Regression (LR), K-Nearest Neighbor (KNN), Random Forest (RF), Gradient Boosting Decision Trees (GBDT), Artificial Neural Networks (ANN), Multilayer Perceptron (MLP), and Decision Trees (DT) [1], [3], [4], [6].
    b. Fuzzy logic was applied for stress-level classification and sensory management in uncertain conditions [2], [3].
2. **Feature Selection:**
    a. Included physiological signals (e.g., heart rate, GSR, HRV), environmental data (e.g., light, temperature, noise), and behavioural attributes derived from tools like the Q-CHAT-10 [1], [3], [6].
    b. Feature reduction methods like Genetic Algorithms (GA) and DBSCAN clustering were employed to improve model efficiency [5].
3. **Training and Validation:**
    a. Cross-validation methods like 5-fold cross-validation and hyperparameter optimization (e.g., grid search) ensured robust results [3], [4].

1.7.2 Sensors and Platforms Used

1. A combination of wearable and IoT-based sensors was used to gather real-time physiological and environmental data:
2. Wearable Sensors:
    a. Expatica E4 Wristband: Captured heart rate, GSR, temperature, and movement [1].
    b. Apple Watch: Provided heart rate and accelerometer data for motion tracking [3], [4].
    c. Arduino Uno and DHT11: Monitored environmental parameters like temperature, noise, and humidity [3], [4].
3. Robotics and Interaction Stimuli:
    a. Robots such as NAO and PARP Seal were integrated for social and therapeutic interactions [1], [5].

   b. Toys like rubber balls and wooden blocks engaged children during experiments [1].
4. IoT Platforms:
   a. Data from wearable sensors were processed in IoT-enabled environments, often with cloud servers for real-time analysis and feedback [3], [5].

1.7.3 Real-Time Data Collection and Processing

The studies emphasized real-time data handling for detecting ASD-related behaviours:

1. Annotation and Preprocessing:
   a. Sensor data underwent preprocessing, including noise removal and time-domain feature extraction [1], [4].
   b. Video annotations labelled behaviours (e.g., challenging vs. non-challenging) using software like BORIS [1].
2. Data Fusion and Management:
   a. Physiological data were combined with sensory profiles to tailor recommendations and interventions [3], [4].
   b. Mobile apps enabled caregivers to view real-time alerts and data visualizations [3], [4].
3. Experimental Protocols:
   a. Simulated stress-inducing scenarios (e.g., arithmetic tasks or sensory adjustments) validated the systems' real-time capabilities [2], [4].

1.8 Evaluation and Metric

The systems were assessed for performance, usability, and real-world applicability:

1. Performance Metrics:
   a) Accuracy, precision, recall, F1-score, and inference time were used to evaluate models [1], [3], [4].
   b) XG Boost consistently demonstrated high performance with accuracies of up to 99% [1], [2], [4].
2. Controlled vs. Real-World Testing:
   a) Most systems were tested in controlled settings to ensure replicability, with plans for real-world deployment [1], [4], [5].

3. Limitations and Challenges:
   a) Constraints included unbalanced datasets, limited participant diversity, and challenges in long-term wearable device usage [1], [6].
   b) IoT data security and the need for continuous caregiver involvement were notable concerns [2], [3], [5].

1.9 Limitations

1. Limited sample size:
   a) Limited participant diversity affected generalizability. [1],[2],[3],[4],[5],[6].

2. Gender differences: [1].

3. Limited real-world deployment:
   a) Most studies were conducted in controlled environments, limiting real-world applicability.[1],[4],[5].

4. In tracking Physiological signals efficiently:
   a) Sensors did not fully capture all ASD-related behaviors (e.g., emotional and social cues). [2],[3],[5].

5. Device size and usability:
   a) Discomfort in wearable devices limited long-term usage.[1],[2],[3],[5].

6. Unbalanced data:
   a) Low frequency of observed challenging behaviors compared to non-challenging ones.[1],[6].
7. Continuous human involvement is required for applying the recommended strategies:[3].

8. IoT Data Security:
   a) Challenges ensuring data privacy, encryption, and integrity during transmission.[5].
9. Limited Attribute Scope: The dataset focused on behavioural questions without incorporating physiological or multimodal features [3],[6].

1.10 Results:

Table1 Results of Related work

<table>
<tr><th>Paper Number</th><th>Model</th><th colspan="2">Accuracy</th></tr>
<tr><td>Paper [1]</td><td>XG Boost</td><td colspan="2">99%</td></tr>
<tr><td rowspan="4">Paper [2]</td><td>XG Boost</td><td colspan="2">99%</td></tr>
<tr><td>DT</td><td colspan="2">98%</td></tr>
<tr><td>MLP</td><td colspan="2">97%</td></tr>
<tr><td>SVM</td><td colspan="2">85%</td></tr>
<tr><td rowspan="10">Paper [3]</td><td rowspan="2">Logistic Regression (LR)</td><td>Attention</td><td>65.71%</td></tr>
<tr><td>Stress</td><td>65.30%</td></tr>
<tr><td rowspan="2">K-Nearest Neighbor (KNN)</td><td>Attention</td><td>81.90%</td></tr>
<tr><td>Stress</td><td>93.92%</td></tr>
<tr><td rowspan="2">Random Forest (RF)</td><td>Attention</td><td>79.05%</td></tr>
<tr><td>Stress</td><td>98.82%</td></tr>
<tr><td rowspan="2">Artificial Neural Network (ANN)</td><td>Attention</td><td>80.95%</td></tr>
<tr><td>Stress</td><td>96.89%</td></tr>
<tr><td rowspan="2">Gradient Boosting Decision Tree (GBDT)</td><td>Attention</td><td>86.67%</td></tr>
<tr><td>Stress</td><td>98.50%</td></tr>
</table>

Paper [4]	**Attention Detection**	SVM	80.00%
		Random Forest (RF)	80.95%
		KNN	81.90%
		Gradient Boosting Decision Tree (GBDT)	86.67%
	Stress Detection	Artificial Neural Network (ANN)	96.89%
		Random Forest (RF)	99.05%
		Gradient Boosting Decision Tree (GBDT)	98.94%
Paper [5]	**SVM**		98%
Paper [6]	**LR**		97.15%
	NAÏVE BAYES		94.79%
	SVM		93.84%
	KNN		90.52%
	RF		81.52%

Chapter Three
“System Analysis and Design”

Chapter Three : System Analysis

1.11 Problem Definition

Children with Asperger's syndrome often struggle with emotional regulation, leading to stress and challenging behaviors. Parents may find it difficult to detect early signs of distress, which makes timely intervention challenging. Current methods of monitoring emotional states are subjective and lack real-time feedback.

This project aims to address this gap by developing a wearable bracelet and a mobile app that monitors key physiological indicators such as heart rate, sweating rate, temperature, and motion. The system will provide real-time insights to parents, enabling them to respond promptly and support their child's emotional well-being.

1.12 System Requirements

1.12.1 Functional Requirements

1. **User Authentication**:
   i. **Account Creation**: Parents should be able to create accounts using an email address and password.
   ii. **Secure Login**: Parents must log in securely to access the app and monitor their child's status.
2. **Health Monitoring:**
   i. **Heart Rate Monitoring**: The bracelet continuously monitors the child's heart rate and sends the data to the app in real-time.
   ii. **Sweating Rate Monitoring**: The bracelet tracks the rate of sweating as an indicator of stress and sends updates to the app.
   iii. **Temperature Monitoring:** The bracelet monitors the child's body temperature and sends updates to the app.
   iv. **Motion Tracking**: The bracelet tracks the child's movements to detect changes in activity levels and possible stress or discomfort, transmitting this data to the app
3. **Data Transmission and Storage:**
   i. **Real-Time Data Sync**: Physiological data should be transmitted in real-time from the bracelet to the app.

ii. **Data Storage**: The app should store historical data for trends and analysis.

4. Behavioral Feedback:

i. **Behavior Insights**: The app should analyze physiological data to give insights into the child's behavior.

ii. **Trend Analysis**: Display trends based on data, such as periods of high stress, which can help parents better understand triggers.

5. Guidance and Testing:

i. **Educational Resources**: Provide articles for parents on interacting with their autistic children.

ii. **Autism Screening and IQ Tests**: Include an autism screening test and an IQ test in the app, designed for the age group of 5–9.

1.12.2 Non-functional Requirements

1. Performance:

i. The system must provide low-latency communication between the wearable device and the mobile app, ensuring real-time feedback within seconds.

ii. The app should remain responsive even when processing large datasets over time.

2. Reliability:

i. The system should ensure continuous data collection without frequent interruptions, ensuring reliable monitoring of the child's emotional state throughout the day.

ii. The wearable device and app should be robust, with minimal failure rates, especially during critical intervention moments.

3. Usability:

i. The mobile app should have a user-friendly interface, making it easy for parents to navigate, configure settings, and initiate interventions.

ii. The wearable device should be comfortable, non-intrusive, and easy for the child to wear for extended periods.

4. **Battery Life:**

    i. The wearable device must offer a long battery life (12-24 hours), ensuring it can operate continuously throughout the day without frequent recharging.

    ii. The mobile app should be optimized to conserve batteries when running in the background or during extended usage.

5. **Scalability:**

    i. The system should be able to handle multiple users and devices without a decrease in performance, supporting families with more than one child or multiple wearable sensors.

    ii. The backend infrastructure should be able to scale up to accommodate a larger user base over time.

6. **Security:**

    i. The system must incorporate strong encryption for data storage and transmission to protect sensitive health data.

    ii. The app should implement secure user authentication to ensure that only authorized users can access the system.

7. **Compatibility:**

    i. The mobile application should be compatible with both iOS and Android devices, ensuring accessibility for a wide range of users.

    ii. The wearable device must be compatible with common wireless communication standards like Bluetooth for easy integration with smartphones.

8. **Maintainability:**

    i. The system should be easy to update and maintain, with remote software updates for both the app and wearable device.

    ii. The app should be designed for easy troubleshooting, ensuring any issues can be quickly identified and resolved.

9. Cost-Effectiveness:

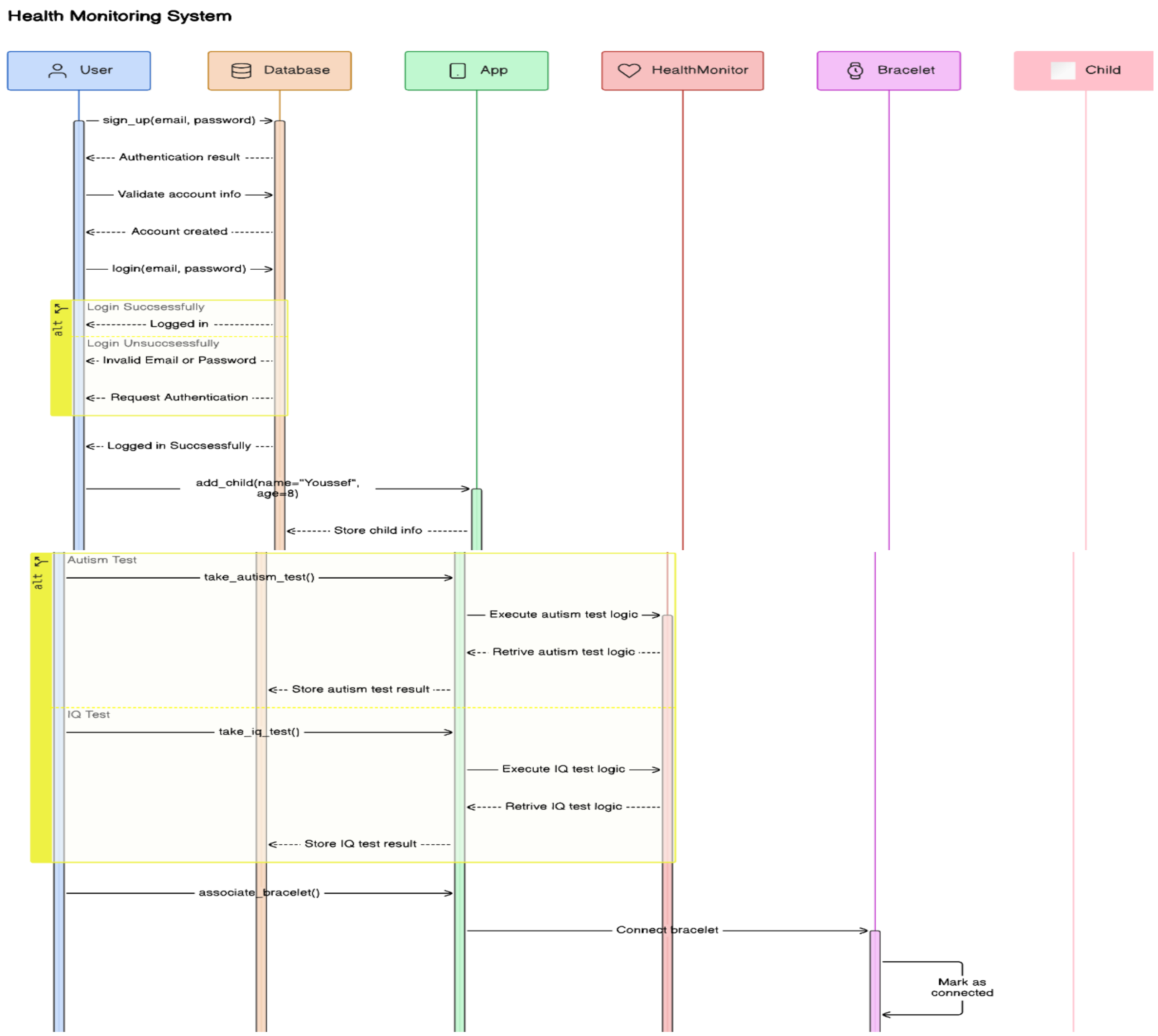
i. The system should be affordable for families to use, considering the cost of the wearable device, mobile app, and any subscription or maintenance fees.

ii. Efforts should be made to keep costs low without sacrificing performance or quality

1.13 System Modeling

1.13.1 Sequence Diagram

Sequence diagrams showcase the interaction flow between system components. In this system, the diagram highlights how the bracelet collects real-time physiological data (heart rate, sweating, temperature, motion) from the child and sends it to the mobile app. The app processes the data and provides feedback to the parent, enabling timely responses to the child's emotional and physiological needs. This ensures efficient system functionality to support parental care.



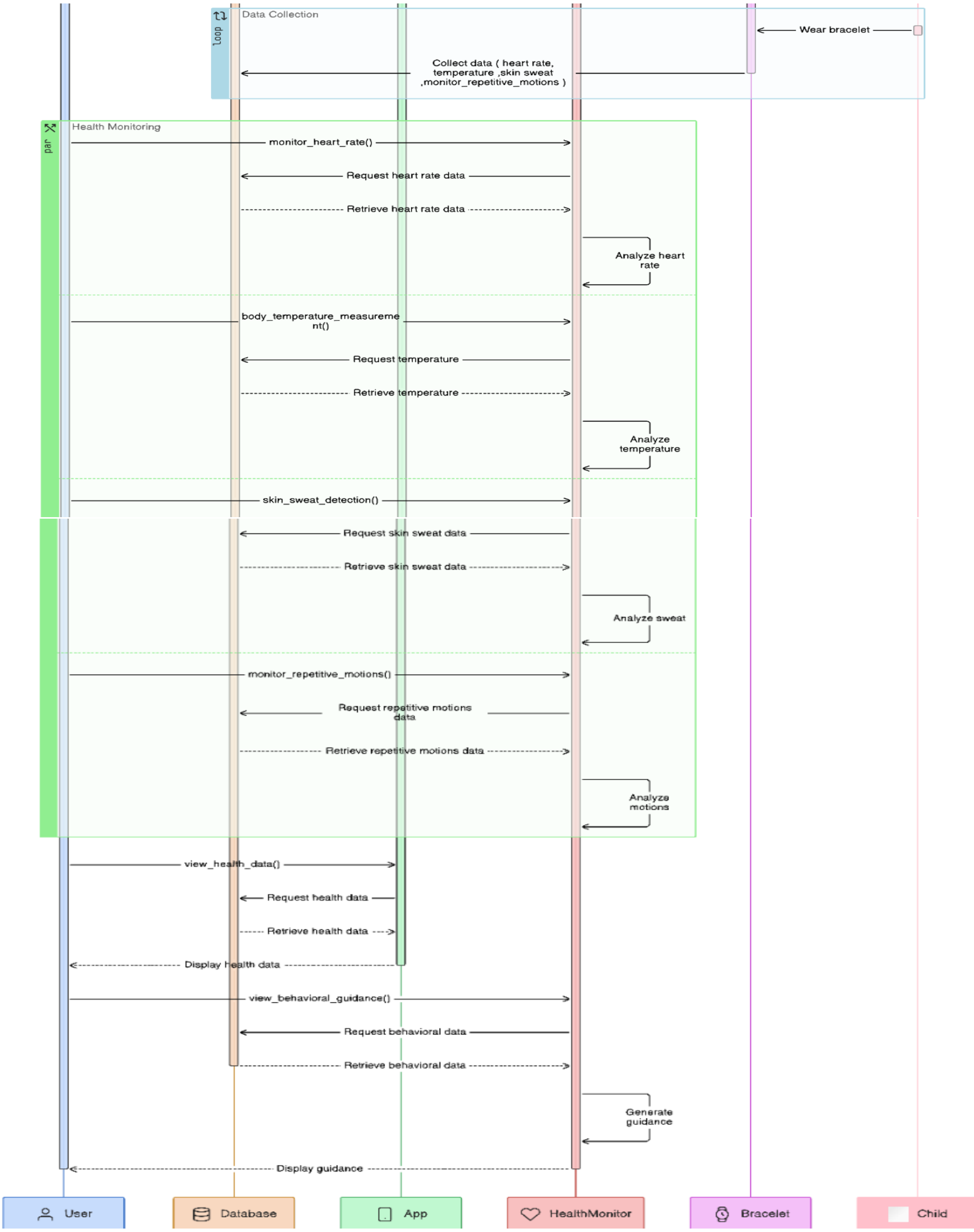


Figure 0.1 Sequence Diagram

1.13.2 Use- Case Diagram

The use case diagram represents the key functionalities and interactions within the system. It illustrates how the wearable bracelet collects physiological data (e.g., heart rate, sweating, temperature, and motion) from the child and transmits it to the mobile app. The parent, as the primary user, interacts with the app to monitor the child's emotional state, receive alerts in distress situations, and take necessary actions, such as sending calm responses. This diagram visually maps the relationship between users and system processes, ensuring a seamless flow of operations for effective child support.

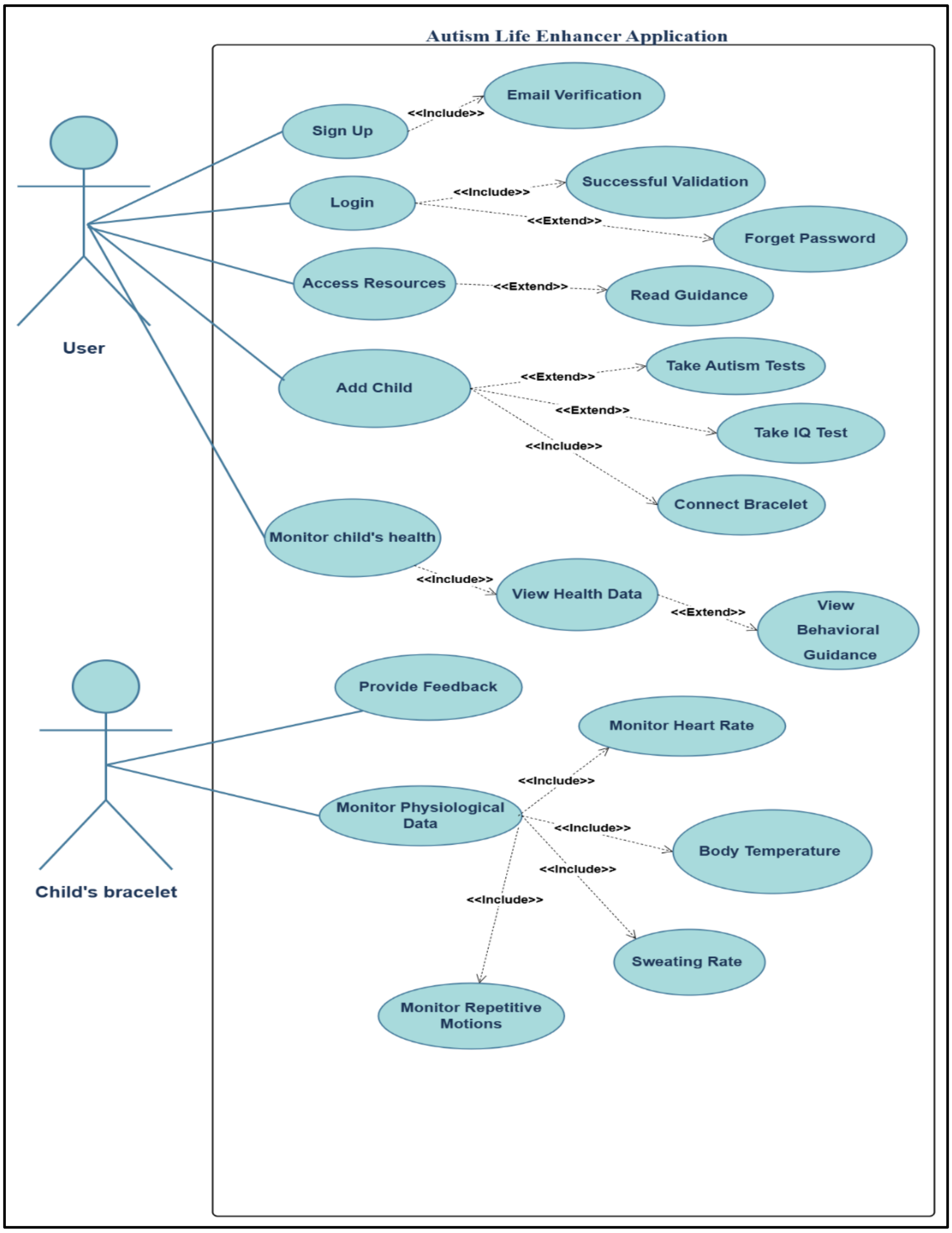


Figure 0.2 Use Case Diagram

1.13.3 Class Diagram

The diagram highlights the interaction between the Child, Bracelet, and Mobile App, with the Parent overseeing the data and receiving actionable insights. This structure ensures seamless communication and real-time feedback for effective autism care management.

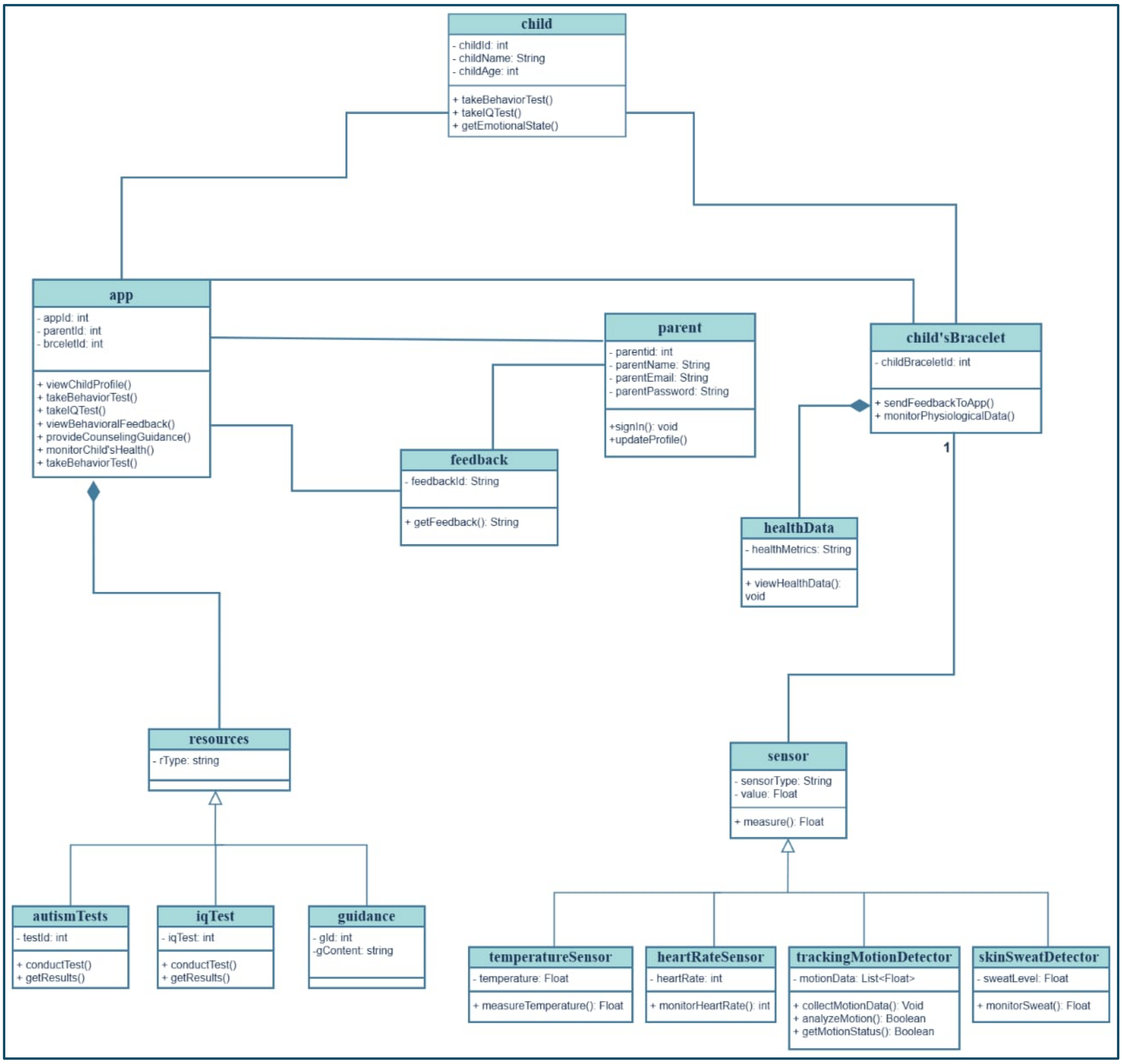


Figure 0.3 Class Diagram

1.13.4 Entity Relationship Diagram

The Entity-Relationship Diagram (ERD) represents the core components and data flow within the system. It illustrates how the wearable bracelet collects physiological data (e.g., heart rate, sweating, temperature, and motion) from the child and links it to the mobile app. The parent, as the primary user, accesses the app to monitor the child's emotional state, view real-time data, and respond to alerts during distress situations. This ERD visually captures the relationships between key entities (Parent, Child, Bracelet, Mobile App) and their attributes, ensuring an organized and efficient data structure to support the system's functionalities.

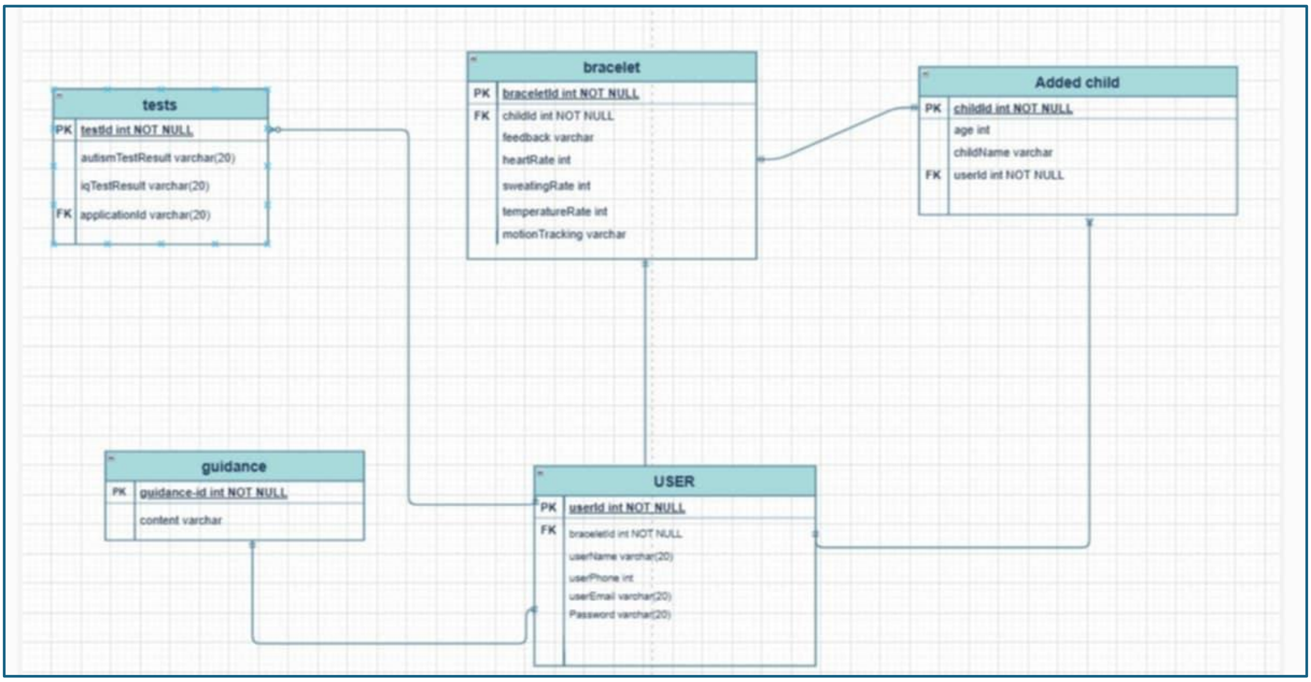


Figure 0.4 Entity Relationship Diagram

1.13.5 Data Flow Diagram (Level 0)

The Level 0 Data Flow Diagram (DFD) provides a high-level view of the system's processes and data flow. It shows how the wearable bracelet collects physiological data from the child, sends it to the system for processing, and displays data analyzed on the mobile app. The parent uses the app to monitor the child's emotional state, view updates, and receive alerts. This diagram highlights the key entities (Parent, Child, Bracelet, Mobile App) and their interactions, ensuring a clear understanding of the system's functionality.

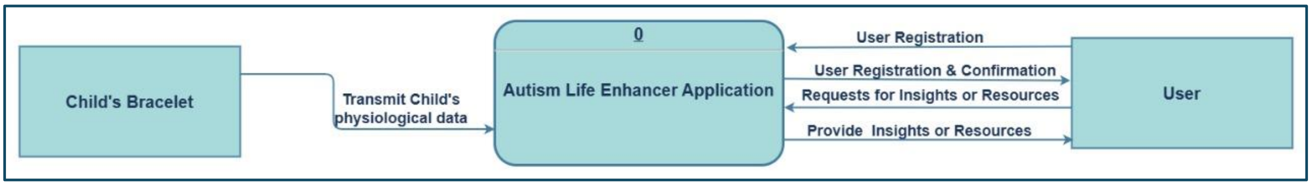


Figure 0.5 Data flow diagram (level 0)

1.13.6 Data Flow Diagram (Level 1)

The Level 1 Data Flow Diagram (DFD) expands on the system's processes, breaking them into specific functions. It details how the bracelet collects physiological data from the child, which is then processed to analyze emotional states. The analysis generates real-time insights and alerts, which are sent to the mobile app. Within the app, the parent can access detailed reports, monitor trends, and respond to notifications. This level focuses on internal processes and their interactions, offering a deeper understanding of how data moves through and supports the system.

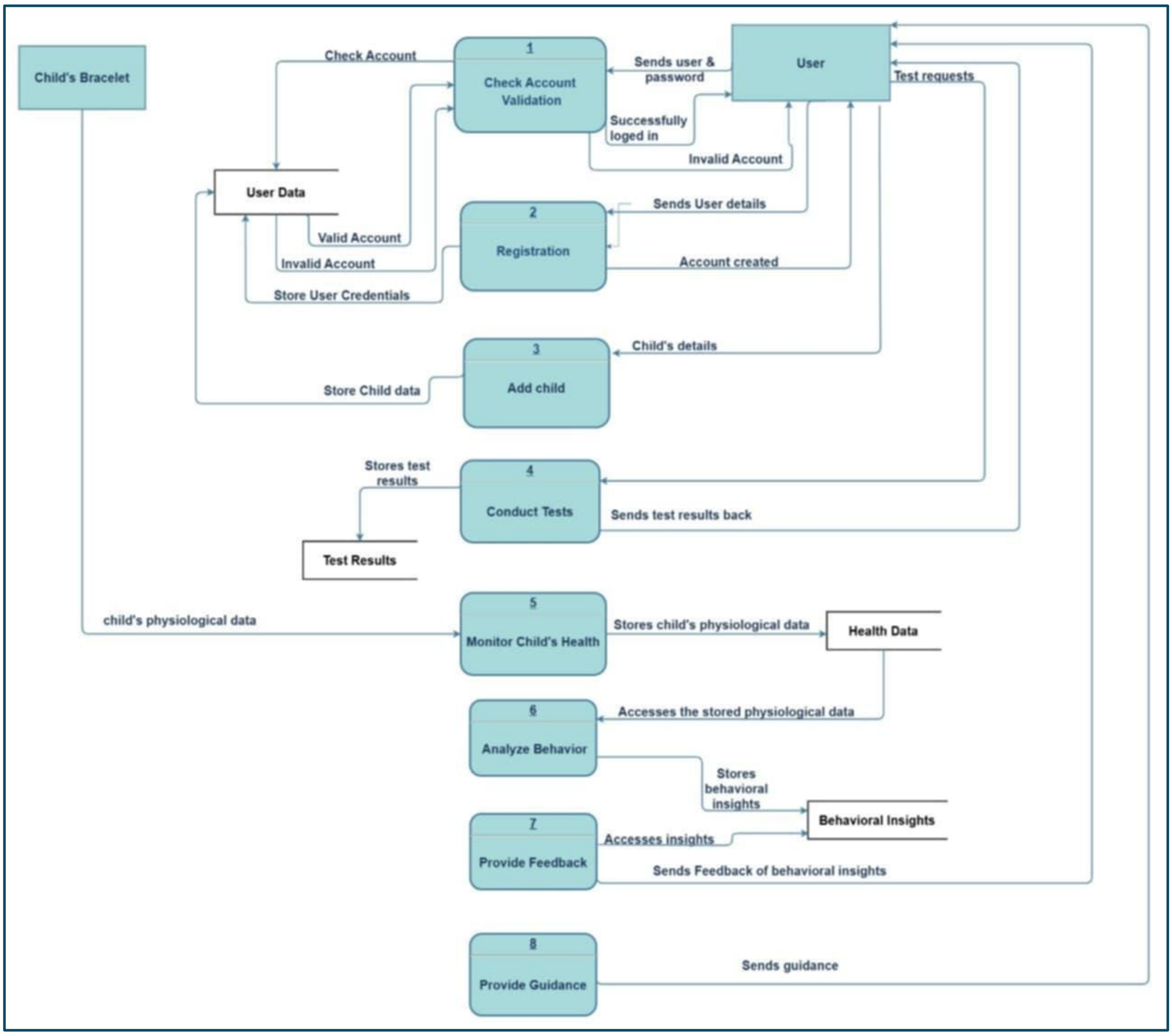


Figure 0.6 Data flow diagram (level 1)

Chapter Four
“Implementation Work”

Chapter Four : Implementation Work

1.14 Overview

This chapter describes how we implemented the system to support children with Asperger's syndrome. The system consists of a wearable bracelet that tracks physiological signals such as heart rate, temperature, sweating, and acceleration. Along with this, there's a mobile app that allows users to monitor this data in real time and respond when necessary. We also used a machine learning model to analyze the data and identify if the child is experiencing a behavioral challenge.

In this chapter, we'll cover the dataset we used, the machine learning model we built, how the different parts of the system communicate through an API, and give details on the hardware setup and the mobile app design. Finally, we'll present the results we obtained from testing the system.

1.15 Dataset in Details:

The dataset we used in this project is essential for training and testing the machine learning model. It contains over 350,000 records, each representing a single moment in time collected from a child wearing the bracelet. Every row includes several values such as body movement (X, Y, Z axes), heart rate (HR), skin temperature (TEMP), sweating, acceleration, and electrodermal activity (EDA), which is associated with stress levels. The accelerometer readings fall within the range of approximately -1.984375 to 2.0. Other sensor value ranges include:

EDA: 0 to 9

TEMP: 26.51°C to 35.68°C

HR: 60.77 bpm to 179.38 bpm

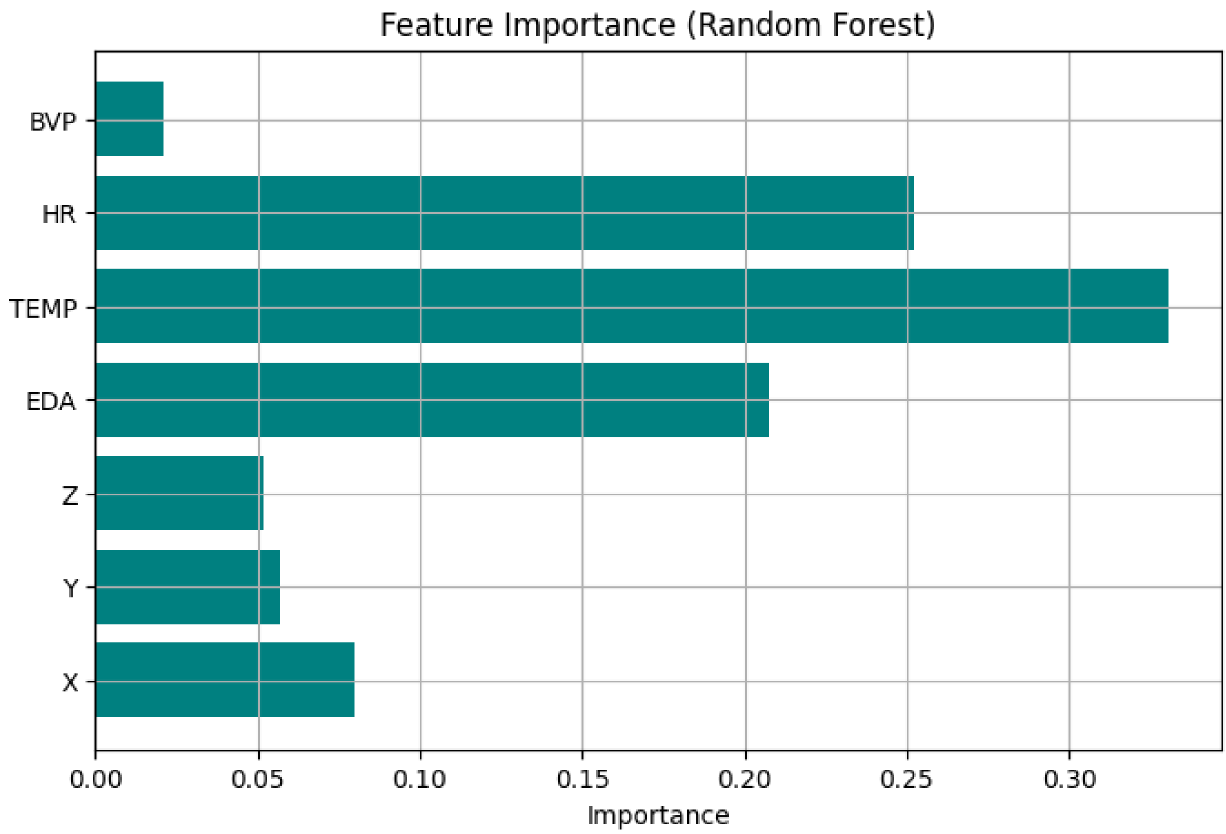


Figure 0.1 Feature Importance Bar Chart

The target column (label) tells whether the moment recorded was considered a "Challenging" or "Non-Challenging" behavior. We converted these labels into numeric form — 0 for Non-Challenging and 1 for Challenging — so the model could process them.

One important issue we encountered was that the dataset was imbalanced, with far more "Non-Challenging" behaviors than "Challenging" ones. The original class distribution was as follows:

Original: Counter({0: 269,975, 1: 13,674})

To address this imbalance, we applied SMOTE (Synthetic Minority Over-sampling Technique) to balance the dataset by generating synthetic samples for the minority class. After applying for SMOTE, the class distribution was as follows:

After SMOTE: Counter({0: 269,975, 1: 269,975}

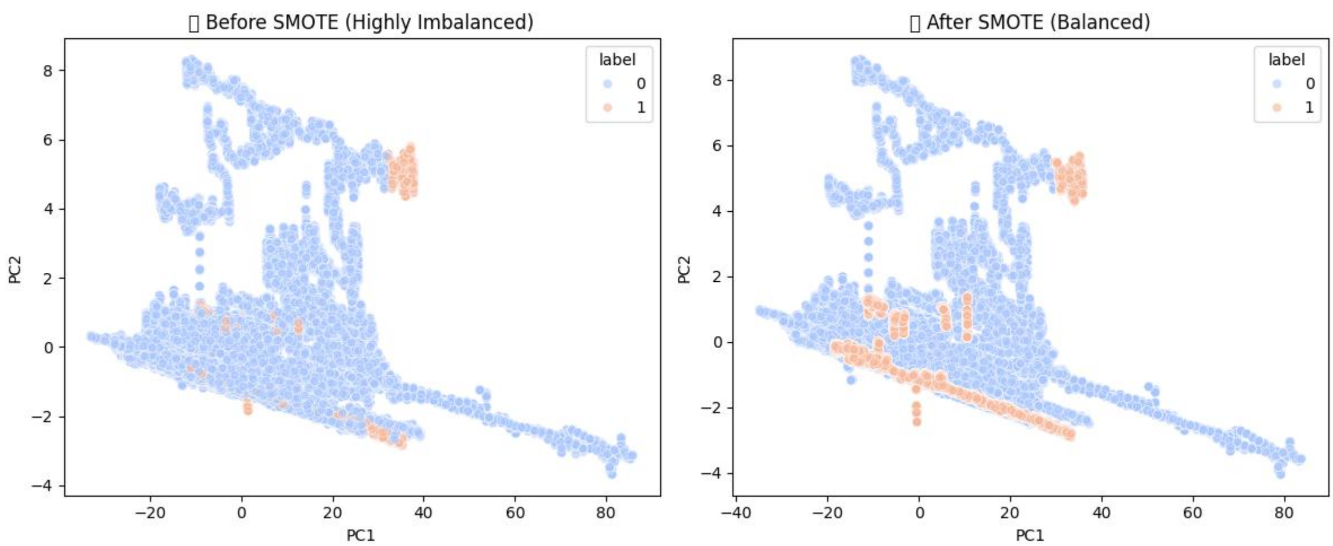


Figure 0.2 Visualization of Class Distribution Before and After SMOTE Using PCA

Before training, we did some basic preprocessing, such as removing unnecessary columns and identifying which features were most important. A Random Forest model helped us determine that the most useful features for making predictions were heart rate, EDA, and motion.

1.16 Model:

Since this project is in the healthcare domain, reducing **False Negatives (FN)** was our top priority. Missing a detection of challenging behavior could result in delayed interventions for the child, which may have serious consequences. Therefore, we focused on models that minimized FN while maintaining high overall accuracy and low False Positive Rates (FPR).

After evaluating several machine learning models, **LightGBM was selected as the final model** used in this project because it demonstrated excellent performance in minimizing False Negatives, while still achieving high accuracy and acceptable precision and recall.

Below is a summary of the models we tested and their evaluation results:]

LightGBM (Final Model – Without SMOTE)

LightGBM automatically handles class imbalance using the is unbalance parameter. It was ultimately chosen for this project based on its balance of accuracy, precision, and its exceptionally low FN.

Accuracy: 0.985

True Positives (TP): 3414

True Negatives (TN): 66,496

False Positives (FP): 999

False Negatives (FN): 4

False Positive Rate (FPR): 0.0148

False Negative Rate (FNR): 0.001

XGBoost

XGBoost performed strongly with a low number of false negatives and excellent overall metrics.

Accuracy: 0.999

True Positives (TP): 3411

True Negatives (TN): 67,396

False Positives (FP): 99

False Negatives (FN): 7

False Positive Rate (FPR): 0.0015

False Negative Rate (FNR): 0.0020

Random Forest

Random Forest provided a very low false positive rate and high overall accuracy but had a slightly higher number of false negatives compared to LightGBM and XGBoost.

Accuracy: 0.999

True Positives (TP): 3404

True Negatives (TN): 67,464

False Positives (FP): 31

False Negatives (FN): 14

False Positive Rate (FPR): 0.0005

False Negative Rate (FNR): 0.0041

Logistic Regression

Although Logistic Regression had acceptable accuracy, it produced high numbers of both false positives and false negatives, making it less reliable for healthcare use.

Accuracy: 0.789

True Positives (TP): 3317

True Negatives (TN): 52,639

False Positives (FP): 14,856

False Negatives (FN): 101

False Positive Rate (FPR): 0.2201

False Negative Rate (FNR): 0.0295

XGBoost with Class Weights

Class weights were set based on the imbalance ratio (approx. 19.74), helping improve the model's sensitivity to the minority class.

Accuracy: 0.999

True Positives (TP): 3410

True Negatives (TN): 67,376

False Positives (FP): 119

False Negatives (FN): 8

False Positive Rate (FPR): 0.0018

False Negative Rate (FNR): 0.0023

Summary

Among all the models tested, **LightGBM** was selected as the final model for deployment in this project. It achieved the **lowest False Negative rate (FN = 4)**, which aligns with the critical goal of minimizing the risk of overlooking challenging behaviors. **XGBoost** and **Random Forest** also showed competitive results, making them strong secondary options for future model comparisons or improvements.

1.17 Api

To enable communication between our machine learning model and the Flutter mobile application, we used Flask to develop a RESTful API. This API serves as a bridge that allows the app to send data to the model for prediction and receiving results in real time.

In addition, we integrated the ChatGPT API to include a chatbot feature within the application. This chatbot is designed to assist users by providing general information about autism and answering common questions. It aims to support users by offering guidance and helping them better understand the condition through an interactive, conversational interface.

Key functionalities of the API:

Model Prediction Endpoint: Receives input data from the Flutter app and returns the model's prediction.

Chat Endpoint: Sends user queries to the ChatGPT API and returns the corresponding response from the chatbot

Error Handling: Built-in checks to manage invalid input or connection issues.

This API layer ensures smooth integration between the mobile app, the machine learning model, and the chatbot functionality, providing a responsive and supportive user experience.

1.18 Hardware Image with Description

The wearable bracelet is designed using several sensors and components to track physiological and motion-related signals. Each of the following hardware modules contributes to monitoring different aspects of the child's emotional and physical state.

While we initially aimed to use more compact components to ensure a sleeker, child-friendly wearable, these smaller versions were not readily available in Egypt. Therefore, we proceeded with the standard components listed below to complete the prototype effectively.

1.18.1 GSR Skin Electrical Sensor Kit - Sweat Sensor

Purpose: Measures Electrodermal Activity (EDA)

Description: This sensor detects changes in the skin's electrical conductance, which varies with moisture levels caused by sweating. It serves as an indicator of stress or emotional arousal in children.

Figure 0.3 Galvanic Skin Response

1.18.2 MPU-6050 (IMU – 3-Axis Gyroscope + 3-Axis Accelerometer)

Model: Renovated MPU-6050

Purpose: Detects body motion and orientation

Description:
The MPU-6050 integrates a 3-axis gyroscope and a 3-axis accelerometer in a single chip. It is capable of detecting linear acceleration and angular velocity in all three dimensions (X, Y, and Z axes). In our system, this sensor plays a key role in tracking the child's motion patterns, detecting hyperactivity, sudden movements, or restlessness—behaviors often linked to emotional distress or sensory overload in children with Asperger's syndrome.

Figure 0.4 MPU-6050

1.18.3 Heart Rate Pulse Sensor:

Purpose: Monitors heart rate

Description: This sensor detects the heartbeat optically by measuring the pulsing of blood flow through the skin. It's used to monitor stress and anxiety levels in real time.

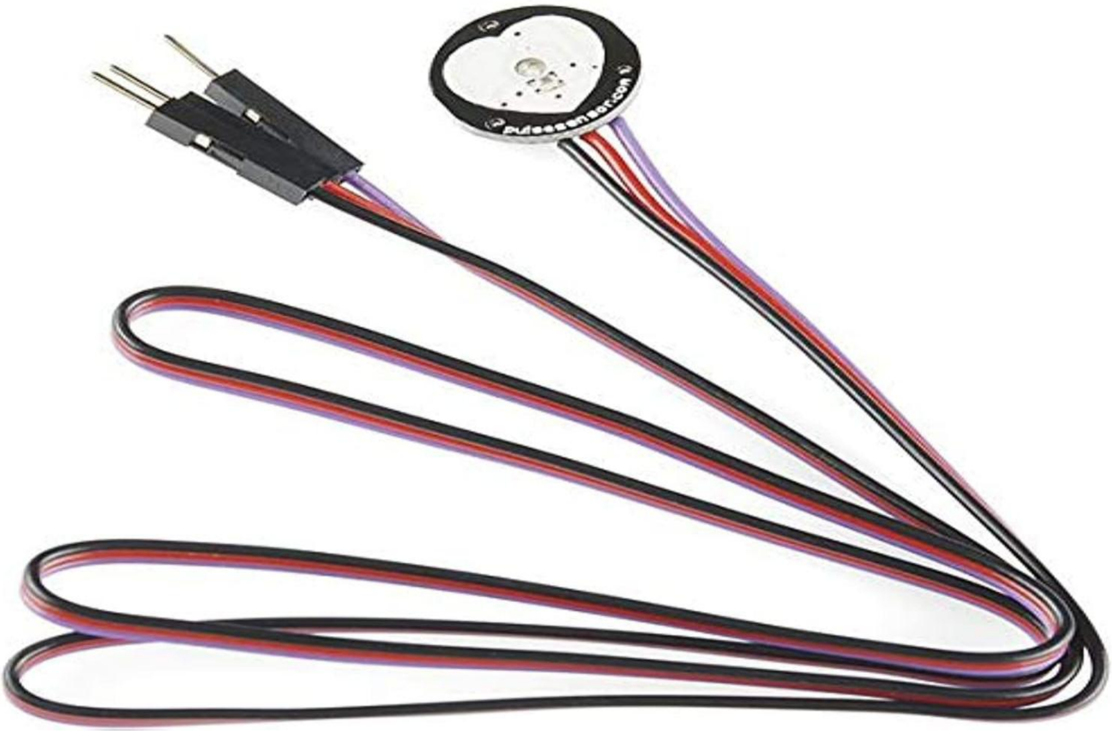


Figure 0.5 Heart Rate Sensor

1.18.4 DS18B20 Waterproof Temperature Sensor:

Purpose: Measures body/skin temperature

Description: A digital temperature sensor enclosed in a waterproof casing, used to measure the child's skin temperature. Variations in temperature can be linked to emotional or physical stress.

Figure 0.6 Temperature Sensor

1.18.5 ESP32 Module:

Purpose: Wireless communication and microcontroller

Description: A powerful microcontroller that supports both Wi-Fi and Bluetooth. It transmits the collected sensor data from the bracelet to the mobile application in real time.

Figure 0.7 ESP32

1.18.6 Arduino Uno:

Purpose: Central controller (Development & Integration)

Description: Used during the development phase for sensor integration and testing.

It processes signals from all sensors before sending them via ESP32. It's an easy-to-use open-source microcontroller board.

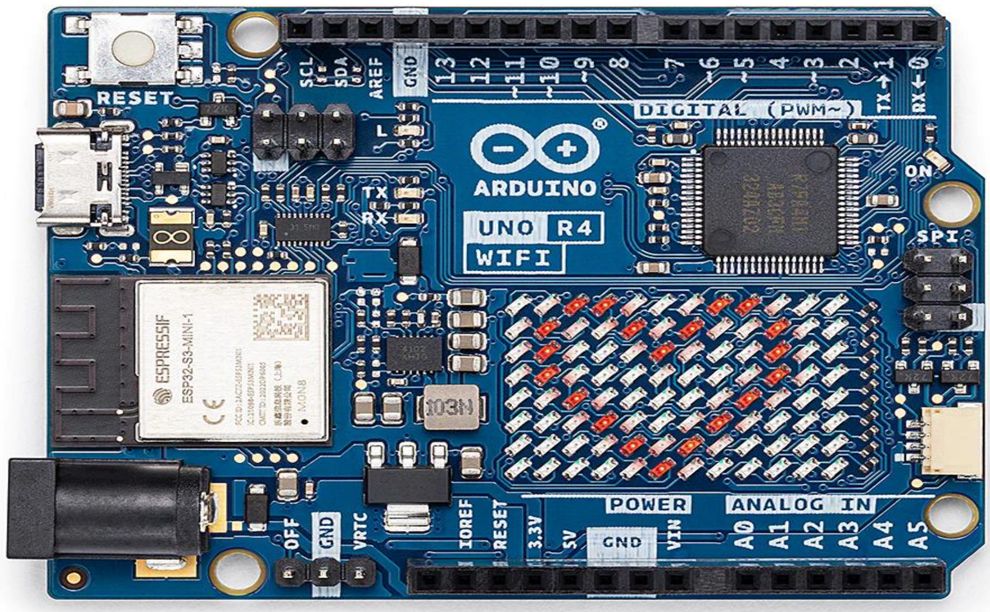


Figure 0.8 Arduino Uno

1.18.7 Hardware Circuit Design – Sensor Integration with Arduino UNO

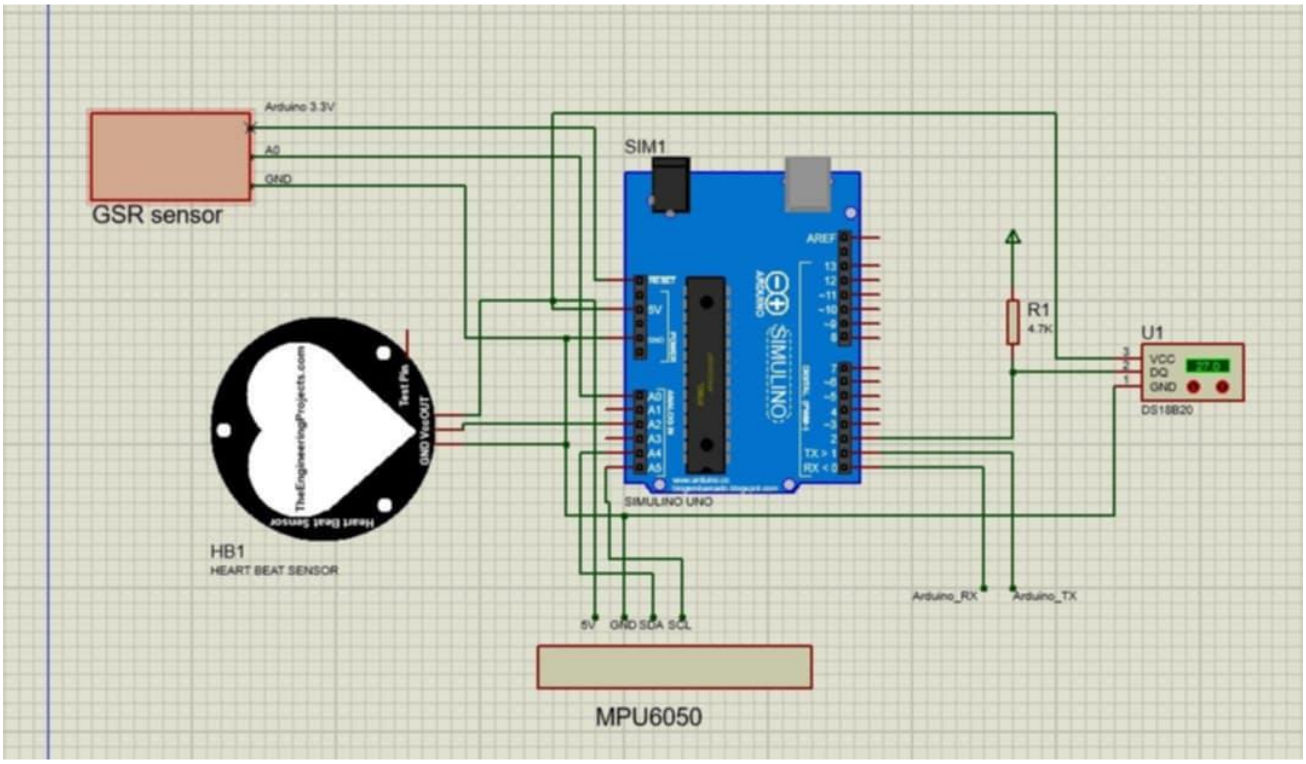


Figure 0.9 Hardware Simulation

This diagram illustrates the hardware setup for the wearable system used to monitor a child's physiological indicators in real-time. The circuit is designed around an **Arduino UNO board** that serves as the central microcontroller, interfacing with multiple sensors:

- **GSR Sensor**: Measures of electrodermal activity (stress response)
- **Heartbeat Sensor**: Detects pulse rate in BPM
- **DS18B20 Temperature Sensor**: Monitors skin/body temperature
- **MPU6050 Module**: Captures motion and orientation (accelerometer + gyroscope)

The Arduino collects data from all sensors and communicates the readings to the ESP32 or mobile application for real-time monitoring and behavioral prediction.

1.19 Mobile app image with description

The mobile application is an essential component of our system, providing users and caregivers with a user-friendly interface to monitor their child's physiological data in real time. Built using Flutter, the app connects to the wearable bracelet via a RESTful API and displays heart rate, skin temperature, Galvanic Skin Response (GSR), and motion data. It also includes visual indicators for detecting behavioural challenges based on predictions from the LightGBM model. Additionally, the app integrates a chatbot powered by the ChatGPT API to assist users with general information about Asperger's syndrome and offer practical support.

1.19.1 Mobile App Splash Screen

The image below illustrates the splash screen of the mobile app, featuring the ASD Care logo and color scheme. This screen appears upon launching the app and reinforces brand identity while the system initializes in the background.

Figure 0.10 Splash Screen

1.19.2 Mobile App Onboarding

The onboarding sequence introduces new users to the app's core purpose and features in a clear and welcoming way. These splash screens highlight the app's mission, functionality, and personalization options:

Welcome to ASD CARE:

Empowers users to support children with Autism Spectrum Disorder (ASD) through guided care and tools.

Track with Ease:

Enables effortless monitoring of the child's health and emotions using real-time data from the wearable device.

Child's Information:

Allows users to input personal data and access customized assessments to support developmental needs.

Figure 0.11 Mobile App Onboarding 1

Figure 0.13 Mobile App Onboarding 3

Figure 0.12 Mobile App Onboarding 2

1.19.3 Mobile App Create Account

This screen allows new users to register for the app by providing essential details. It includes input fields for email, name, password, and confirm password to ensure accurate account setup. Users can easily sign up by tapping the Sign Up button or use the Sign Up with Google option for quicker registration. For returning users, a prompt with “Have an account? Sign In” directs them to the login screen, streamlining access for everyone.

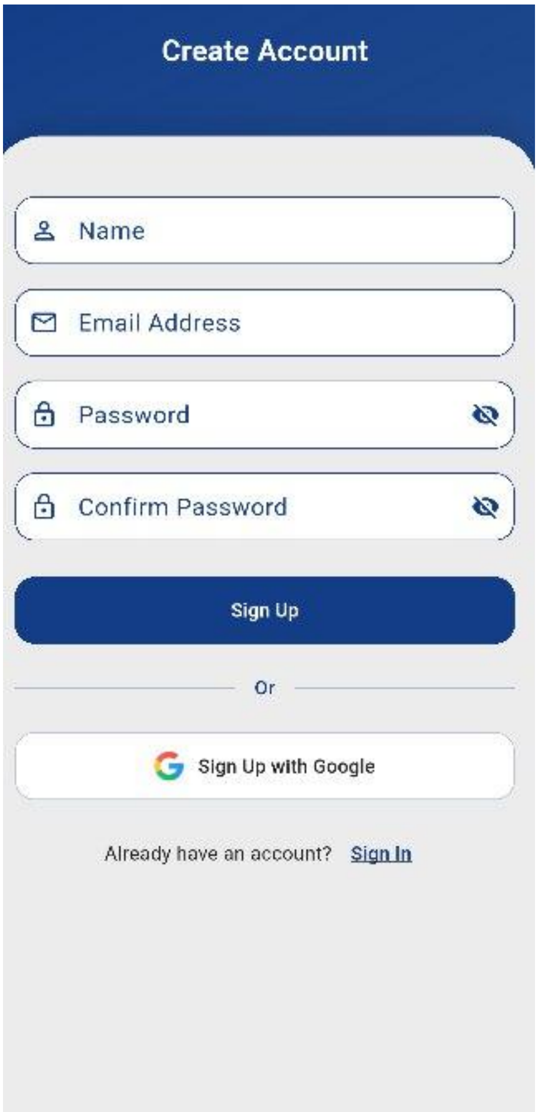


Figure 0.14 Create Account Screen

1.19.4 Mobile App Sign In

This screen allows existing users to access their accounts by entering their email and password. It includes a Forgot Password option for easy recovery. Users can log in by tapping the Log In button or choose Sign In with Google for faster authentication. For new users, a prompt "Don't have an account? Sign Up" redirects them to the create account screen, ensuring smooth navigation between sign-in and sign-up flows.

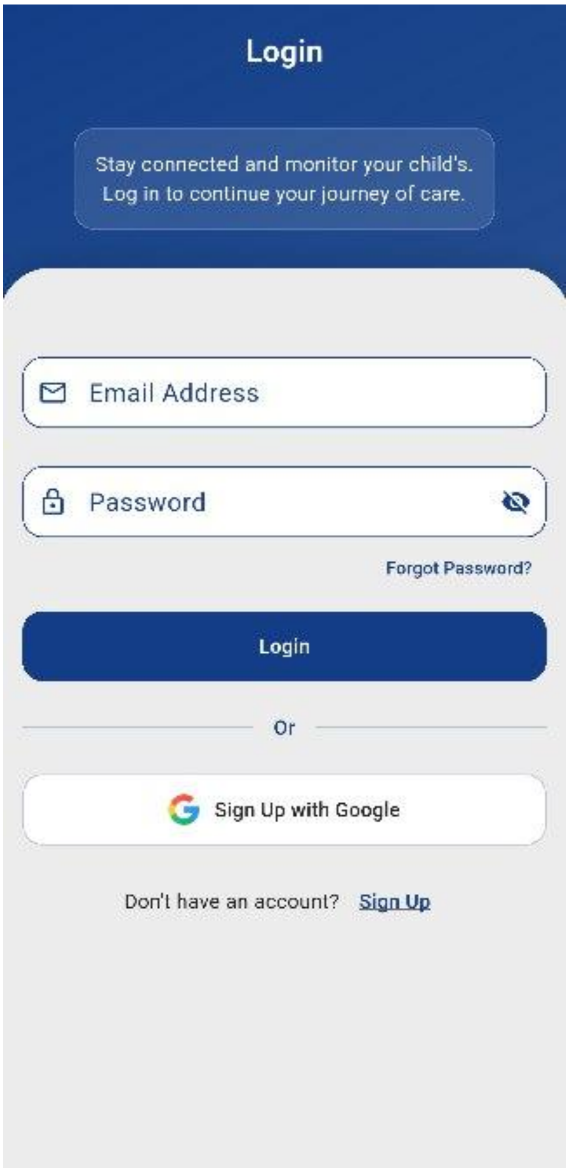


Figure 0.15 Sign in Screen

1.19.5 Home – Child Health Monitoring Overview

This home screen provides a welcoming and intuitive dashboard for users to monitor their child's well-being. At a glance, users can view key health indicators such as heart rate and blood pressure, presented in a clear and user-friendly format. The screen also features a status summary that indicates the overall condition of the child, helping users stay informed and reassured. With visual cues, real-time updates, and quick access to notifications and messages, this screen supports ongoing, proactive care in a simple and engaging.

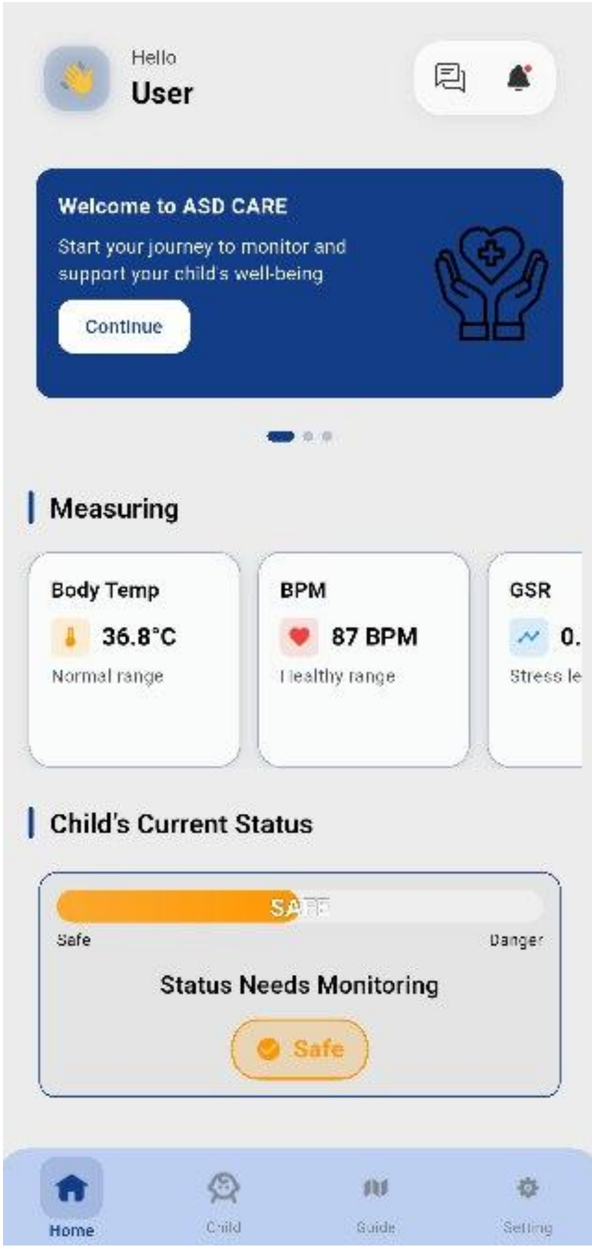


Figure 0.17 Home Page Light

Figure 0.16 Home Page Dark Arabic version

1.19.6 Notifications– Real-Time Alerts for Proactive Parenting

The Notifications screen provides a centralized hub for timely updates regarding your child's health and well-being. Designed for clarity and quick recognition, this interface ensures that users receive immediate alerts—such as reminders for scheduled tests or changes in physiological signals like heart rate and emotional state. Notifications are neatly grouped by day, allowing for easy review of recent activity and patterns. Whether it's a prompt to take the IQ test or a real-time alert about your child's emotional health, this screen empowers caregivers to stay informed and respond promptly to their child's needs.

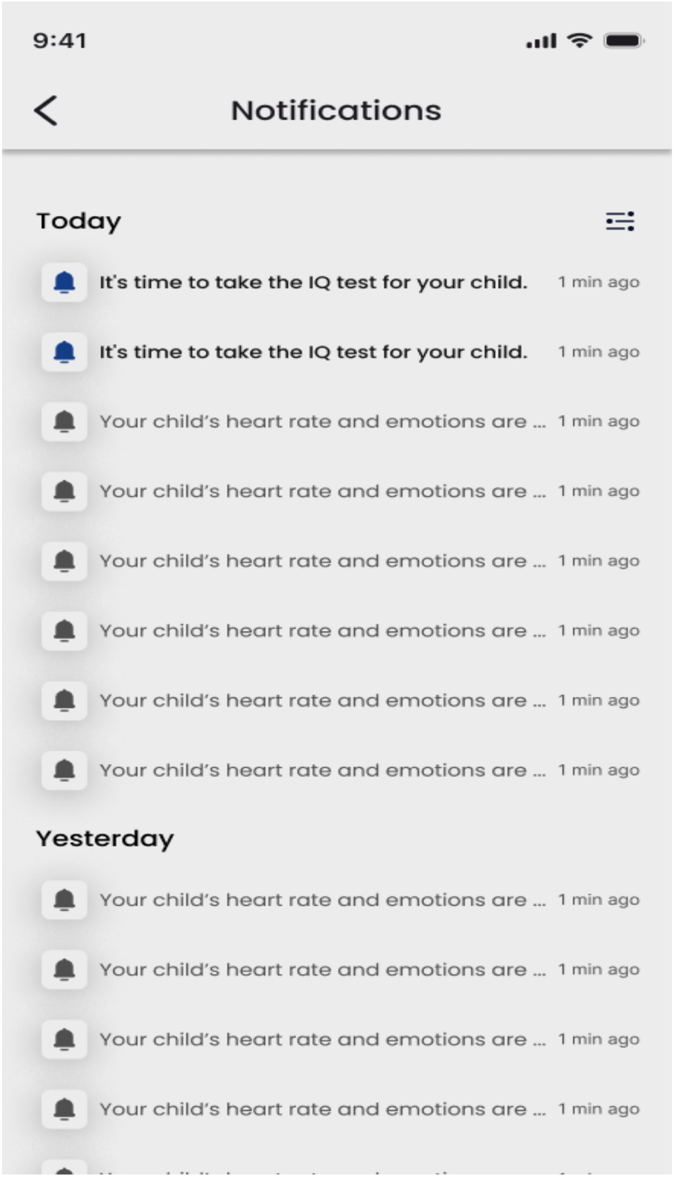


Figure 0.18 Notification Screen

1.19.7 Chat Bot – Instant Support for Concerned Users

The Chat Bot screen offers a quick and intuitive way for users to ask questions and receive immediate responses regarding their child's health, behavior, and daily updates. Whether you're inquiring about your child's emotional state or looking for specific reports, the chatbot is available 24/7 to provide assistance in a conversational format.

Figure 0.19 Chat Bot Screen Light

Figure 0.20 Chat Bot Screen Dark

1.19.8 Child Profile – Personalized Insights at a Glance

The Child Profile screen provides a centralized view of your child's key information and developmental progress. Users can easily view test scores such as cognitive assessments and behavioral evaluations, all categorized by completion status and performance level. With just one tap, you can edit details like name, age, and guardian information through the Edit Profile screen. This feature ensures your child's profile stays accurate and up to date, enabling more informed support and decision-making.

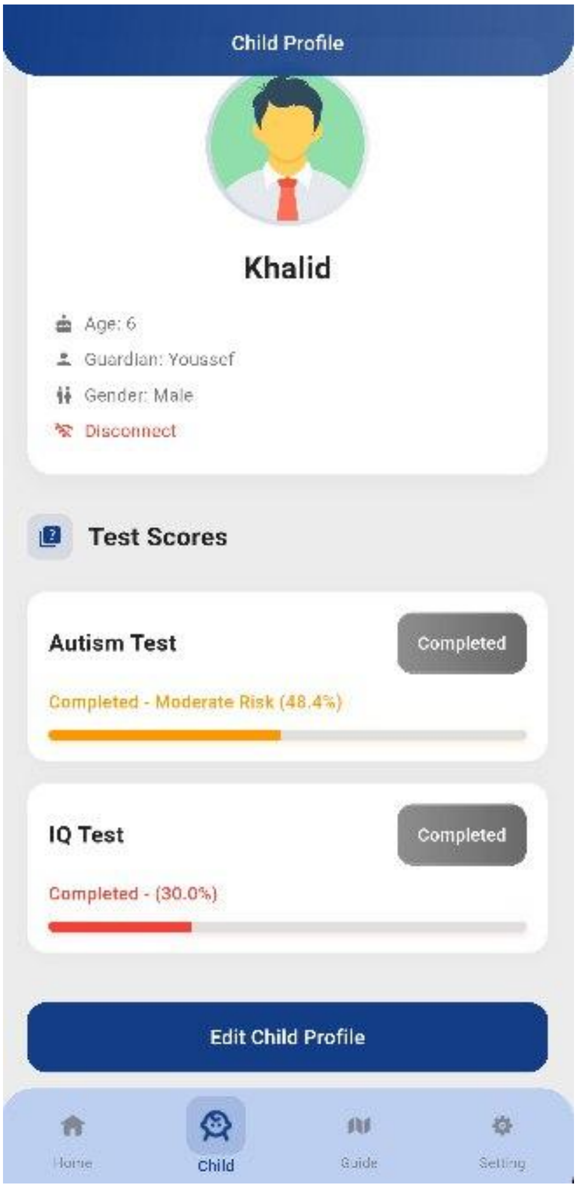


Figure 0.21 Child Profile Screen Light

Figure 0.22 Child Profile Screen Dark

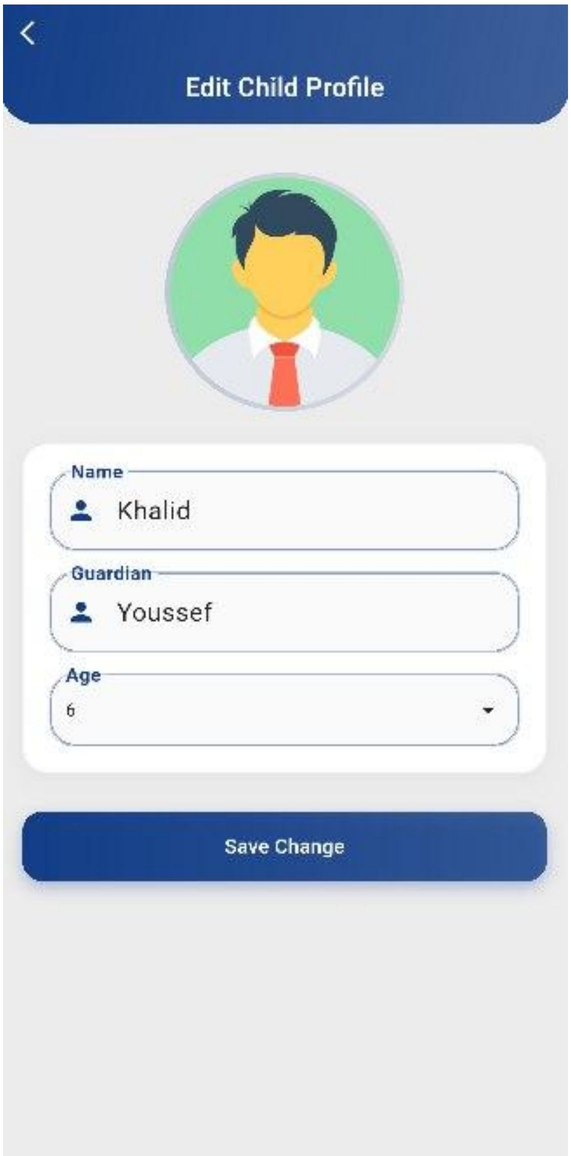


Figure 0.23 Edit Profile Screen

1.19.9 User Profile – Personalized Guardian Detail

The User Profile screen showcases essential information about the child's guardian, including name, contact email, and a brief description. With a simple and user-friendly design, users can easily view and edit their details by navigating to the Edit Profile screen. This feature ensures accurate identification and communication, helping to maintain a trusted and personalized connection between caregivers and the system.

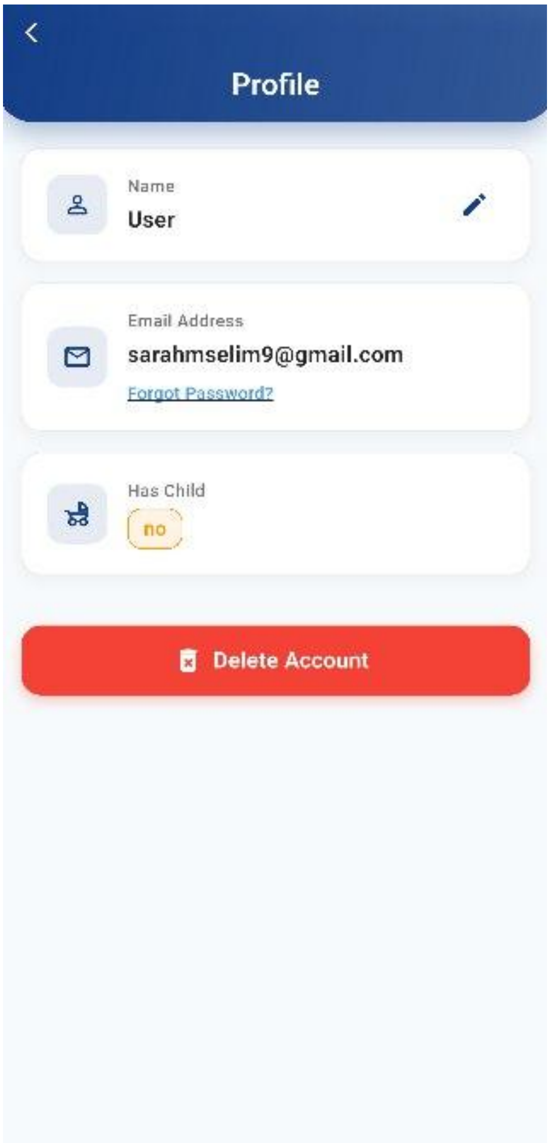


Figure 0.24 User Profile Screen

1.19.10 Settings – Control Your Experience with Ease

The Settings screen gives users full control over their app preferences, including account management, language selection, and display mode. Seamlessly switch between English and Arabic, enable Dark Mode for comfortable viewing, or update account details with a single tap. With a clean and accessible layout, this screen ensures every user can personalize their experience to fit their needs and lifestyle.

Figure 0.26 Setting Screen Dark Arabic Version

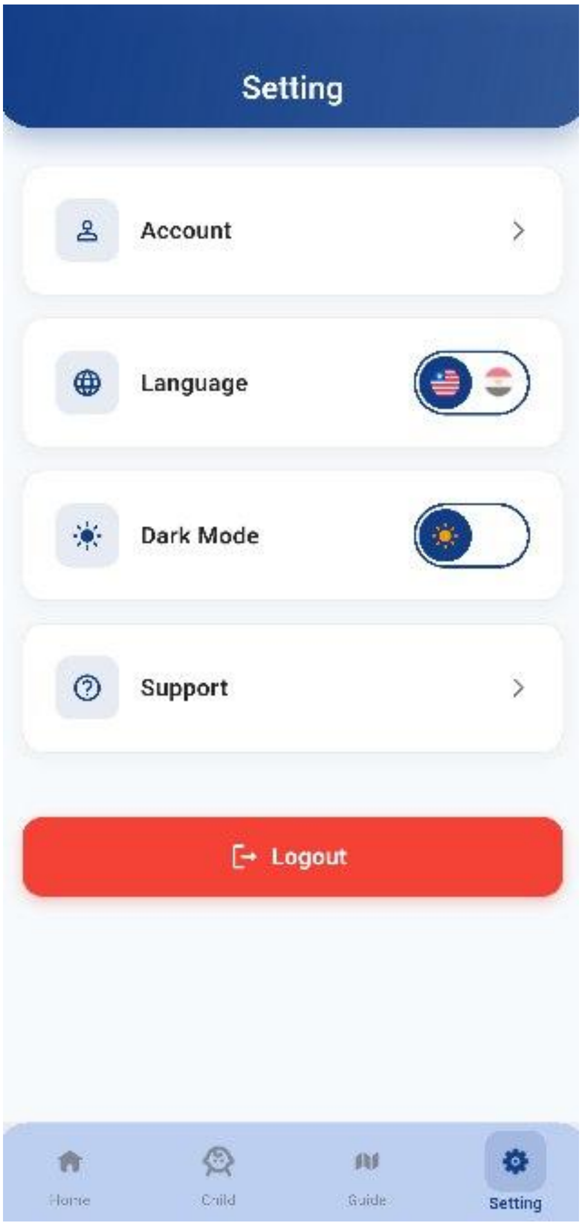


Figure 0.25 Setting Screen Light

1.19.11 Guide – Practical Cases for Everyday Challenges

The Guide screen provides quick access to a library of real-life behavioral scenarios designed to help users support their child's social and emotional development. Each case, like “Social Misunderstanding,” offers practical advice and structured solutions to everyday situations children may face. With clearly labeled entries and simple navigation, caregivers can explore and apply expert-backed strategies to guide their children through common challenges with empathy and confidence.

Figure 0.28 Guide Screen Light

Figure 0.27 Guide Screen Dark Arabic Version

1.19.12 Case Scenarios – Guiding Social Growth Through Real-Life Situations

This screen features one of ten real-life scenarios available in the Guide screen, designed to build children's social awareness and emotional intelligence. In this specific case—Social Misunderstanding—users receive a clear breakdown of the situation along with step-by-step guidance on how to address it. From teaching empathy to using role-play techniques, these guided cases provide caregivers with actionable strategies to help children face social challenges with confidence and kindness.

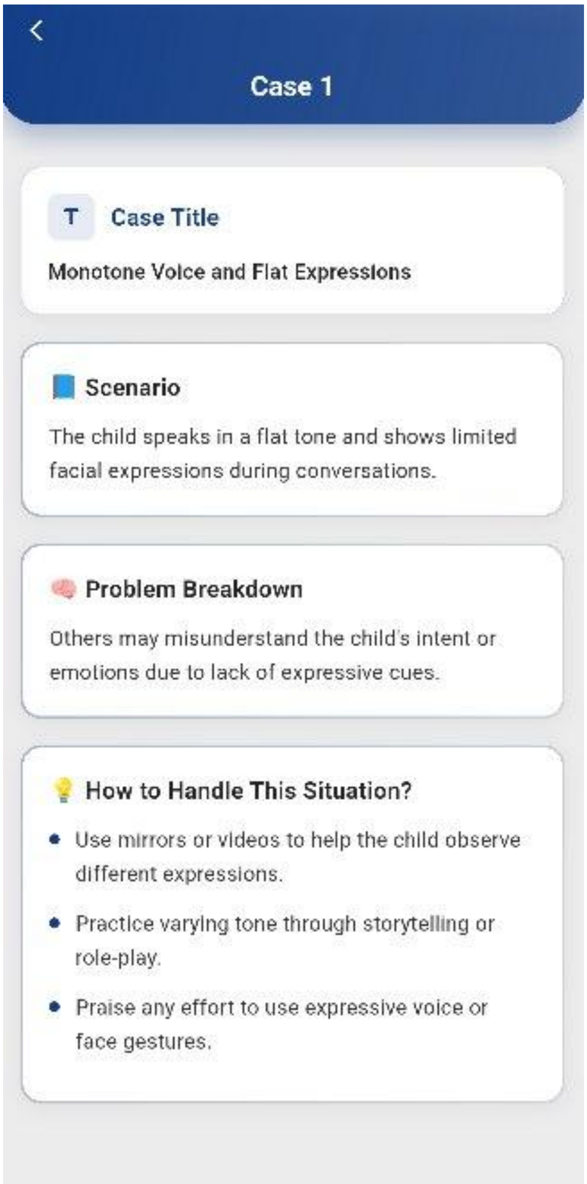


Figure 0.29 Case Scenario Screen

1.19.13 Support – Expert Guidance When You Need It Most

Get the help you need with a free 15-minute consultation from a specialist autism clinician. Whether you want to understand your results or explore the next steps, our experienced neurodiversity professionals are here to support you. If phone conversations feel overwhelming, you can reach out through email for a more comfortable experience. We're here to walk with you, every step of the way.

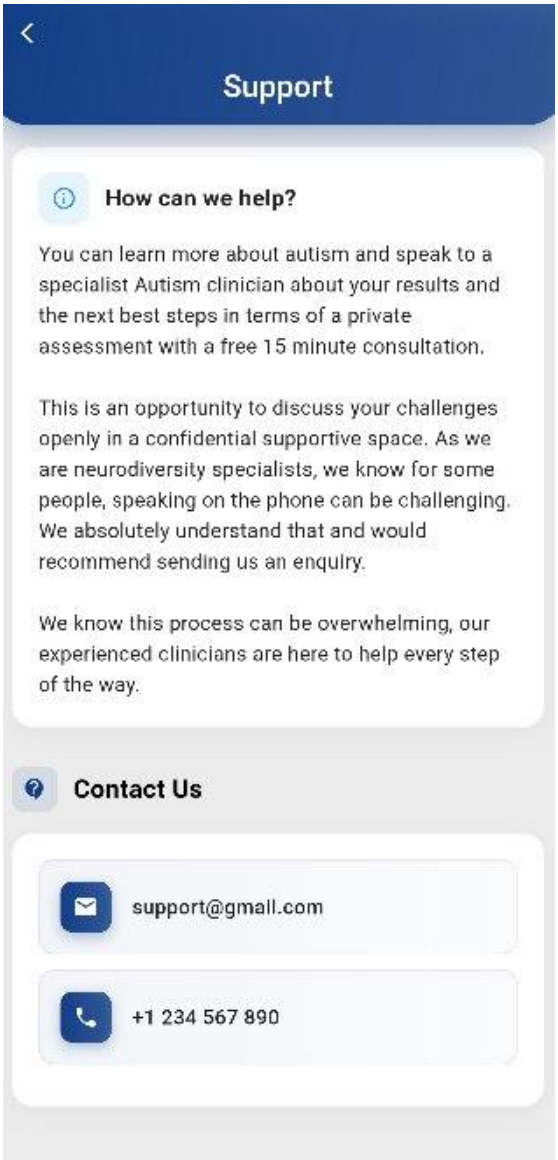


Figure 0.30 Support Screen Light

1.19.14 Admin Dashboard – Powerful Tools for Seamless Management

The Admin Dashboard centralizes all administrative functions, providing complete control over user accounts, child records, and admin access and providing control over updating Test Link, updating Guides, and viewing reports. With a simple layout and segmented controls, admins can add or delete users, review children's profiles, and manage platform access. This module supports smooth, secure operations and efficient user management.

Figure 0.33 Guide Management Screen

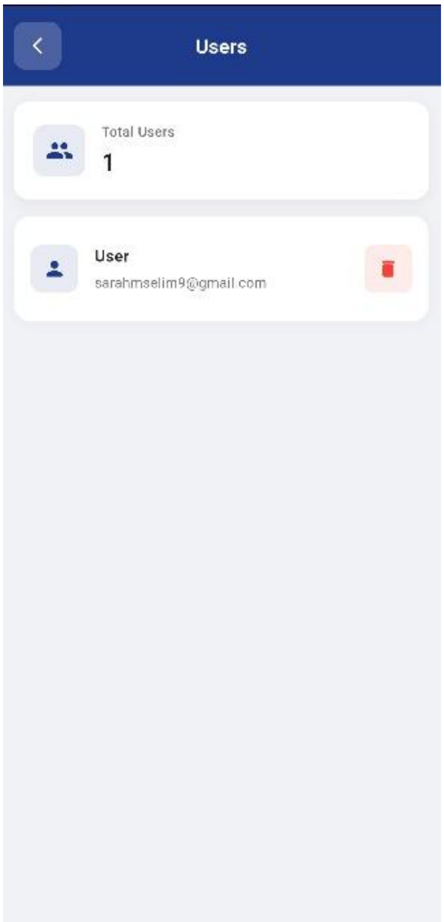


Figure 0.32 Users Screen

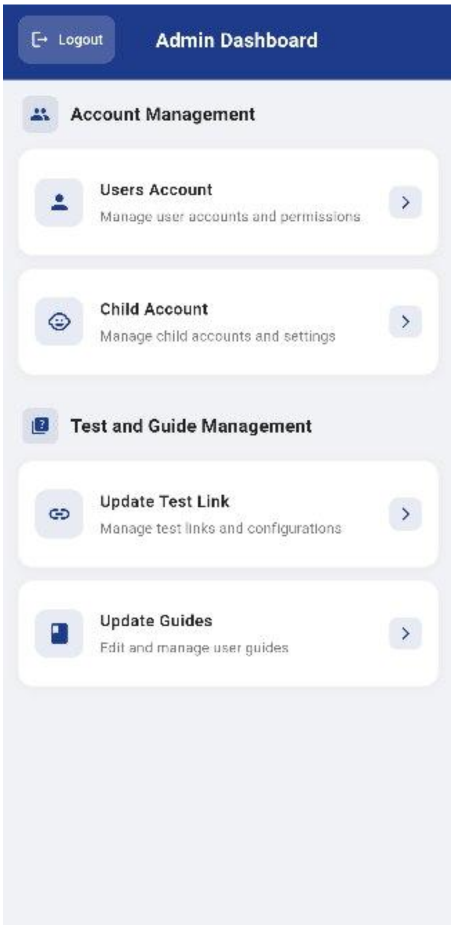


Figure 0.31 Admin Dashboard Screen

1.19.15 Super Admin Dashboard – Admins Management Page

This page is exclusively accessible to Super Admins and is used to manage Regular Admins. It allows Super Admins to add new Regular Admins by filling in details like name and email, and to remove existing ones from a list. Super Admins cannot assign or promote others to Super Admin level. Regular Admins and other users cannot access this page.

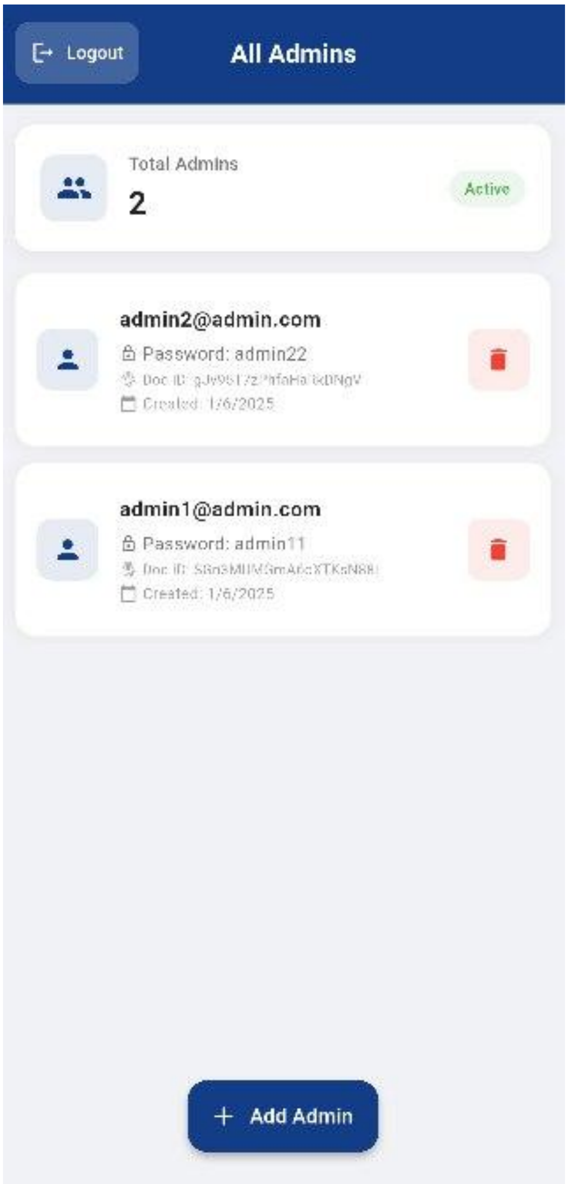


Figure 0.34 Super Admin Screen

1.20 Results

This section presents the comprehensive outcomes of our system, combining advanced machine learning performance with real-time physiological data acquisition. Our LightGBM model was thoroughly evaluated on unseen data, demonstrating strong classification capabilities in detecting challenging behaviours, with an emphasis on reducing false negatives to enhance early intervention accuracy. Simultaneously, the real-time sensor readings captured from accelerometer, heartbeat, galvanic skin response, and body temperature sensors validate the system's robustness in continuously monitoring vital physiological signals. Together, these results underscore the successful integration of predictive analytics and real-world sensing, paving the way for effective and timely behavioural assessments.

1.20.1 AI Model

To evaluate the performance of our final machine learning model (LightGBM), we analyzed its predictions using a variety of classification metrics. The model was tested on unseen data after training and preprocessing, including SMOTE oversampling to address class imbalance. Our main goal was to reduce False Negatives, as missing a challenging behavior could negatively impact timely interventions for the child.

The following chart provides a visual summary of the model's precision, recall, and F1-score for both classes — "Non-Challenging" (class 0) and "Challenging" (class 1). These metrics help illustrate how well the model can detect both normal and challenging behaviors.

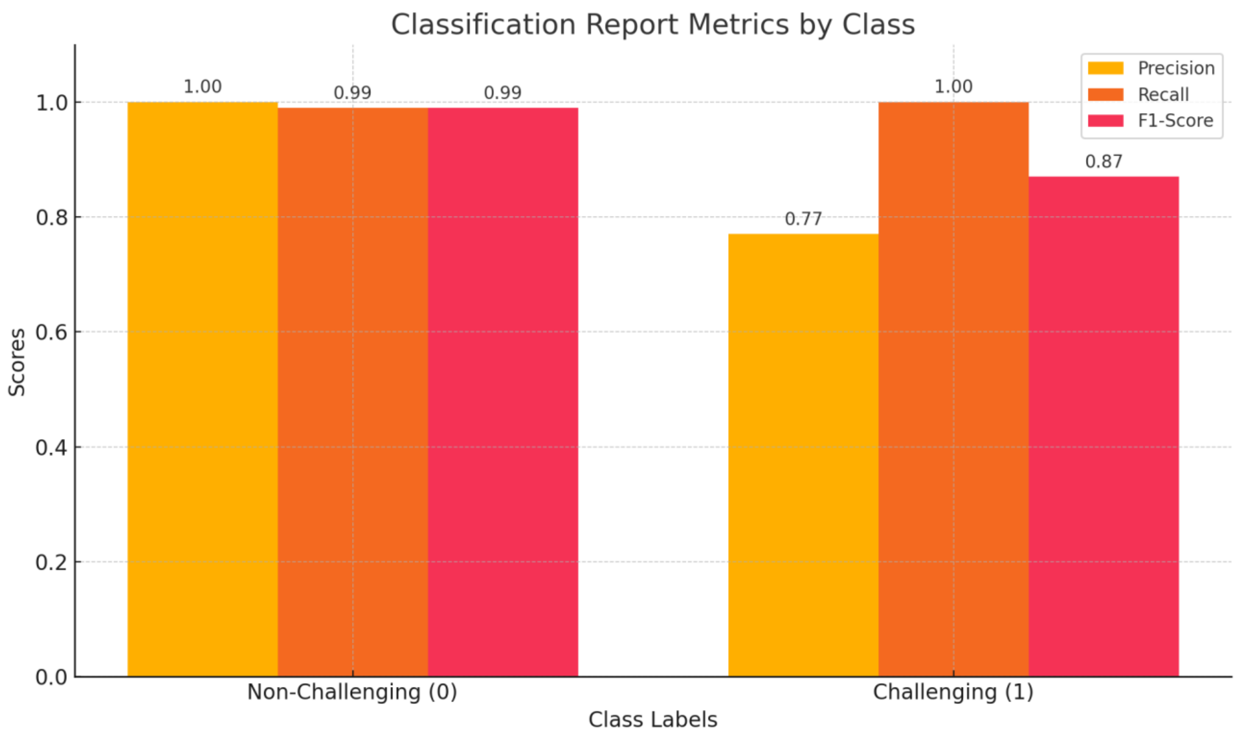


Figure 0.35 Classification Report Metrics

1.20.2 Real-Time Sensor Readings Output

```
AccelX: -0.32 | AccelY: -0.33 | AccelZ: 0.07 | GyroX: -16.03 | GyroY: 12.45 | GyroZ: 1.10 | GSR: 1 | Body Temp: 36.38 | BPM: 130
AccelX: -0.31 | AccelY: -0.33 | AccelZ: 0.06 | GyroX: -15.68 | GyroY: 11.52 | GyroZ: 1.39 | GSR: 1 | Body Temp: 36.38 | BPM: 174
AccelX: -0.32 | AccelY: -0.34 | AccelZ: 0.08 | GyroX: -16.53 | GyroY: 12.85 | GyroZ: 1.24 | GSR: 1 | Body Temp: 36.38 | BPM: 174
AccelX: -0.31 | AccelY: -0.34 | AccelZ: 0.07 | GyroX: -16.02 | GyroY: 13.01 | GyroZ: 1.21 | GSR: 1 | Body Temp: 36.44 | BPM: 129
AccelX: -0.31 | AccelY: -0.33 | AccelZ: 0.08 | GyroX: -16.71 | GyroY: 13.43 | GyroZ: 1.27 | GSR: 1 | Body Temp: 36.44 | BPM: 111
AccelX: -0.31 | AccelY: -0.33 | AccelZ: 0.08 | GyroX: -16.42 | GyroY: 13.38 | GyroZ: 1.34 | GSR: 1 | Body Temp: 36.44 | BPM: 105
AccelX: -0.31 | AccelY: -0.33 | AccelZ: 0.08 | GyroX: -16.26 | GyroY: 13.45 | GyroZ: 1.29 | GSR: 1 | Body Temp: 36.50 | BPM: 85
AccelX: -0.31 | AccelY: -0.33 | AccelZ: 0.08 | GyroX: -16.01 | GyroY: 13.23 | GyroZ: 1.25 | GSR: 1 | Body Temp: 36.50 | BPM: 78
AccelX: -0.32 | AccelY: -0.34 | AccelZ: 0.08 | GyroX: -16.40 | GyroY: 13.01 | GyroZ: 1.21 | GSR: 1 | Body Temp: 36.50 | BPM: 68
AccelX: -0.32 | AccelY: -0.34 | AccelZ: 0.08 | GyroX: -16.61 | GyroY: 13.40 | GyroZ: 1.15 | GSR: 1 | Body Temp: 36.50 | BPM: 79
AccelX: -0.32 | AccelY: -0.34 | AccelZ: 0.07 | GyroX: -16.50 | GyroY: 13.35 | GyroZ: 1.30 | GSR: 1 | Body Temp: 36.50 | BPM: 69
AccelX: -0.32 | AccelY: -0.34 | AccelZ: 0.08 | GyroX: -16.57 | GyroY: 13.45 | GyroZ: 1.39 | GSR: 1 | Body Temp: 36.50 | BPM: 65
AccelX: -0.31 | AccelY: -0.34 | AccelZ: 0.08 | GyroX: -16.56 | GyroY: 13.24 | GyroZ: 1.14 | GSR: 1 | Body Temp: 36.50 | BPM: 85
AccelX: -0.31 | AccelY: -0.33 | AccelZ: 0.07 | GyroX: -16.56 | GyroY: 13.67 | GyroZ: 1.25 | GSR: 1 | Body Temp: 36.56 | BPM: 101
AccelX: -0.32 | AccelY: -0.33 | AccelZ: 0.08 | GyroX: -16.46 | GyroY: 13.00 | GyroZ: 1.17 | GSR: 1 | Body Temp: 36.50 | BPM: 191
AccelX: -0.31 | AccelY: -0.33 | AccelZ: 0.08 | GyroX: -16.65 | GyroY: 13.28 | GyroZ: 0.90 | GSR: 1 | Body Temp: 36.56 | BPM: 221
AccelX: -0.31 | AccelY: -0.34 | AccelZ: 0.08 | GyroX: -16.46 | GyroY: 13.13 | GyroZ: 1.28 | GSR: 1 | Body Temp: 36.56 | BPM: 233
AccelX: -0.31 | AccelY: -0.33 | AccelZ: 0.08 | GyroX: -16.81 | GyroY: 13.44 | GyroZ: 1.11 | GSR: 1 | Body Temp: 36.56 | BPM: 232
AccelX: -0.31 | AccelY: -0.33 | AccelZ: 0.07 | GyroX: -16.18 | GyroY: 12.27 | GyroZ: 1.47 | GSR: 1 | Body Temp: 36.56 | BPM: 218
AccelX: -0.31 | AccelY: -0.33 | AccelZ: 0.08 | GyroX: -16.53 | GyroY: 13.35 | GyroZ: 1.30 | GSR: 1 | Body Temp: 36.63 | BPM: 154
AccelX: -0.31 | AccelY: -0.33 | AccelZ: 0.08 | GyroX: -16.26 | GyroY: 13.34 | GyroZ: 1.15 | GSR: 1 | Body Temp: 36.63 | BPM: 126
AccelX: -0.31 | AccelY: -0.33 | AccelZ: 0.08 | GyroX: -16.18 | GyroY: 13.23 | GyroZ: 1.06 | GSR: 1 | Body Temp: 36.63 | BPM: 120
AccelX: -0.31 | AccelY: -0.33 | AccelZ: 0.08 | GyroX: -16.44 | GyroY: 13.53 | GyroZ: 1.09 | GSR: 1 | Body Temp: 36.63 | BPM: 197
AccelX: -0.31 | AccelY: -0.34 | AccelZ: 0.08 | GyroX: -16.30 | GyroY: 13.30 | GyroZ: 1.15 | GSR: 1 | Body Temp: 36.63 | BPM: 175
AccelX: -0.31 | AccelY: -0.34 | AccelZ: 0.08 | GyroX: -16.71 | GyroY: 13.55 | GyroZ: 1.13 | GSR: 1 | Body Temp: 36.63 | BPM: 139
AccelX: -0.31 | AccelY: -0.33 | AccelZ: 0.07 | GyroX: -16.89 | GyroY: 13.36 | GyroZ: 1.10 | GSR: 1 | Body Temp: 36.63 | BPM: 111
AccelX: -0.32 | AccelY: -0.34 | AccelZ: 0.07 | GyroX: -16.62 | GyroY: 13.30 | GyroZ: 1.03 | GSR: 1 | Body Temp: 36.69 | BPM: 99
AccelX: -0.31 | AccelY: -0.33 | AccelZ: 0.08 | GyroX: -16.55 | GyroY: 13.27 | GyroZ: 1.45 | GSR: 1 | Body Temp: 36.69 | BPM: 88
AccelX: -0.31 | AccelY: -0.33 | AccelZ: 0.08 | GyroX: -16.63 | GyroY: 13.46 | GyroZ: 1.23 | GSR: 1 | Body Temp: 36.69 | BPM: 95
AccelX: -0.31 | AccelY: -0.34 | AccelZ: 0.08 | GyroX: -16.51 | GyroY: 13.37 | GyroZ: 0.84 | GSR: 1 | Body Temp: 36.69 | BPM: 136
```

Figure 0.36 Arduino Real Time Outputs

The image above shows the real-time output from the Arduino Serial Monitor, displaying data collected from various sensors integrated into the system. The output includes:

Accelerometer Data (Accel \[g]: Represents the movement in X, Y, and Z axes using the MPU6050 sensor.

Heartbeat Detection: Indicates when a heartbeat is detected, along with the current BPM (Beats Per Minute).

GSR (Galvanic Skin Response): Reflects the skin conductance level, which changes with emotional arousal.

Body Temperature: Measured using the Dallas Temperature sensor, showing the user's current body temperature in Celsius.

These outputs demonstrate that the system is functioning correctly and accurately capturing physiological signals from the user in real time

1.21 Application Features

As part of the autism support system, the mobile application was designed with a focus on usability, accessibility, and real-time responsiveness to the needs of both children and their users. Key features include:

Dark Mode: The app offers a dark mode option to enhance user comfort during night-time or low-light conditions, reducing eye strain and improving visibility.

Multi-language Support: Users can choose between languages such as English and Arabic. This makes the application accessible to a broader audience, especially users from diverse cultural backgrounds.

Sensor Integration: The system is connected to a smart sensor that detects the child's presence or specific activities. When the sensor identifies a predefined behavior or movement, it sends an instant notification to the user's app.

AI Mode (Optional): The application includes an AI-based mode that helps analyze sensor data and detect abnormal patterns, further supporting early intervention and monitoring.

Real-Time Notifications: Users receive immediate alerts via the application, enabling quick action if their child needs attention.

Chatbot Support: An integrated chatbot is available to provide users with instant answers to common questions, guidance on using app features, and support in managing various child-related situations, offering 24/7 assistance and improving overall user experience

User-Friendly Interface: The app features an intuitive layout with a bottom navigation bar for easy access to Home, Child, Guide, and Settings sections. This ensures users can quickly find and use the information they need.

“Conclusion and Future Work”

Chapter Five

1.22 Conclusion

This project delivers a comprehensive, intelligent, and user-centric system designed to support children with autism particularly those diagnosed with Asperger's syndrome and their families. By combining the power of real-time physiological monitoring, machine learning, and mobile technology, the system enhances the ability of caregivers to detect and respond to emotional and behavioral challenges in a timely and informed manner.

The mobile application offers a seamless and inclusive user experience, featuring dark mode, multi-language support, and an interactive chatbot for instant assistance. From the start, users can securely register with email verification, log in, and create individual profiles for their children. The app guides them through essential steps, including autism and IQ assessments, storing the results to help parents and caregivers better understand their child's cognitive and emotional profile.

A wearable bracelet plays a vital role by continuously capturing key physiological indicators such as heart rate, body temperature, sweating levels, and motion activity every 10 seconds. These metrics are instantly visualized within the application through intuitive measuring cards.

An integrated AI model (Lightgbm), developed and deployed through a Flask based API, evaluates the incoming sensor data after every 10 readings. It classifies the child's current condition into three actionable states: "Safe", "Needs Attention", or "In Danger." This real-time behavioral prediction allows caregivers to act promptly and provide the necessary emotional or physical support, minimizing the escalation of distress.

The application also features a dedicated support section that includes verified contact information for medical organizations and professional help, offering an added layer of assistance when needed. To maintain system integrity and manage operations efficiently, an admin dashboard is available for authorized personnel to oversee users, child profiles, assessment links, and guidance materials. Super administrators hold extended privileges, including the ability to manage admin accounts and ensure the overall functionality and security of the system.

By seamlessly integrating mobile development, AI-powered analytics, and wearable IoT technology, this system not only empowers parents and guardians with actionable insights but also significantly improves the daily lives of children with Asperger's syndrome. It encourages early intervention, informed decision-making, and a more supportive care environment, paving the way for a more compassionate, connected, and technology-driven approach to autism support.

1.23 Future Work

While the current system provides a robust platform to support children with Asperger's syndrome, there are several directions for future improvement that could enhance its functionality, usability, and reach:

1. **Expanded Sensor Capabilities**

   Future versions of the bracelet could integrate additional sensors such as ECG for heart rhythm, SpO_2 for oxygen saturation, or even facial expression analysis via computer vision. This would provide a more comprehensive understanding of the child's emotional and physical state.

2. **Offline Functionality and Cloud Sync**

   Implementing offline access will ensure that users can still collect and view data without a continuous internet connection. Data would be automatically synced with the cloud once the connection is restored, enhancing reliability in low-connectivity areas.

3. **Integration with Therapy and Educational Tools**

   The app could be expanded to include therapy-supporting tools such as mood journals, therapist dashboards, and educational content tailored to individual needs. This would make the system more beneficial for long-term development and collaboration with professionals.

4. **Global Language Support and Accessibility Enhancements**

   Adding more language options and improving accessibility features (e.g., screen readers, voice control, high contrast modes) will make the system more inclusive and usable for a wider range of families around the world.

5. **Gamification and Child Engagement**

   Introducing gamified features like rewards, interactive animations, or child-friendly feedback could increase engagement and help children become more comfortable with the system and self-regulation techniques.

6. **Wearable Hardware Development**

   Designing a specialized bracelet with consideration for sensory sensitivities—making it lightweight, soft, and child-friendly—can improve comfort, usability, and overall system adoption.

7. **Broader Autism Spectrum Coverage**

   While this project primarily targets children with Asperger's syndrome, future development can tailor the system to support a wider range of autism spectrum conditions by adjusting monitoring strategies and intervention logic.

“References”

“References”

[1] MDPI. (n.d.) Robotics: Special Issue on Advances in Robotics for Healthcare Applications. Available at: https://www.mdpi.com/2218-6581/12/2/55.

[2] Jurnal Teknologi. (n.d.) Article 9453: Advances in Technology and Applications. Available at: https://journals.utm.my/jurnalteknologi/article/view/9453/5588.

[3] MDPI. (2022) ‘Sensors: A Comprehensive Study on Advancements’, Sensors, 22(15), p. 5803. Available at: https://www.mdpi.com/1424-8220/22/15/5803

[4] ACM Digital Library. (2021) ‘Article: Advances in Interactive Systems’, Proceedings of the ACM Conference on Interactive Systems, pp. 1–10. Available at: https://dl.acm.org/doi/abs/10.1145/3484377.3484381

[5] Vakadkar, K., Purkayastha, D. and Krishnan, D. (2021) 'Detection of Autism Spectrum Disorder in Children Using Machine Learning Techniques', SN Computer Science, 2, p. 386. Available at: https://doi.org/10.1007/s42979-021-00776-5

[6] Hosseinzadeh, M., Koohpayehzadeh, J., Bali, A.O. et al. (2021) ‘A review on diagnostic autism spectrum disorder approaches based on the Internet of Things and Machine Learning’, Journal of Supercomputing, 77, pp. 2590–2608. Available at: https://doi.org/10.1007/s11227-020-03357-0

[7] Bhat, S., Acharya, U.R., and Adeli, H. (2021) 'Autism Spectrum Disorder Detection and Monitoring Using Wearable Technology: A Review', *IEEE Reviews in Biomedical Engineering*, 14, pp. 110–123. Available at: https://doi.org/10.1109/RBME.2020.2972334.

[8] Tariq, Q., Daniels, J., Schwartz, J., and Washington, P. (2020) 'Real-Time Autism Detection Using Wearable Biosensors and Machine Learning', *Nature Biomedical Engineering*, 4, pp. 52–59. Available at: https://doi.org/10.1038/s41551-019-0435-4.

[9] Chen, Y., Mao, Z., and Huang, J. (2020) 'IoT-Driven Wearable Devices for Autism Spectrum Disorder: Development and Challenges', *Frontiers in Psychology*, 11, p. 575569. Available at: https://doi.org/10.3389/fpsyg.2020.575569.

[10] Xu, W., Song, J., Li, J., and Zhang, J. (2021) 'Smart Wearable Devices for Autism Spectrum Disorder Intervention: Opportunities and Challenges', *Journal of Healthcare Engineering*, 2021, Article ID 6678023. Available at: https://doi.org/10.1155/2021/6678023.

[11] Sutherland, A., Coyle, D., and O’Reilly, G. (2023) 'Using Wearable Technology to Predict Emotional Dysregulation in Children with Autism Spectrum Disorder', *Journal of Autism and Developmental Disorders*, 53(2), pp. 430–442. Available at: https://doi.org/10.1007/s10803-022-05589-4.

[12] Kim, J., Lee, S., and Park, Y. (2023) 'Designing Wearable Solutions for Emotional Support in Autism Spectrum Disorder', *IEEE Transactions on Biomedical Engineering*, 70(1), pp. 132–144. Available at: https://doi.org/10.1109/TBME.2022.3214567.

“Appendices”

Appendices

1.24 Appendix A: Machine Learning Model Code (LightGBM Classifier)

```python
import lightgbm as lgb
from sklearn.metrics import classification_report, confusion_matrix

# Create the dataset for LightGBM
train_data = lgb.Dataset(X_train, label=y_train)
test_data = lgb.Dataset(X_test, label=y_test)

# Count of each class
import numpy as np
unique, counts = np.unique(y_train, return_counts=True)
class_counts = dict(zip(unique, counts))
print("Class distribution:", class_counts)

# Calculate scale_pos_weight (only if binary classification)
scale_pos_weight = class_counts[0] / class_counts[1]  # adjust if needed

# LightGBM parameters
params = {
    'objective': 'binary',
    'metric': 'binary_logloss',
    'is_unbalance': True,  # Fix imbalance automatically
    'boosting': 'gbdt',
    'num_leaves': 31,
    'learning_rate': 0.05,
    'verbose': -1
}
```

Figure 0.1 ML Code Snippet

```python
# Train model
lgb_model = lgb.train(params, train_data, num_boost_round=100, valid_sets=[test_data])

# Prediction
y_pred = lgb_model.predict(X_test)
y_pred_binary = [1 if i > 0.5 else 0 for i in y_pred]

# Evaluation
print(confusion_matrix(y_test, y_pred_binary))
print(classification_report(y_test, y_pred_binary))

# Confusion matrix
cm1 = confusion_matrix(y_test, y_pred_binary)

# Extract values
TN, FP, FN, TP = cm1.ravel()

# Print results
print(f"True Positives (TP): {TP}")
print(f"True Negatives (TN): {TN}")
print(f"False Positives (FP): {FP}")
print(f"False Negatives (FN): {FN}")

# Calculate error rates
error_type_1 = FP / (FP + TN)  # False Positive Rate (FPR)
error_type_2 = FN / (FN + TP)  # False Negative Rate (FNR)

# Print results
print(f"Error Type 1 (False Positive Rate): {error_type_1:.4f}")
print(f"Error Type 2 (False Negative Rate): {error_type_2:.4f}")
```

Figure 0.2 ML Code Snippet 2

1.25 Appendix B: Hardware Microcontroller Code (Arduino/ESP32)

```
  if (QS == true) {
    if((BPM >= 60)&&(BPM <= 180)){
Serial.print(" | BPM: ");
Serial.println(BPM);  // 👈 Critical change: println(BPM) instead of print(BPM)
    }
     QS = false;
  }
 // Send individual sensor values
    Serial.print("AccelX: ");
    Serial.print(aX, 2);
    Serial.print(" | AccelY: ");
    Serial.print(aY, 2);
    Serial.print(" | AccelZ: ");
    Serial.print(aZ + 1, 2); // Adjusted Z value
    Serial.print(" | GyroX: ");
    Serial.print(gX, 2);
    Serial.print(" | GyroY: ");
    Serial.print(gY, 2);
    Serial.print(" | GyroZ: ");
    Serial.print(gZ, 2);
    Serial.print(" | GSR: ");
    Serial.print(gsrValue, 2);
    Serial.print(" | Body Temp: ");
    Serial.print(bodyTemp, 2);
  delay(1000);  // Adjust delay as needed
}
```

Figure 0.3 BPM Sensor Code Snippet

monitoring_sensors.ino

```
#include <Wire.h>
#include <OneWire.h>
#include <DallasTemperature.h>

// MPU6050
const int MPU_ADDR = 0x68;
int16_t ax, ay, az, gx, gy, gz;
float aX, aY, aZ, gX, gY, gZ;

// Heart Rate (Pulse Sensor)
const int pulsePin = A2;
volatile int BPM;
volatile int Signal;
volatile int IBI = 600;
volatile boolean Pulse = false;
volatile boolean QS = false;
volatile int rate[10];
volatile unsigned long sampleCounter = 0;
volatile unsigned long lastBeatTime = 0;
volatile int P = 512;
volatile int T = 512;
volatile int thresh = 525;
volatile int amp = 100;
volatile boolean firstBeat = true;
volatile boolean secondBeat = false;

// GSR / Breathing Rate
const int GSR_PIN = A1;
float gsrValue = 0;
```

Figure 0.4 Heart Rate Code snippet

1.26 Appendix C: Organizational Document (Collaboration Letter)

السيد الأستاذ الدكتور/آمال سليمان

مدير مركز أركان للإرشاد النفسي والبحث العلمي

تحية طيبة وبعد

نرجو من سيادتكم التكرم بالسماح لطلاب السنة النهائية بالكلية لدينا والمسجلين لمشروع التخرج بالكلية للعام الأكاديمي ٢٠٢٤/٢٠٢٥ بمقابلة السادة المختصين لديكم بالمركز لأخذ رأيهم في استفسارات علمية في المجال الطبي تخص مشروعات التخرج ويسعدنا التعاون معكم بالمشاركة في الاشراف على مشروعات التخرج لدينا فيما يخص المادة العلمية الطبية ومراجعتها لتوطيد التعاون العلمي والأكاديمي بين مؤسسات الدولة وجامعتنا الموقرة.

مع وافر الشكر

منسق لجنة مشروعات التخرج

أ.م.د/ حسام البحيرى

عميد الكلية

أ.د/ نبيلة محمد حسن

جامعة ٦ أكتوبر
كلية
نظم المعلومات وعلوم الحاسب

تم موافقة مدير المركز

Figure 0.5 Collaboration Letter