Ellie's Adventures: A Gamified Application to Enhance Communication, Emotional, Cognitive, and Motor Skills in Children with Autism.

RP 24-25J-114

Project Proposal Report

Helapalla K. O. P. S. - IT21264016

B.Sc. (Hons) in Information Technology, Specializing in Software Engineering

Department of Computer Science and Software Engineering

Sri Lanka Institute of Information Technology, Sri Lanka

Declaration

I declare that this is my own work, and this proposal does not incorporate without acknowledgement any material previously submitted for a degree or diploma in any other university or Institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text.

Name	**Student ID**	**Signature**
Helapalla K. O. P. S.	IT21264016	

Signature of the Supervisor Date

(Dr. Kalpani Manathunga)

……. ..……

Abstract

The study presented in this research suggests a game-based smartphone application for improving emotion identification and reciprocation abilities in children with ASD due to the problem of scarce availability of therapy in Sri Lankan and other developmental states. The app draws on artificial intelligence and 3D avatars to create fun, tailored and quantifiable home-based therapies with the focus on children and parents. The application also includes options as feedback, attention tracking, and context-aware voice synthesis to make the educational content as tolerant as possible to children with ASD, making it both a sensory-friendly and motivating tool.

This research aims to fill the void in current treatment methods by presenting an affordable and effective technique that engagements the parents as active agents in the development of the child. The study focuses on the possibility of technology aiding in a better therapeutic process and consequently a better quality of life for ASD children and their families, thereby raising the social participation factor and boosting the children’s morale.

Table of Contents

List of Figures

List of Tables

List of Abbreviations

Abbreviation	Description
ASD	Autism Spectrum Disorder
AI	Artificial Intelligence
CNN	Convolutional Neural Network
LSTM	Long Short-Term Memory
FAU	Facial Action Unit
GenAI	Generative Artificial Intelligence
ABA	Applied Behavior Analysis
ConvLSTM	Convolutional Long Short-Term Memory
FCE	Facial Cues and Expressions

Table 1 - Abbreviations

1 Introduction

1.1 Background and Literature survey

Autism spectrum disorder (ASD) is a neuro-developmental disorder that is associated with a multitude of deficits, which includes areas like social interaction, emotion recognition, and communication [1]. Children with ASD often suffer from challenges in perceiving, and understanding others' emotions, and responding emotionally in an appropriate manner [2]. An alarming number of individuals are diagnosed with this disorder and over the decades there have been an explosive growth in numbers [2], reporting at least 6 out of 1000 individuals [2] to have ASD. These individuals often show symptoms of withdrawal from social interactions and lack of emotional empathy to others. This is associated with their ability to understand and express emotions [3]. Further, parents face numerous challenges when navigating autism diagnosis and support services, limited knowledge, and mental health difficulties [3].

Children with ASD exhibit impairments deficits and in recognizing and expressing emotions according to studies [1] [4] conducted in face processing. These impairments are widespread in them present from early ages. This affects their perception of both memory and face, and even perception of direction of gaze. These set children with ASD apart from normal children who can identify these cues and interact with people on regular basis.

Studies report this impairment in face processing which leads to lack of emotion skills is due to weak activation of the *fusiform gyrus* [1] (depicted in Figure 1), the part of brain that is responsible for processing high-order visual information related to faces, bodies and stimuli. As a result of this, autistic individuals struggle to take the entire visual context into account when involved in activities that require emotion skills [1].

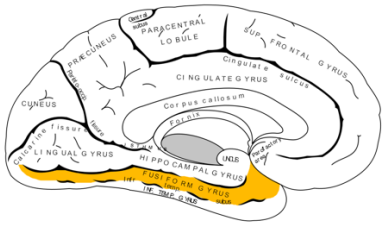

Figure 1 – The fusiform gyrus of the brain

Various solutions and interventions involving computer vision and artificial intelligence have been presented to help children with ASD to improve emotion cognition skills. Computer vision plays a major role in such solutions since it is a reliable way, when properly adopted, to provide guidance for child/user without human intervention. These predominantly use artificial intelligence mechanisms like Convolutional Neural Networks (CNN), Recurrent Neural Networks (RNN) like Long Short-Term Memory (LSTM) along with user interfaces which are appealing to children. Further, children with ASD were more likely to interact with computer supported applications according to studies. They seem to learn more, pay more attention and seemed to have more motivation in such software that were designed on behavioral learning principles than in programs involving human instructors [5]. Also computerized intervention programs like *Mind Reading* designed to train individuals with ASD to recognize emotions in faces and voices too have shown significant improvement in emotion recognition skills [6]. Results show that these intervention programs are effective, and they have beneficial results, and especially in environments where there is lack of access to therapy and support, these can be much useful.

These applications and solutions revolve around the main problem of having less access to therapy and having lesser knowledge of parents in training and working up with their children. Children with ASD are sensitive just like other children with any disorder, and the fact that they struggle in expressions, make it even tough for parents to deal with them [7]. Providing a solution that supports these problems and lets parents help the children with therapy exercises with minimum field-specific knowledge is vital in bridging the gap between therapy and home exercises.

Interactive mobile applications have shown promise in facilitating emotion recognition and expression in individuals with ASD and addresses the above-mentioned issues. Notably, *EmoTrain* [2] (shown in figure 2) leverages the device's camera and deep learning models to provide real-time feedback on facial expressions. Through a gamified approach, users engage in activities matching faces with emotions and practicing expression, thereby enhancing their understanding and communication of emotions. The app's focus on basic human emotions and utilization of a custom-trained CNN model contribute to its effectiveness in this domain.

Another similar application is a game [3] that teaches facial expressions to children. It employs the webcam to establish a visual feedback loop. This input is used both to animate an avatar

mimicking the player's expressions and to recognize the player's emotions. The game features various modes including identifying specific expressions, constructing facial expressions on an avatar, mirroring avatar expressions, and responding to emotional cues within a story. These are designed in accordance with Applied Behavioral Analysis (ABA) which is a convenient and proven way of treating children with autism spectrum disorder [8]. The game uses facial feature tracking, facial puppetry for avatar animation, and facial expression recognition using machine learning techniques.

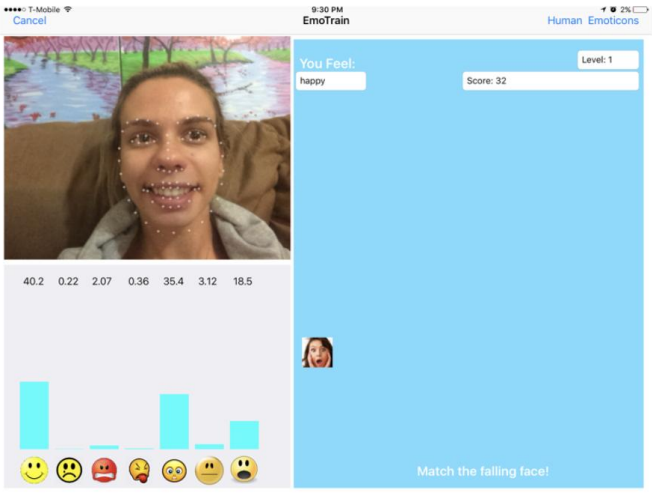

Figure 2 – EmoTrain application interface

Another approach was found in *eMot-iCan* [9] which is an emotion recognition game for individuals with ASD. It provides customizable learning based on the child's skill level and difficulty levels, and evaluations. *World of Kids* [10] is another system of mobile games aimed at enhancing facial emotion recognition in children with ASD. Another application *Ying* [11], a mobile application of the same purpose complements therapeutic approaches like ABA and provides several games like matching emotions and showing faces. This utilizes Microsoft Emotion API.

1.2 Research Gap

While there is a multitude of solutions and technological interventions as explained above, there are drawbacks and advantages of various technologies in comparison, and there are areas of improvement as well. To analyze this, we chose three different solutions that have similarities to what we plan to achieve in this research.

The research "A" presents an interactive platform that aims to enhance facial expression recognition and emotional reciprocity in individuals with autism spectrum disorder (ASD). While previous research has explored computer-based interventions for ASD, they often lack real-time emotion recognition and personalized feedback. It bridges this gap by integrating a deep learning-based emotion recognition model with a gamified interface, enabling real-time tracking and feedback on users' facial expressions. This combination facilitates the development of crucial social-communication skills in a more engaging and effective manner.

The research “B” proposes a game-based software utilizing touch screen technology to capture and analyze kinematic movement data in children. It provides solutions for time-consuming and subjective observational methods for ASD diagnosis. The proposed software aims to address this by offering a quantitative and engaging approach to assess motor patterns, potentially aiding in the earlier identification of ASD and providing objective metrics for evaluating motor skills. This

Research “C” introduces an interactive computer game that leverages facial expression recognition and avatar animation to teach children with ASDs about emotions. The game provides a fun and interactive platform that utilizes real-time facial tracking and feedback to help children learn to identify and express various emotions. This uses a mirroring emotion system (MES) to apply facial action units (FAU) on the 3D avatar real-time.

SYSTEM	An avatar mirroring expressions (MES)	Use facial landmark analysis	Realtime Interaction with the child	Serious-game features with rewards	Constructive feedback with GenAI
RESEARCH A	✓	✓	✓	✗	✗
RESEARCH B	✗	✗	✓	✓	✗
RESEARCH C	✗	✓	✗	✗	✗
PROPOSED SYSTEM	✓	✓	✓	✓	✓

Figure 3 – Comparison table of research gap

Figure 3 shows a table of comparison of these solutions. When considering all these applications and papers, the proposed solution will focus on implementing similar outcomes in more optimized and child-friendly ways. Further we found out that none of them use real-time voice feedback along with a 3D avatar while the child is performing each exercise. (Studies have shown that using a 3D avatar in conjunction with such applications increase the attention level of the child [12].) Generative artificial intelligence (AI) will also be used in the proposed application in several components, which will be explained in the following sections.

1.3 Research Problem

Children with autism spectrum disorder exhibit difficulties and deficits in multiple areas like speech and language, cognitive skills, emotional skills and motor skills. Among these, deficits in expressing and recognizing emotions is significant in children with ASD and leads to withdrawal from social interactions, further showing a lack of emotional sympathy towards each other. These symptoms and deficits are portrayed by children at early stages and can be moderated if therapeutic practices are applied at earliest stages [3].

Even though children with ASD receive therapy at early stages, in third world developing countries like Sri Lanka, this practice has limitations due to various reasons. Parents often face hardships due to economic issues, having limited knowledge on dealing with children properly and having limited access to free or low-cost therapy programs. While various solutions have been presented by previous researchers to improve essential skills in children with ASD with therapy approved methods, there seem to be a prominent gap in solutions aligning with the idea of "therapy at home" by providing accessible, measurable and child-friendly solutions that tackle the above issues [13].

Another problem is lack of proper knowledge of parents in working up with their children. This leads the parents to suffer from trauma, and even conditions like depression. Parents need to be aware about the child's capabilities and how they react in different situations. There are situations where the child has trouble grasping what the parents communicate, and this builds barriers between them. Providing ways to overcome this especially in complementary therapy activities is essential [13].

Complementary therapy activities are always an added advantage, if there is possibility to provide. Many children often get exposed only to a weekly limited time of therapy activities. Therapy frameworks like applied behavior analysis (ABA) have shown drastic improvements in children's skills and progress when the time of exposure to such exercises were increased. Reports say 20-40 hours of exposure to such activities have proven to be very useful in some cases [14].

Gamified technological solutions are often looked at in a different angle which many therapists/parents discourage (especially in Sri Lankan context), but recent reports [15] and studies have shown that they are much effective when compared to activities that directly involve human interaction [11].

2 Objectives

2.1 Main Objectives

The main objective of this research component is to find a feasible technological solution to help children with ASD improve their skills in the area emotions and facial expressions while supporting the idea "therapy at home". To achieve this, a gamified mobile application is proposed where the child is supposed to perform various therapeutic exercises in the form of games with the supervision (and at times, intervention) of parents.

2.2 Specific Objectives

The suggested solution, the gamified application covers mainly two areas

a. Emotion recognition – Focuses on improving emotion recognition skills
b. Emotion reciprocation – Focuses on improving emotion/facial expression reciprocation skills

The whole application is dissected into several subcomponents with specific objectives as follows.

Developing a game that evaluates children's current competency in overall emotion skills

This step comprises several games that are designed to evaluate the child's current context and competency in emotion skills, both recognition and reciprocation. After this is done, it should provide a score for the child's competency in these areas.

Implementing a series of games that train the child to express or reciprocate emotions and expressions

This focuses on developing a therapeutic serious game that trains the child to express facial expressions and have proper cognition in doing so. This is proposed to be achieved using a custom trained AI model that will detect the accuracy of child's expressions and a supportive 3D avatar component.

Implementing a series of games to improve child's emotion recognition skills with a leveling up algorithm

This sub objective focuses on implementing a series of games that helps the child recognize facial expressions and emotions in different situations. Further, a need for an algorithm to assess the level of the child should be implemented along with this component.

Develop and train a ConvLSTM model that can analyze the child's facial expressions in 3D space

Providing ways to measure the child's progress along with the exercises is crucial. In this scenario, an AI model will be trained using a gathered dataset that would be used in identifying the accuracy of facial expressions performed by the child. The facial expression data will be provided as 3D cartesian coordinates, and the model should be able to analyze subtle changes in them. This will utilize the device camera to capture small video snippets of the child doing the action and will be processed.

Implement a customizable 3D avatar that can portray facial blendshapes/FAUs real-time

The 3D avatar component is essential to support the child in this set of exercises. This component will be used to mimic/mirror the child's facial expressions exactly using a pre-defined set of facial blendshapes as provided by MediaPipe face landmarking model. The model should be able to clearly express these facial blendshapes and actions. The model further should be customizable with a look the child feels comfortable with, and it should perform lip animations properly.

Develop a game engine that can provide an interactive user interface along with a sensory friendly user experience

This sub objective focuses on developing a game engine that will be utilized throughout the main component, which will provide a sensory friendly user experience for the children. Since children with ASD are sensitive to the subtlest features, it is essential to minimize distraction, avoid abrupt transitions and appearance throughout the application. This should be accompanied with various sound effects that will satisfy the child while engaging.

Implement a feedback module for positive and negative reinforcement in conjunction with Generative AI

The feedback module will be utilized throughout the game to provide positive and negative reinforcement for the child's progress. This reinforcement method is actively used in ABA and is proven to be effective. Further this is proposed to use generative AI to generate fresh responses for the child in each scenario based on the context.

Implement an attention tracking module that is integrated with the games

An attention tracking module is proposed with the games such that it can detect when the child is inattentive to the exercise, and then provide a visual and auditory cue to get the child back on track. It uses the device camera continuously to analyze the pupil movements. The analysis is done using MediaPipe face landmark model, and an algorithm should be implemented to detect the gaze direction and attention from that data.

Implement a child-friendly voice synthesis module with context-aware tone

The children should be provided with audio visual feedback, and this sub objective focuses on providing realistic voice feedback to the child. Since there are various technological advancements in realistic tone processing, it is proposed to add a context aware tone changing functionality along with customization features like speed of speech, etc.

3 Methodology

3.1 System Architecture

The proposed system will provide two main series of exercises to the child, to improve emotion recognition and emotion expression skills. First, to understand the current competency level of the child, a small set of exercises will be given, and a score will be calculated as per the child's responses. Then the child will be shown an emotion along with the expression on the 3D avatar. Then the child is given a time to reciprocate that exact expression. The device camera will be used to monitor how accurately the child performs these expressions, and at the same time the expression will be mirrored and shown by the avatar. If there are improvement points, the avatar will provide real-time voice feedback. The other set of exercises take another approach. In these exercises the child is shown an expression along with the emotion and is asked to match it with the correct one. Different social settings and various other factors will be considered when designing these games. Further, the complexity of these games will be planned according to how the child progresses.

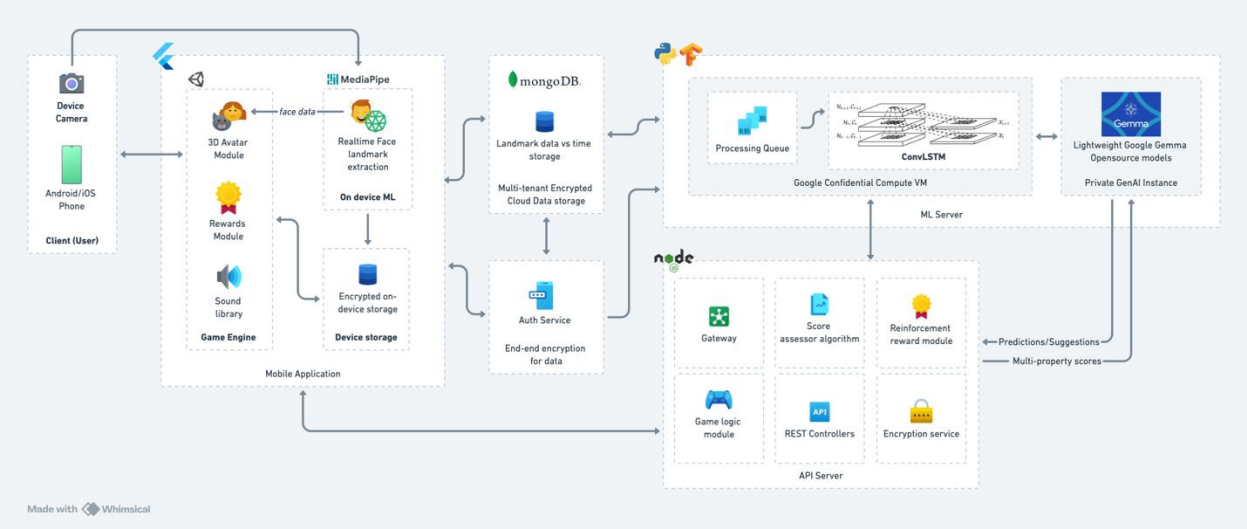

Figure 4 – High level system overview diagram

Figure 4 explains a high-level system overview diagram of the emotion related component of the application. The system will detect the child's expressions real-time by analyzing facial landmarks. These facial landmarks are provided by MediaPipe's Face Landmarking model [16] [17] which

will provide a set of 3-dimensional coordinates for the face. This facial landmark model further provides a set of pre-defined facial blendshapes (see figure 5). When the child performs the exercise, a small video snippet is captured. Then this video is used to analyze the change in such facial landmark coordinates in the 3D cartesian plane, and this data will be stored as time-series data, frame by frame. Afterwards, the data is sent to the AI model server to be processed. The AI model used will be able to detect whether the child's expression is accurate compared to the pre-defined data. The game uses a set of standard emotion expressions for now, such as anger, sadness, disgust, happiness, and so on.

An AI model will be trained using data obtained from children with ASD to fine tune the model to fit their specific behaviors. The model used here would be a Convolutional Long Short-Term Memory (ConvLSTM) model, where it keeps track of the previous context. This context is essential since we are dealing with time-series data (in this case, frames of facial data including coordinates). A ConvLSTM model is a combination of a CNN and a LSTM model. LSTMs are a category of Recurrent Neural Networks (RNN) and these are very effective at modeling sequential data, including time series and text. ConvLSTMs combine the strengths of CNNs and LSTMs. They replace the matrix multiplications in LSTM gates with convolution operations, allowing them to process spatiotemporal data efficiently. ConvLSTM models are very effective in video prediction and video classification tasks [18]. The ConvLSTM model will be trained using Tensorflow and a custom dataset is to be captured to make this specific in Sri Lankan context, from a therapy center in Sri Lanka.

A 3D avatar component will be implemented, with the main aim of supporting the child in terms of motivation and interactivity. Studies show that using a 3D model for applications for children with ASD yield much higher results than normal user interfaces. The 3D avatar would be a customizable animatronic face which is capable of showing a multiple number of essential facial blend shapes. These expressions should be recognizable by children with ASD and should be easier to detet than performing the exercise with a human therapist. When performing the exercises, the avatar will first show how to do the exercises and then after a timer, it will star mirroring the child's expression. The child is supposed to do what is said, and whenever the child fails to achieve the day's goal, the avatar will speak up in a friendly voice with instant feedback. This mirroring system

is shown to be effective in another solution and is introduced as a mirroring emotion system (MES).

Facial landmark analysis is provided by Mediapipe which, under the hood contains a Single Shot multibox Detector (SSD) model which is also a type of a CNN. Mediapipe's Face landmarking model provides a set of 478 landmarks, and a set of 52 blendshape coefficients. These help in accurately detecting and modelling the child's expression. Further, FaceNet can also be utilized in this area.

The application contains a live visual feedback loop which helps adapt the game (both areas of the game) to the child, rather than making the child adapt to the game. This visual feedback loop is attained by using the device camera to continuously monitor the child's facial expressions. As mentioned, the facial landmarks are obtained, and the child is constantly monitored. Such games also mentioned as serious games are proven to be beneficial for the children [3].

A realistic voice synthesis and an attention tracking module is planned to be integrated with the system so it makes it easier to track whether the child is attentive of the task, and if the child shows symptoms of drifting away from the game, the 3D avatar will come into play and will provide a visual and an auditory clue to get the child back into track.

Generative AI will be used to generate feedback for the exercises based on the scores the child get. This approach was suggested to have a realistic approach to providing feedback rather than having a pre-defined set of feedback lines. This enhances the child's motivation to do these exercises.

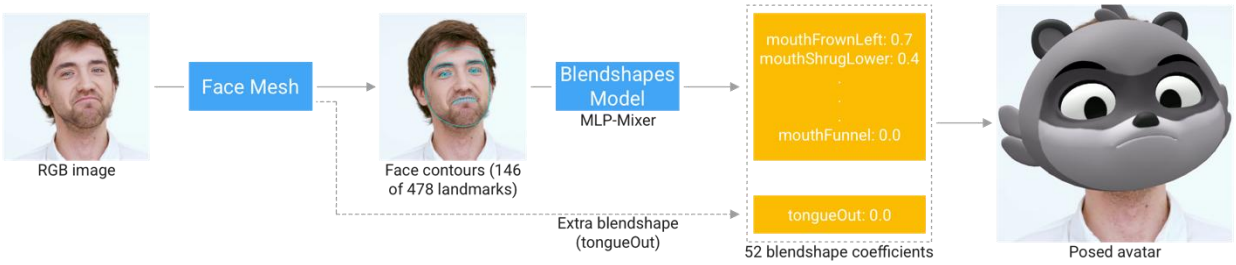

Figure 5 – Mediapipe Facial Blendshapes

Measures will be taken to ensure data integrity and security throughout the application since it deals with sensitive data of children when storing them. These will be discussed in detail in the software solution section below.

3.2 Software Solution

The app consists of various sub-components that require several technological implementations. The complete application will be a mobile app that can run on both iOS and Android operating systems. This will be achieved via Flutter development framework, which offers a cross platform solution for developing applications. For the 3D avatar, and implementations related to the game engine, Unity 3D will be utilized in conjunction with Flutter, integrating game components where necessary, seamlessly within the application. The user interface should be a smooth and sensory friendly one, so that a separate library of animations and interfaces will be built.

The Mediapipe face landmarking models utilized in this application are referred to as Google AI Edge [19], which means the processing is done real-time on the device itself, so they are by default lightweight models that can be run on most mobile devices on the market. These solutions are useful in building embedded applications which require artificial intelligence functions but have limited resources.

The AI models will be deployed on Azure AI cloud platform, and it will be accessible via a REST API. The video snippets of the children performing exercises will be sent to the server and the response (the accuracy value) will be sent back to the application. End to end encryption will be implemented throughout the endpoints where sensitive data is shared between components.

A generative AI model such as Google Gemma Opensource which is a light weight model is proposed to be hosted on a server such that all the components can have access to the model, but individual memories will be isolated using data stores using vector databases such as Neo4J. As a solution to store data privately, a private tenant storage will be utilized. These storage buckets will be end to end encrypted, and will only be decrypted by the device while accessing the data. Further,

solutions like Google Confidential Computing [20] will be utilized where necessary due to private threading and storage capabilities provided for processing sentitive data.

3.3 Commercialization

The application is offered as two subscription plans:

The free tier consists of basic features, and limited real-time feedback. This solution is great for those who are new and want to try it out first. This has limited features like generative AI and limits the access to games once a certain level is hit. This measure is taken to ensure that the app can be maintained and run efficiently.

Priced at LKR 4000, the paid tier unlocks all the features, gives personalized feedback, and more AI-powered tools. This package contains all the features in the free tier and includes generative AI features like customized feedback to make the child more engaged in the games. Further, the parents get access to a dashboard where they can monitor the child's progress and future predictions for growth.

This approach gives users choices and ensures the app can keep growing and getting better, with new features and improvements added regularly.

4 Project Requirements and Design

4.1 Requirements

The following section discusses the requirements of the application in a detailed manner.

4.1.1 Functional Requirements

4.1.1.1 Evaluate Competency

Accurately assess a child's initial proficiency in emotion recognition and expression through interactive games.

4.1.1.2 Train Expressions

Provide a series of engaging games that guide children in practicing and refining facial expressions and emotional recognition.

4.1.1.3 Monitor Progress

Track and quantify a child's progress using an adaptive leveling algorithm and AI-powered analysis of facial expressions.

4.1.1.4 3D Avatar Interaction

Feature a customizable 3D avatar capable of mirroring facial expressions and delivering real-time feedback.

4.1.1.5 Sensory-Friendly Interface

Offer an intuitive, engaging, and minimally distracting user experience.

4.1.1.6 Reinforcement/Rewards System

Utilize positive and negative reinforcement through AI-generated feedback to encourage and motivate the child.

4.1.1.7 Attention Tracking

Employ attention tracking to identify moments of inattention and re-engage the child with visual and auditory cues.

4.1.1.8 Voice Synthesis module

Incorporate context-aware voice synthesis to provide natural and encouraging feedback.

4.1.1.9 Data Security

Implement robust security measures to protect sensitive user data.

4.1.2 Non-Functional Requirements

4.1.2.1 Usability

The app must be easy to use and navigate for both children with ASD and their parents. The children should be able to navigate and see the things on screen clearly.

4.1.2.2 Accessibility

The app must be designed to be accessible to children with a range of abilities and needs. For this, international conventions on accessiblity (a11y) will be utilized.

4.1.2.3 Performance

The app must be responsive and performant even on older devices since in the context of Sri Lanka, most of the population does not have access to latest technological devices.

4.1.2.4 Reliability

The app must be reliable and free from crashes or errors. The scores predicted by the system should be accurate and be reliable. The screening test at the start should be able to grade the child properly to have a proper head start.

4.1.2.5 Security

The app must be secure and protect user data from unauthorized access. Since the system deals with sensitive data, steps should be taken to ensure data security in every step.

4.1.3 System Requirements

4.1.3.1 Mobile Platforms

iOS and Android compatibility

4.1.3.2 Hardware

Front-facing camera, sufficient processing power, and storage

4.1.3.3 Connectivity

Internet access for AI model interaction and data synchronization

4.1.3.4 Software

Flutter framework, Unity 3D game engine, MediaPipe library, Azure AI cloud platform

4.1.4 Personnel Requirements

4.1.4.1 Field specific personnel (external supervisor)

The research team is coordinating with the National Program Manager, Child Development and Special Needs at Family Health Bureau, Ministry of Health Sri Lanka, Dr. Asiri Hewamalage to get the external supervision required for the project and the field specific expertise, along with access to data collection.

4.1.4.2 Speech Therapists

The external supervisor has given the research team, the opportunity to interact with several licensed therapists who are in the area of therapy related to ASD.

4.1.4.3 Parents/Caregivers

For this requirement, a circle of parents are in contact with the research team, and the team is planning to participate in a discussion to get to know about the problems they are facing and how the app can help them.

4.2 Design (System and Software design documents)

4.2.1 Use Case Diagram

This diagram shows a brief and a high level use case diagram of the system (tentative)

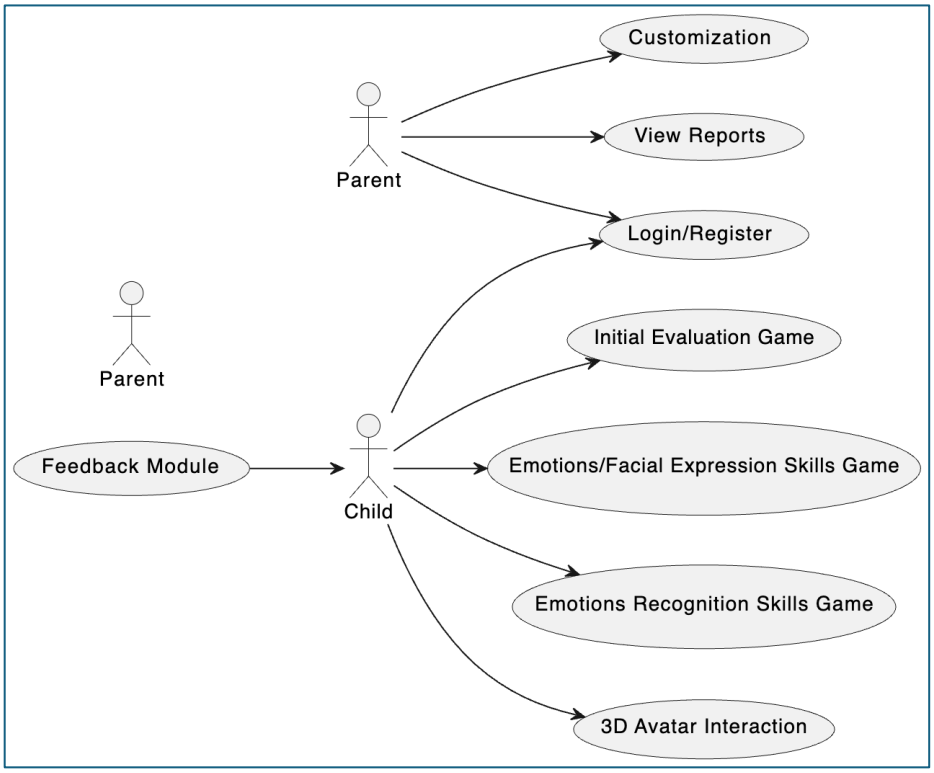

Figure 6 – High level use case diagram

4.2.2 Tentative UI wireframes

The following UIs have been developed as initial drafts to be shown as a prototype when performing ethnographic field study at a renowned therapy centre in Sri Lanka.

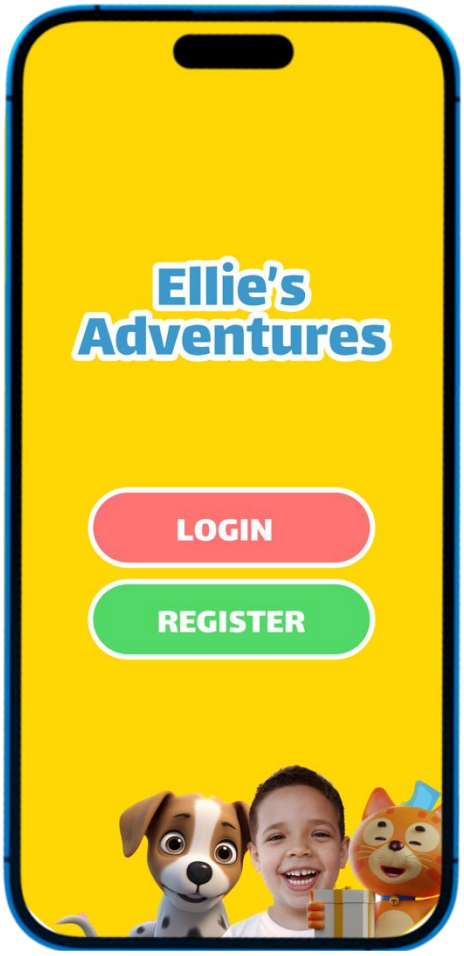

Figure 7 – Onboarding screen

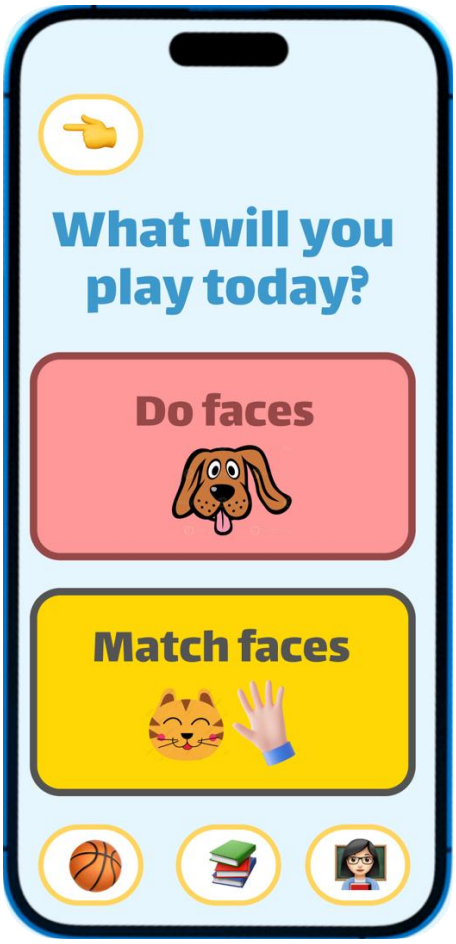

Figure 8 – Game selection screen

4.3 Gantt Chart

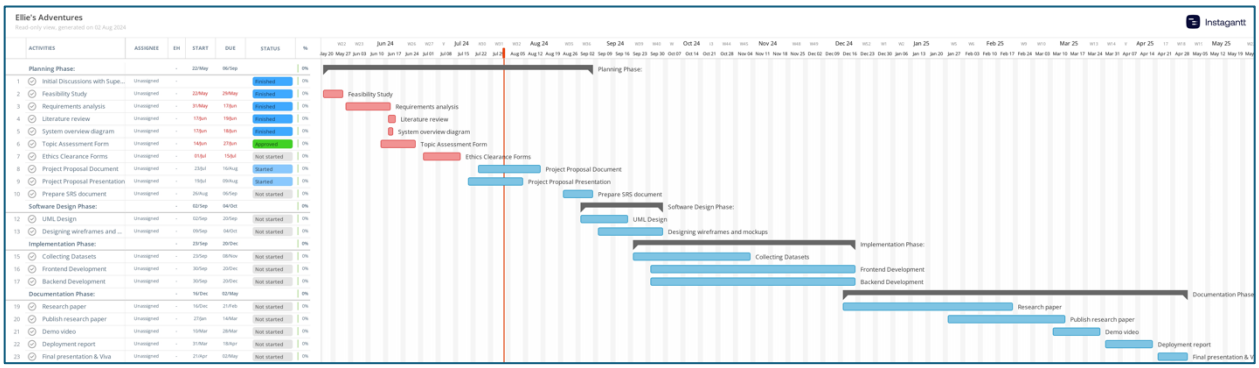

Figure 9 – Gantt chart

4.4 Work Breakdown Structure (WBS)

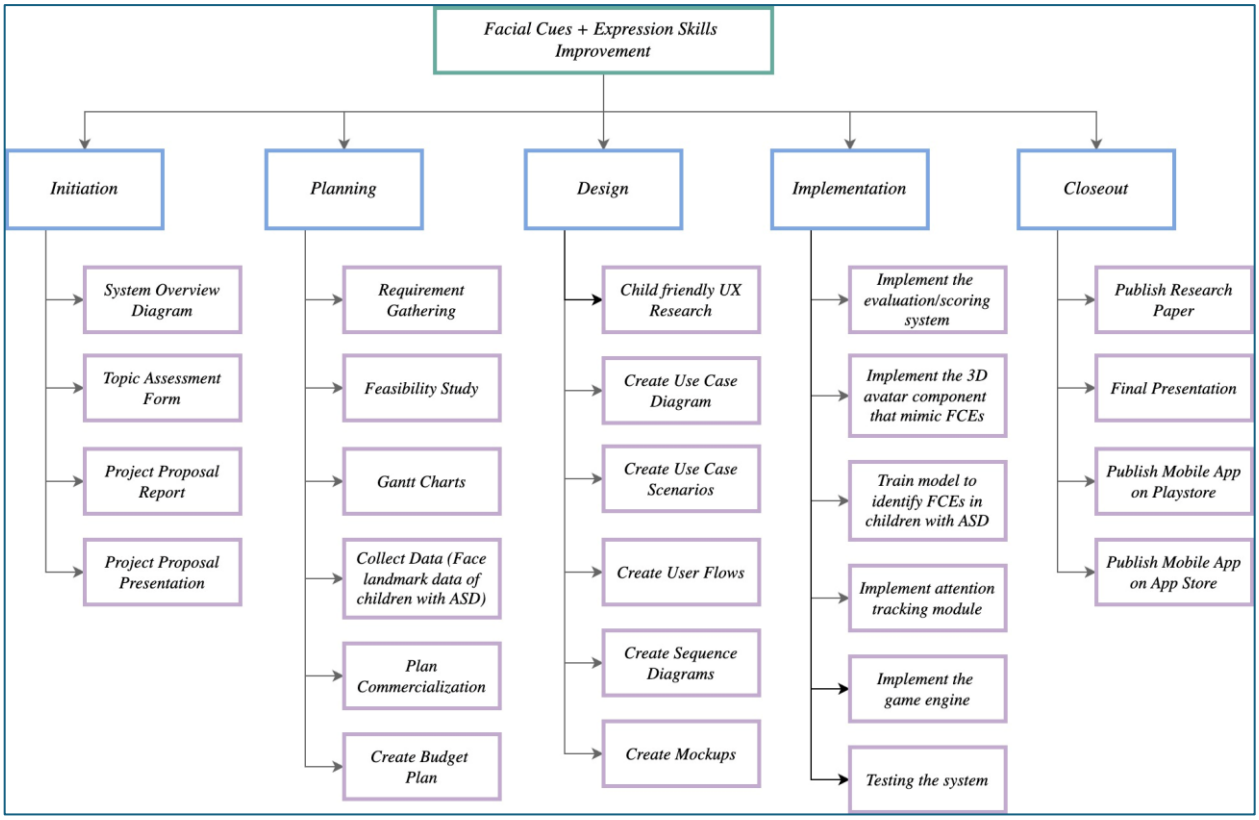

Figure 10 – Work breakdown structure

5 References

[1] M. Behrmann, G. Avidan, G. L. Leonard, R. Kimchi, B. Luna, K. Humphreys and N. Minshew, "Configural processing in autism and its relationship to face processing," *Neuropsychologia,* vol. 44, no. 1, pp. 110-129, 2006.

[2] C. Tsangouri, W. Li, Z. Zhu, F. Abtahi and T. Ro, "An interactive facial-expression training platform for individuals with autism spectrum disorder," *2016 IEEE MIT Undergraduate Research Technology Conference (URTC),* 2016.

[3] S.Jain, B.Tamersoy, Y.Zhang, J. K.Aggarwal and V.Orvalho, "An interactive game for teaching facial expressions to children with Autism Spectrum Disorders," *2012 5th International Symposium on Communications, Control and Signal Processing*, 2012.

[4] S. Faja, E. Aylward, R. Bernier and G. Dawson, "Becoming a face expert: A computerized face-training program for high-functioning individuals with autism spectrum disorders," *Developmental Neuropsychology,* vol. 33, no. 1, 2007.

[5] M. Heimann, K. E. Nelson, T. Tjus and C. Gillberg, "Increasing reading and communication skills in children with autism through an interactive multimedia computer program," *Journal of Autism and Developmental Disorders,* vol. 25, no. 5, 1995.

[6] O. Golan and S. Baron-Cohen, "Systemizing empathy: Teaching adults with Asperger syndrome or high-functioning autism to recognize complex emotions using interactive multimedia," *Development and Psychopathology,* vol. 18, no. 02.

[7] J. Smith, A. Aulich, C. Bent, C. Constantine, K. Franks, N. Goonetilleke, C. Green, R. Ijaz, K. Patel, H. Said, S. Wood and K. Hudry, "“We go through trauma”: South Asian parents’ experiences of autism diagnosis and early supports for their autistic children in Australia," *Research in Autism Spectrum Disorders,* vol. 114.

[8] S. Eikeseth, "Outcome of comprehensive psycho-educational interventions for young children with autism," *Research in Developmental Disabilities*, vol. 30, no. 1.

[9] D. Sturm, E. Peppe and B. Ploog, "eMot-iCan: Design of an assessment game for emotion recognition in players with Autism," *2016 IEEE International Conference on Serious Games and Applications for Health (SeGAH),* 2016.

[10] N. Heni and H. Hamam, "Design of emotional educational system mobile games for autistic children," *2016 2nd International Conference on Advanced Technologies for Signal and Image Processing (ATSIP)*, 2016.

[11] M. Alharbi and S. Huang, "An augmentative system with facial and emotion recognition for improving social skills of children with autism spectrum disorders," *2020 IEEE International Systems Conference (SysCon)*, 2020.

[12] O. Mantziou, I. Vrellis and T. A. Mikropoulos, "Do children in the spectrum of autism interact with real-time emotionally expressive human controlled avatars?," *Procedia Computer Science*, vol. 67.

[13] A. H. Vanniarachchy, "Autism in Sri Lanka," Ceylon Today, [Online]. Available: https://ceylontoday.lk/2024/07/20/autism-in-sri-lanka/. [Accessed 23 08 2024].

[14] A. S. Shminan, L. J. Choi and S. Sharif, "AutiTEACCH: Mobile-based learning in a structured teaching approach for autistic children caregivers," *2020 International Conference on Informatics, Multimedia, Cyber and Information System (ICIMCIS)*, 2020.

[15] Unicef, "Responsible Innovation in Technology for Children," Unicef, 2024.

[16] Google, "Face landmark detection guide," Google, 21 5 2024. [Online]. Available: https://ai.google.dev/edge/mediapipe/solutions/vision/face_landmarker. [Accessed 23 08 2024].

[17] I. Grishchenko, G. Yan, E. G. Bazavan, A. Zanfir, N. C. K. Raveendran, M. Grundmann and C. Sminchisescu, "Blendshapes GHUM: Real-time Monocular Facial Blendshape Prediction," 26 2 2024. [Online]. Available: https://ar5iv.labs.arxiv.org/html/2309.05782. [Accessed 23 08 2024].

[18] S. Silva, A. Jayasinghe, R. Dilshan, C. Dissanayake, S. Vidhanaarachchi and D. D. Silva, "Effectiveness of Deep Learning Technologies to Assist Educational Inclusion for Children with Down Syndrome," *2023 5th International Conference on Advancements in Computing (ICAC)*, 2024.

[19] "Google AI Edge - Google AI for Developers," [Online]. Available: https://ai.google.dev/edge. [Accessed 23 8 2024].

[20] Google, "Confidential Computing," [Online]. Available: https://cloud.google.com/security/products/confidential-computing?hl=en. [Accessed 23 8 2024].

6 Appendices

6.1 Plagiarism Report

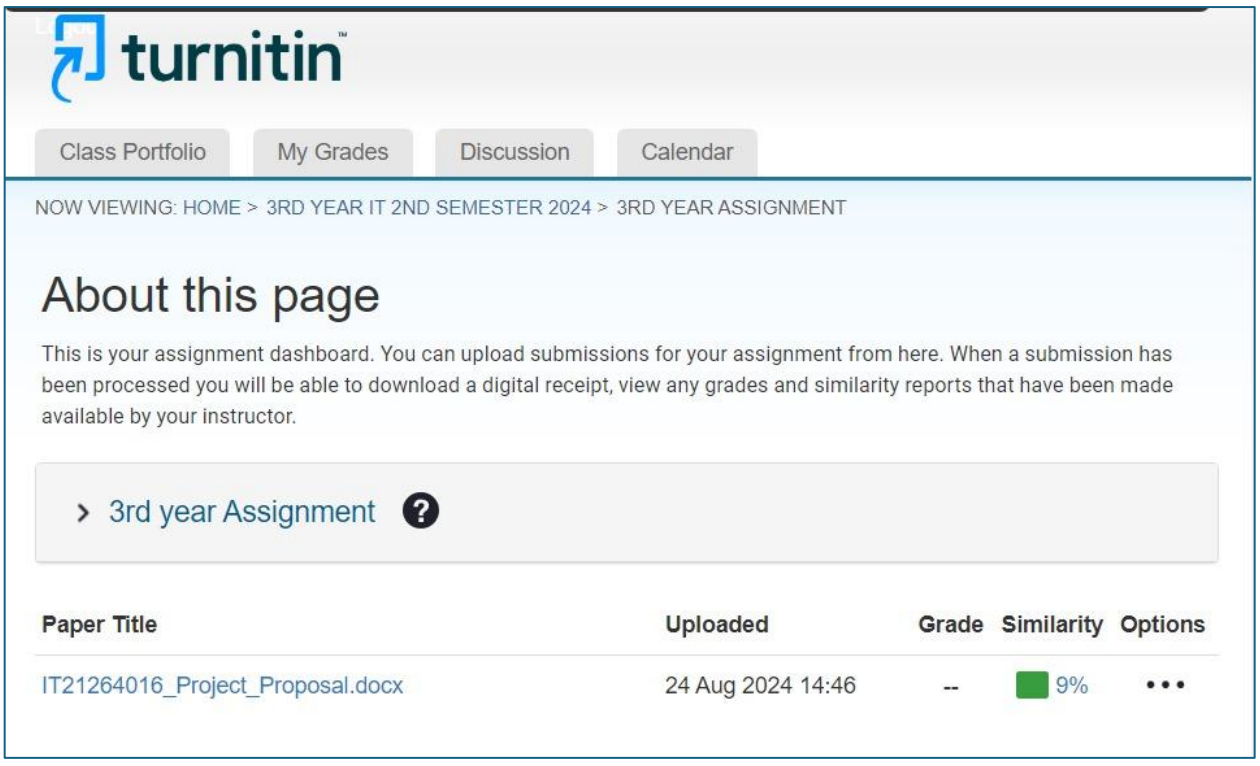

Figure 11 – Turnitin plagiarism report similarity value