EmoLand: Enhancing Facial Emotion Skills among Children with Autism Spectrum Disorder (ASD) in Sri Lanka

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***Abstract*—Autism Spectrum Disorder (ASD) is a neurodevelopmental disorder characterized by a variety of symptoms, one of which is difficulties in emotional intelligence (EI). Children with ASD frequently find it challenging to recognize and express facial emotions, which could significantly harm their overall well-being. There remains a notable gap in access to effective early intervention methods for children with ASD in Sri Lanka, particularly for the 2-7 age group. This research addresses this necessity by utilizing recent advancements in artificial intelligence (AI), intense learning (DL), to implement a user-friendly mobile application designed as an early intervention solution enhancing facial emotion recognition (FER) and production. The proposed solution leverages Ekman's six basic emotions framework for facial emotion detection, progressive learning materials with familiar faces, and context-based evaluations to monitor the children's development. The research includes developing a custom model for face emotion recognition utilizing the DeepFace library and the Flutter framework for the mobile application.**

Keywords—autism spectrum disorder, facial emotion recognition, early intervention, emotional intelligence, DeepFace

I. Introduction

Autism Spectrum Disorder (ASD) includes a spectrum of neurodevelopmental challenges, including impairments in social skills, communication, and cognitive abilities such as facial emotion recognition (FER) and theory of mind (ToM). Individuals with ASD frequently have lower emotional intelligence (EI), particularly in understanding emotions within their surroundings, being empathetic to others' experiences, interpreting emotions from social cues, and being in control of both their own and others' emotions [1]. FER is a critical aspect of non-verbal and social interaction that significantly impacts social interactions, effective communication, and the overall well-being of individuals with ASD [2] [3].

The ability model of EI, based on Ekman's six basic emotions (happy, sad, angry, fear, disgust, surprised), introduces a framework for analyzing emotional difficulties experienced by people with ASD. Empathy, a core factor of EI, requires accurately understanding and responding to others' mental states. While people with ASD face challenges in FER, they often possess innate or heightened systemizing abilities, which can facilitate cognitive empathy, particularly in recognizing emotions [4]. Enhancing emotional skills is essential for children, as it supports effective communication and helps them navigate social interactions more positively. Despite the global recognition of the difficulties faced by individuals with ASD, Sri Lanka presents unique challenges. Families with autistic children come across complications in various aspects of life. Due to a lack of knowledge and resources, Sri Lankan schools often discourage the enrollment of students with ASD. The term "early intervention" is essential to meet the developmental needs of children with ASD aged 7 and below. It is fundamental for autistic children to enhance their quality of life. Play-based therapies that target imperative brain developmental stages are the main focus [5]. Following the American Academy of Pediatrics' recommendations for developmental and behavioral examinations at 9, 18, and 30 months, early intervention is emphasized to alleviate the negative impacts of neurodevelopmental disorders. Existing interventions, however, encounter challenges in recognizing facial emotions specific to ASD, as well as issues shared by parents and therapists. ICT plays a key role in helping individuals with ASD overcome these obstacles by providing them with resources for skill development, communication, and emotional exploration [3].

The researchers [6] observe that advancements in mobile computing have facilitated the integration of FER systems into smartphones, making them a viable platform for EI-enhancing applications for children with autism. In order to bridge this gap, this study will implement a user-friendly mobile application that leverages artificial intelligence (AI) to improve the ability of Sri Lankan children with autism, particularly those between the ages of 2 and 7, to recognize and produce facial emotions.

II. Literature Review

A. Existing System Analysis

Facial Expression Wonderland (FEW) and "Let's Face It!" application are notable examples of computer games. FEW prototype [2] is inspired by the Walt Disney film "Alice in Wonderland." It aims to improve autistic children's FER skills by providing voice prompts and animated characters to help them navigate diverse emotional situations. There are concerns regarding the necessity of careful emotion selection and the use of cartoon expressions for emotion assessment. They stress the need for real experiments and eye tracking for precise gaze detection during games. Similarly, "Let's Face It!" [8] has seven interactive games that are divided into three categories: facial identity and expression detection, social context facial cue interpretation, and attention to faces. Although it has been successful in teaching emotional skills, there are still challenges with its effectiveness and its inability to transfer abilities outside of computerized contexts.

Another strategy to assist ASD children is using serious games such as JEMImE and EmoTEA. JEMImE [7] is designed to improve facial expression production in social contexts and includes distinct training and playing phases. It utilizes Curapy.com for data recording, C#, Unity 3D, and Pairwise Conditional Random Forests for evaluation. A small sample size and the requirement for a child-specific facial expression classifier are among the drawbacks. The Android-based serious game EmoTEA [9] is aimed for children between the ages of 6 and 12. To improve EI, it integrates Affective Computing, Tangible User Interfaces (TUIs), and Ekman's six basic emotions methodology. Positive results validate its effectiveness, although there are challenges with the age range and possible interruptions to routines.

Mobile applications, such as World of Kids and Emotions on the Go, offer accessible platforms for emotional learning. World of Kids [10] is a personalized game series designed for mobile and tablet devices. It utilizes FER algorithms and voice recognition tools to provide customized learning experiences, using AndEngine, a 2D game engine library. The limitations include reliance on a local SQLite database, mainly the storage capacity and accessibility. Emotions on the Go [11] is a mobile-based emotion detection system that uses OpenFace for real-time facial expression analysis. The study incorporates Orbeus ReKognition API, AFFDEX SDK, and Fraunhofer SHORE. The study is limited by a short training duration and a small sample size.

Another approach is provided in "The Transporters" DVD series for kids ages 2 to 8. This series enhances the ability to understand and recognize emotions by using animated vehicles to represent them [4]. Despite its effectiveness, the DVD format lacks the accessibility and user-friendliness of mobile applications, limiting its broader application.

B. Technological Analysis

FER has been significantly advanced by the technological developments in machine learning (ML) and deep learning (DL). ML algorithms have shown remarkable efficiency in categorizing high-dimensional facial expression data, particularly Support Vector Machines (SVMs) [5] [12]. Viola-Jones Feature Detection System effectively manages luminosity variations by using rapid object detection and grayscale image enhancement [10]. In facial geometry detection and emotion classification, the modified eyemap and mouthmap algorithm has shown promising results, which uses TensorFlow for neural network execution [13].

In DL techniques, convolutional neural networks (CNNs) are widely used for FER due to their automatic learnability from data. CNN accuracy is significantly enhanced by ReLU activation, maximum pooling, and dropout [5]. Infant facial emotions have been recognized by pre-trained models like ResNet50, VGG19, and MobileNetV2, with transfer learning (TL) serving as an effective method to fine-tune these models [14]. Google Teachable Machine is a user-friendly platform for developing custom classification models through TL, enabling easy integration into lightweight web apps [5] [15].

In ML and DL applications, OpenCV plays a key role as an open-source tool for image processing [5]. Sefik Ilkin Serengil's DeepFace framework is prominent for its high accuracy in face recognition tasks. As evidence in its versatility, DeepFace use CNNs for facial attribute analysis such as age, gender, emotion, and race and integrates state-of-the-art pre-trained models, including VGG-Face, Google FaceNet, OpenFace, Facebook DeepFace, DeepID, ArcFace, Dlib, and SFace [16]. Its CNN architecture is renowned for its simplicity and effectiveness in attaining competitive accuracy in emotion prediction when evaluated against benchmark datasets [17]. OpenCV and DeepFace framework combination forms a powerful tool for facial emotion analysis across various domains, including educational technology [18].

According to the existing literature, there is a substantial research gap about the long-term impact and practical validation of AI-based solutions for enhancing autistic children's abilities for facial expression production and recognition. CNN has limitations when it comes to one-dimensional training data, training stability, and feature duplication, as discovered in technological analysis. The significance of addressing these issues is highlighted by the lack of interventions tailored to the social context of Sri Lanka. It is imperative to close this gap by offering a customized and accessible solution for the intended age group.

III. METHODOLOGY

This research utilized a mixed-methods approach combining quantitative and qualitative methodologies. Data collection involved interviews, expert opinions, and questionnaires in both pre-analysis and post-analysis phases. Pre-analysis interviews with therapists, special needs educators, doctors, and parents gathered insights into existing interventions. In the post-analysis phase, discussions with experts assessed the implemented "EmoLand" application, identifying strengths, weaknesses, and suggesting future improvements. Moreover, a post-analysis questionnaire for parents evaluates the solution's effectiveness statistically.

Thematic analysis of stakeholder interviews, including Ms. Jayani Panapitiya, Mrs. S. D. Rathuwithana, therapists Mrs. Chamila and Mr. Bharatha from Cherish Foundation, and Dr. Savithri Dias, highlighted key themes such as visualization, color preferences, multisensory learning, repetitive teaching, current methodologies, challenges, technical proficiency, and recommended features. Stakeholders emphasized challenges like children's reliance on parental facial expressions and negative home experiences, alongside their proficiency with smartphones requiring parental guidance. Recommendations included a minimalist interface, familiar images, progress tracking, and engaging content.

The proposed solution in Fig. 1, "EmoLand" Phase 1 is an innovative mobile app designed to enhance facial emotional skills in ASD children. It includes Ekman's six basic emotions and integrates DeepFace framework for FER. EmoLand provides a progressive learning strategy with lessons based on familiar faces, mainly parents, to offer an interactive learning experience. Progress tracking feedback is provided through relatable social context evaluations, allowing children to practice emotional development skills in real-life scenarios. This AI-based intervention aims to support and enrich emotional development in early stages and engages both autistic children and their caregivers.

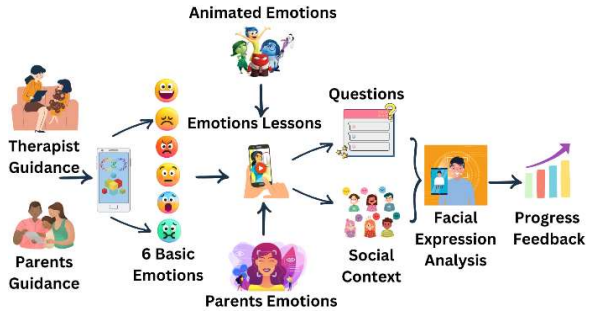


Fig. 1. EmoLand high-level conceptual solution

IV. Implementation

A. Technology

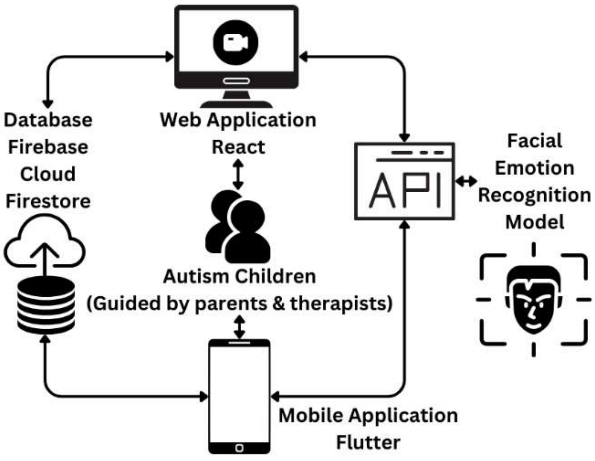
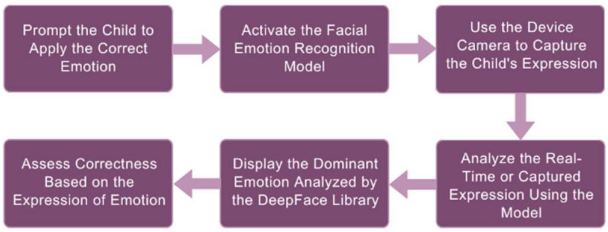


Fig. 2. EmoLand system architecture diagram

Python was used to build the facial emotion recognition model, utilizing OpenCV with Haar Cascade classifier and NumPy for image processing and face detection. DeepFace framework was significant in facial attribute analysis. Flask facilitated API development, with Ngrok ensuring secure hosting of Python APIs. The Flutter framework was used to develop a visually appealing mobile app, tested on the Android Emulator in Android Studio. Alongside, React was utilized for the web-based frontend, focusing on real-time facial emotion detection. Firebase Cloud Firestore served as the NoSQL database for storing user information. The system architecture is depicted in Fig. 2.

Facial Emotion Recognition Model

The FER model is an essential system component designed to assess children's facial emotion production skills. As shown in Fig. 3, after completing emotion lessons, the model evaluates the child's ability to express emotions and their application in real-life scenarios. The outcomes provide feedback within the app, offering insights to enhance the child's emotional development. The FER model is implemented through two methods: image-based and real-time emotion recognition. For images, Python code utilizes the DeepFace library for emotion analysis and OpenCV for face detection, processing input images and overlaying the dominant emotion. For real-time video, frames are captured from a webcam, face detection is applied, and DeepFace analyzes emotions, providing live feedback. Both models are converted into Flask APIs, enabling seamless integration with mobile and web applications. The Fig. 4 shows the results of the real-time facial emotion recognition model.



Process of FER model

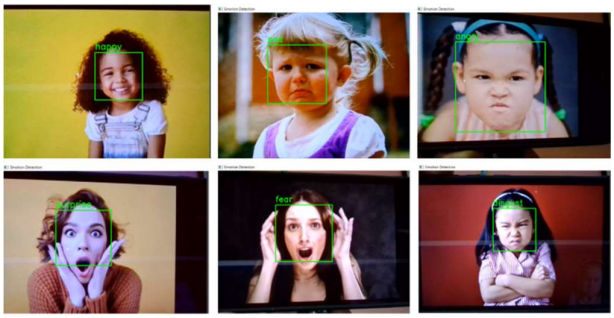


Fig. 3. Results of the real-time FER model

B. User Interface Design and Main Features

"EmoLand" mobile app User Interface (UI) design focuses on providing a practical, user-friendly experience for ASD children. It addresses the needs of ASD children emphasizing predictability and consistency. Color psychology, influenced by personal and cultural factors, is carefully applied to positively affect emotions and behaviors. Some autistic people avoid specific colors, particularly shades of red, possibly due to their universal interpretation of danger, which can trigger strong emotional actions. The UI uses easily readable fonts and minimizes complex elements to enhance usability, addressing reading comprehension challenges often faced by ASD individuals. Also, graphic cues like images and icons are included to illustrate concepts and improve understanding, based on findings from various studies. These considerations aim to design an inclusive and supportive environment for ASD children.

The mobile application incorporates components based on research and interview data analysis. Parents play an important role in the lives of autistic children, making their expressions an effective teaching tool. The application, therefore, uses familiar images of parents to effectively teach facial emotions through a unique Parent Emotions feature. Customized lessons focus on three fundamental emotions, utilizing two lesson formats, parent emotion images, and engaging cartoons images as in Fig. 5. The application features a critical evaluation component, as in Fig. 6, where children respond to emotion-based questions, display corresponding facial expressions, and upload images for assessment using the facial emotion analysis feature. If the

detected emotion matches the correct one, the child receives positive feedback, resulting in an interactive and familiar learning experience similar to the mirroring technique used in therapy. A detailed database tracks their progress, providing insights into their emotional development. The registration process ensures a personalized learning experience for children, aligning with the solution's objectives.

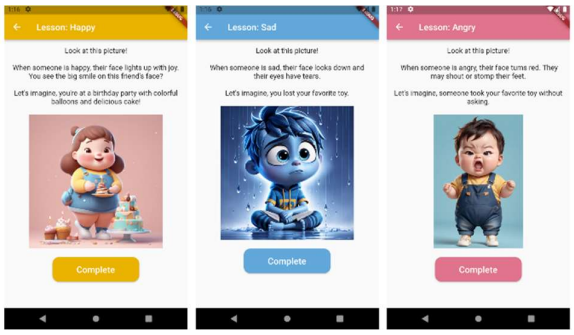


Fig. 4. Emotion Lessons Pages UI

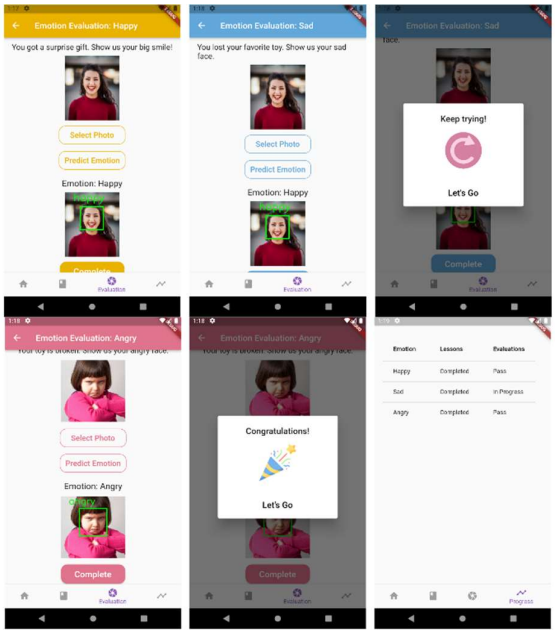


Fig. 5. Emotion evaluation pages UI

V. Evaluation and Results

A. Model Accuracy Testing

The accuracy of the developed FER model, utilizing the DeepFace library, was assessed using a test dataset with 40 sample images per each of the 7 emotions. Python libraries facilitated the analysis, revealing varying accuracies across different emotions. As indicated in the confusion matrix, happy and sad emotion detection achieved higher accuracy likely due to their distinct expressions, while disgust and fear emotions suggested potential overlaps with other emotions, highlighting the need for differentiating visually similar expressions in Fig. 7. Concurrently, the model was benchmarked against a Google Teachable Machine model trained on a hybrid dataset and showed varying accuracy across emotions, performing well in identifying Happy (82%) due to its distinct features but displaying lower accuracy for Angry and Disgust (40%), likely due to overlapping expressions as in Fig. 8. This comparison validated the custom DeepFace-based model's accuracy for the FER system, offering insights into performance and areas for potential improvement, with both models excelling in distinct emotions but struggling with subtle ones.

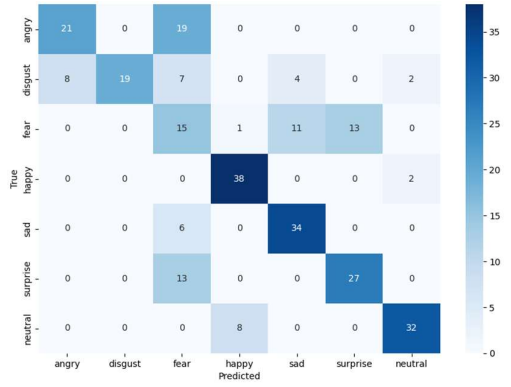


Fig. 6. Confusion Matrix of FER Model

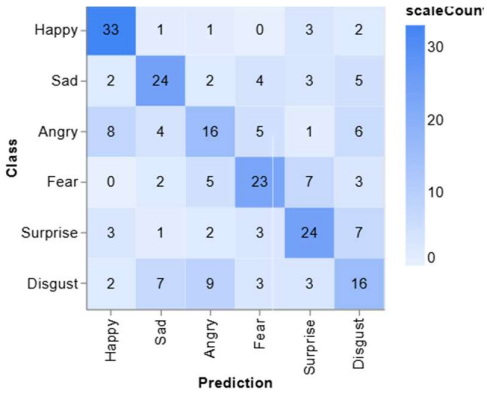


Fig. 7. Confusion matrix of Google teachable machine FER model

B. Solution Effectiveness Analysis

TABLE I. Intervention Results

Child	Age	Lesson Status	Evaluation Status		
			Happy	*Sad*	*Angry*
1	7	All Completed	Pass	Pass	Fail
2	7	All Completed	Pass	Fail	Fail
3	6	All Completed	Pass	Pass	Pass

The Phase 1 prototype of the "EmoLand" application was tested with 3 ASD children currently in therapy and facing mild challenges with emotional skills. All children completed the six lessons within the app, and the evaluation results showed varying levels of success, as detailed in Table I. The findings suggest that the application prototype has differing effectiveness levels across children. While Child 3 successfully recognized and expressed all three emotions, Childs 1 and 2 encountered difficulties with specific emotions. According to the results, all the children passed the Happy emotion evaluation, likely due to the FER model's higher

accuracy to detect Happy emotion. These findings indicate that while the application effectively supports some children, individual differences and challenges play a significant role in outcomes. Further insights and refinements are necessary to personalize the application and adapt it to each child's unique needs for enhanced effectiveness.

C. *Expert Opinions and Survey Results*

"EmoLand" mobile application is a user-friendly AI-based early intervention tool designed for children aged 2-7 with ASD in Sri Lanka. Expert discussions and feedback from parents confirmed its positive impact on emotional development. Tailored to the preferences and challenges of ASD children, the app has been praised for its visual learning approach, use of familiar images, and expression evaluation features. Survey results in Fig. 9 indicate high parent satisfaction levels, highlighting the app's usage and effectiveness. Results mentioned the need for personalization, gamification, and expanded emotion categories to sustain long-term engagement. Evaluation results from 3 ASD children provide real-world validation, aligning with research objectives to evaluate familiar images, assess AI-based interventions, and apply learned emotions to real-life contexts. These insights suggest ongoing improvements to meet evolving needs.

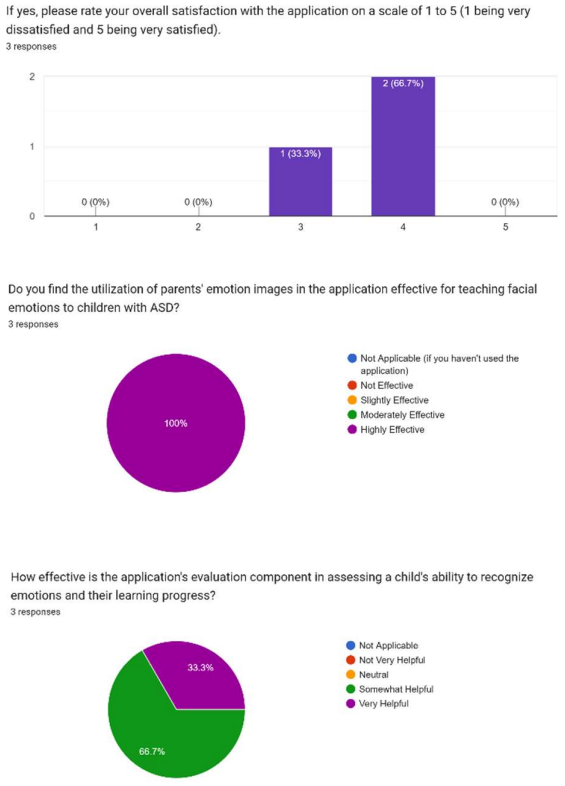


Fig. 8. Satisfaction survey results

VI. Ethical Considerations

Ethical concerns significantly impacted the personal data collection process. Privacy issues also impacted and limited the sharing of personal data and direct communication. Furthermore, it is important to acknowledge that ethical considerations and time constraints limited the sample size to only 3 children for testing the application, which may restrict the comprehensive evaluation and validation of system effectiveness. Additionally, given the need for repetitive learning in ASD children, the relatively short testing duration of approximately 2-3 hours highlights the necessity for further evaluation to thoroughly assess the application's impact.

VII. Future Recommendations

The "EmoLand" app shows promise for future improvements. Recommendations include expanding the emotion list, diversifying lesson delivery methods, and introducing more comprehensive evaluations. Personalization can be enhanced by tailoring content to individual needs based on age, cognitive abilities, and learning styles. Integrating voice instructions and interactive UI would create a more engaging experience. Additionally, improving the accuracy of the FER model is essential, suggesting the exploration of neural networks for enhanced emotion detection and evaluation.

VIII. Conclusion

The primary goal of this research was to analyze and implement an AI-based solution to improve facial emotional skills among ASD children in Sri Lanka. By conducting a thorough investigation and gathering requirements, a functional prototype was implemented. The results and effectiveness assessment indicate substantial promise for the system. The app's integration of parent emotion images and personalized lessons is highly valued. These features address an unexplored area in ASD interventions, particularly in the Sri Lankan context. Despite the current developmental challenges, the application shows strong potential for future enhancements.

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