www.ijarp.com ISSN 2456-9992 Page: 01-06

International Journal Advanced Research Publications

Research Article

Volume: 01
Issue: 02

ECHO BRIDGE: AN INTEGRATED AI AND AAC SYSTEM FOR SUPPORTING CHILDREN WITH AUTISM SPECTRUM DISORDER

***Santhiya M, Shrinithi N, Sujith P, Thulasiram P, Vinothini S.**

Sri Shakthi Institute of Engineering and Technology Coimbatore.

Article Received: 18 September 2025, Article Revised: 08 October 2025, Published on: 28 October 2025

***Corresponding Author Santhiya M.**

Sri Shakthi Institute of Engineering and Technology Coimbatore.

ABSTRACT

Communication and emotional regulation present significant challenges for many children on the Autism Spectrum Disorder (ASD), impacting their daily interactions and learning. Caregivers often require accessible, real-time tools to help navigate these complexities. **Echo Bridge** is a multi-faceted digital companion, developed as a Python-based web application to bridge these gaps and support the holistic well-being of autistic children. The application's core is an integrated support system featuring a customizable Augmentative and Alternative Communication (AAC) board, empowering children to express their needs and thoughts by selecting images and symbols. This is coupled with a real-time, AI-powered emotion detector that analyzes facial expressions via webcam to provide immediate emotional feedback. All interactions, including expressed emotions, are securely logged to a Firebase cloud database. This data populates a Caregiver Dashboard, offering visual charts and actionable insights into the child's communication and emotional patterns over time. Beyond passive monitoring, Echo Bridge provides active support through context-aware calming interventions and engaging, therapeutic games. By integrating a vital communication aid with an intelligent emotional support system, Echo Bridge aims to enhance the child's autonomy, provide caregivers with meaningful data, and foster a more supportive and interactive learning environment.

KEYWORDS: Autism Spectrum Disorder (ASD), Assistive Technology, Artificial Intelligence (AI), Emotion Recognition, Augmentative and Alternative Communication (AAC), Human-Computer Interaction (HCI), Deep Learning.

1. INTRODUCTION

Autism Spectrum Disorder (ASD) is a complex neurodevelopmental condition characterized by challenges in social communication, interaction, and the presence of restricted or repetitive behaviors. A core challenge for many children with ASD is the difficulty in both expressing their own emotions and interpreting the emotions of others. Furthermore, a significant portion of this population is non-verbal or has limited speech, necessitating tools for effective communication.

Traditionally, support systems have consisted of separate, often non-digital tools. For communication, physical Picture Exchange Communication Systems (PECS) are common. For emotional tracking, caregivers rely on manual, subjective journaling. This fragmented approach lacks the integration, real-time feedback, and objective data analysis that modern technology can provide. There exists a clear gap for a unified digital platform that can address these interconnected needs simultaneously.

This paper introduces "Echo Bridge," a novel, integrated software solution designed as a supportive companion for children with ASD and their caregivers. Echo Bridge addresses the limitations of existing systems by combining four key modules into a single, user-friendly web application: (1) an AI-powered Emotion Recognition Engine, (2) a Child Interaction Suite featuring a digital AAC board and therapeutic games, (3) a secure Cloud Database for data logging, and (4) a Caregiver Analytics Dashboard for progress visualization. Our work demonstrates the potential of a holistic, data-driven approach to creating more effective and engaging assistive technology.

2. System Architecture and Methodology

The architecture of Echo Bridge is modular, ensuring that each component is specialized yet seamlessly integrated. The system is built using Python and deployed as a web application via the Streamlit framework.

Module 1: AI Emotion Recognition Engine The core of our intelligent feedback system is a Convolutional Neural Network (CNN) trained for facial emotion recognition. The engine utilizes OpenCV to access the system's webcam and capture the video feed in real-time. For each frame, a pre-trained Haar Cascade classifier detects the presence and location of a face. The facial Region of Interest (ROI) is then extracted, converted to grayscale, resized to 48x48 pixels, and normalized. This preprocessed image is fed into the CNN model, which classifies

the expression into one of seven core emotions: angry, disgust, fear, happy, neutral, sad, or surprise. The model is built and loaded using the TensorFlow and Keras libraries.

Module 2: Child Interaction Suite This module is the primary interface for the child. It includes two main features:

- **AAC Board:** A customizable grid of images and symbols that, when selected, vocalizes the corresponding word or phrase. This provides a vital communication channel for non-verbal users.
- **Emotion Mirror Game:** A therapeutic and enging activity where the application displays an emoji and encourages the child to mimic the expression. The AI engine provides real-time feedback, celebrating successful matches with positive reinforcement (e.g., on-screen confetti), thus making social-emotional learning interactive and fun.

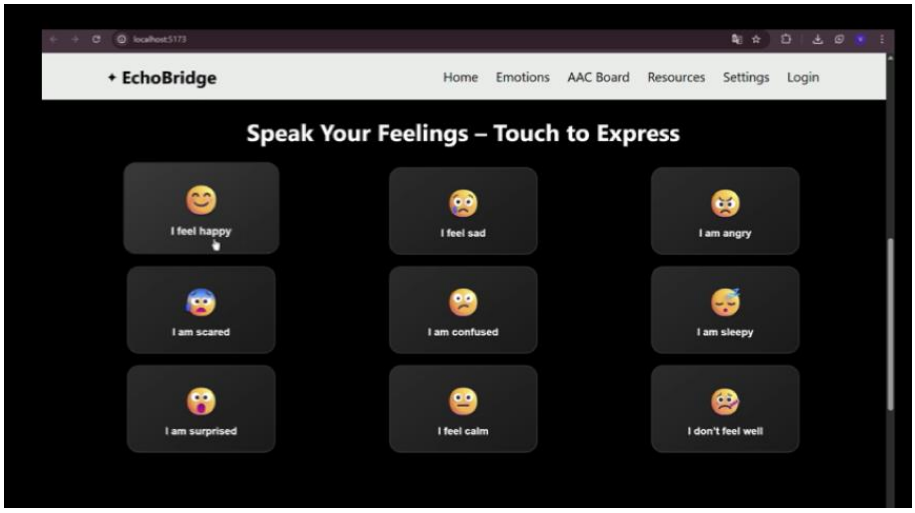

Figure 1: The Caregiver Dashboard visualizing emotion distribution from logged data.

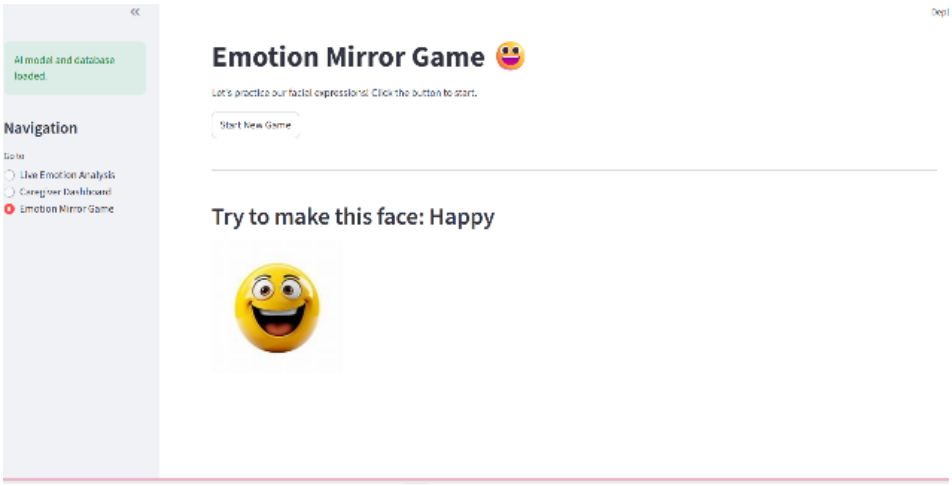

Figure 2: The "Emotion Mirror".

Module 3: Cloud Database and Data Logging To enable progress tracking, Echo Bridge is connected to a secure, real-time NoSQL database using Google Firebase Firestore. When the "Live Emotion Analysis" is active, the application logs the dominant detected emotion every five seconds. Each log entry is a document containing the emotion label and a Coordinated Universal Time (UTC) timestamp. This automated, objective data collection is a significant improvement over manual journaling. All communication is authenticated using a secure service account key.

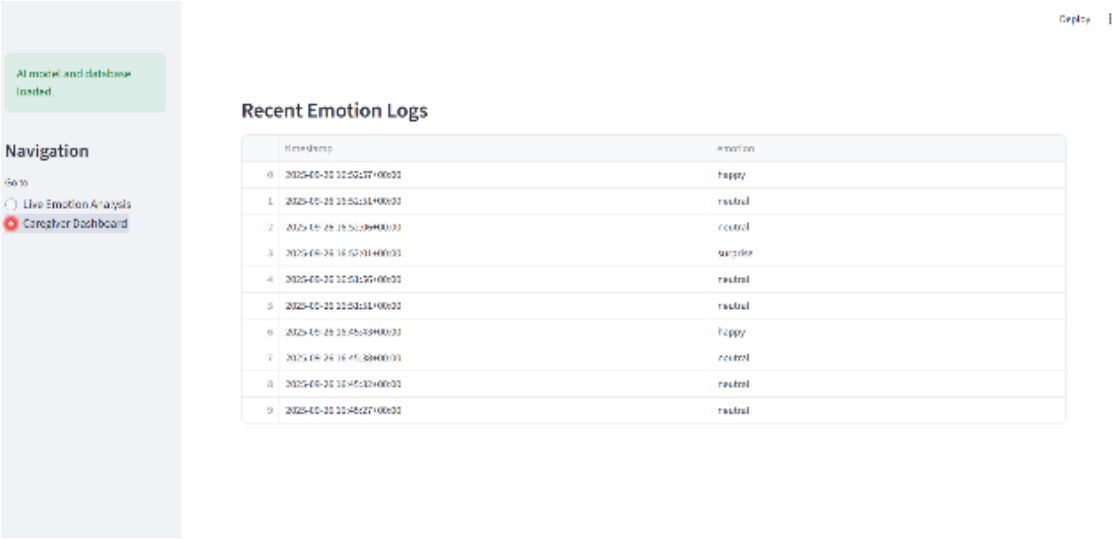

Figure 3: Cloud Database Logging.

Module 4: Caregiver Analytics Dashboard This module serves as the primary interface for the caregiver. Built with Streamlit, it fetches the entire log history from the Firebase database. The raw data is then processed and organized using the Pandas library. The dashboard presents two key visualizations created with Plotly:

1. An interactive pie chart showing the overall distribution of detected emotions.
2. A data table displaying the most recent emotion logs with their timestamps. This provides caregivers with at-a-glance, quantitative insights into the child's emotional patterns.

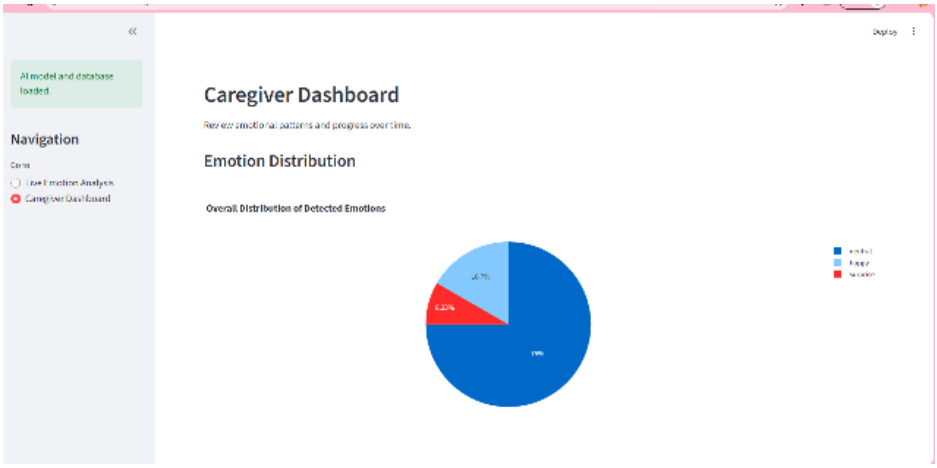

Figure 4: The Caregiver Analytics Dashboard.

3. RESULTS AND ANALYSIS

Functional Prototype: A complete, working prototype of the "Echo Bridge" application was successfully developed and tested. All four core modules were integrated into a single, stable web application.

Real-Time Performance: The application successfully performs real-time emotion prediction from a live video feed, with the predicted emotion and a confidence score overlaid on the video. The end-to-end data pipeline—from AI detection to Firebase logging to dashboard visualization—was established and verified.

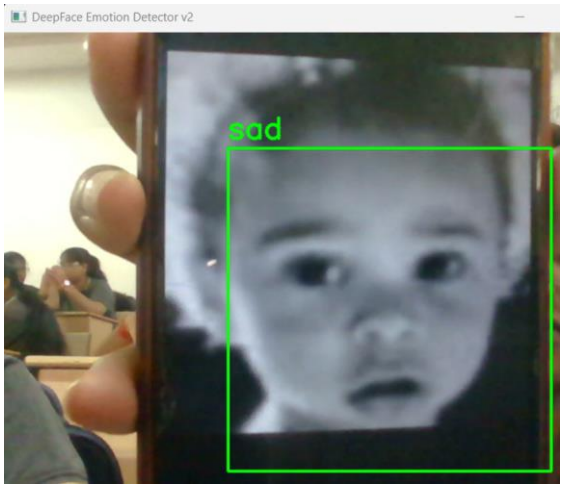

Figure 5: Real-Time Emotion Detection.

Analysis of Strengths: The primary strength of Echo Bridge is its **holistic and integrated design**. By combining a communication aid, an emotion AI, and a data tracker into a single tool, it offers a level of synergy that separate, non-digital methods cannot. The dashboard's

ability to provide **data-driven insights** empowers caregivers to move from subjective observation to objective analysis, helping identify potential emotional triggers or patterns. Finally, the system is **empowering for the child**, actively involving them through games and the AAC board to promote skill-building rather than just passive monitoring.

Analysis of Limitations: It is critical to acknowledge that Echo Bridge is a supportive aid, **not a medical or diagnostic tool**. The AI model's accuracy, while functional, can be affected by real-world variables like poor lighting, non-frontal face angles, and unique facial expressions. Furthermore, the AI **lacks real-world context**; it analyzes facial expressions only and does not understand the external situation causing an emotion. Therefore, all data from the application should be interpreted with human oversight and understanding.

4. Conclusion and Future Work

This paper presented "Echo Bridge," a successful proof-of-concept for an integrated AI companion for children with autism. We have demonstrated that it is feasible to combine real-time emotion recognition, a cloud database, a caregiver dashboard, and interactive tools into a single, cohesive application. The project proves the potential of using AI and data analytics to create more powerful, engaging, and insightful support tools for the autism community.

Future work should focus on three key areas. First, **extensive user testing** with therapists, caregivers, and children is necessary to refine the user interface and validate the tool's real-world effectiveness. Second, **expanding the feature set**, particularly by allowing caregivers to customize the AAC board and intervention strategies. Finally, the project could be **deployed to the cloud** using a service like Streamlit Community Cloud to make it accessible to a wider audience for further testing and feedback.

5. REFERENCES

1. Goodfellow, I. J., Erhan, D., Carrier, P. L., Courville, A., Mirza, M., Hamner, B., ... & Bengio, Y. (2013). Challenges in representation learning: A report on the Black Box Challenge. *Neural Networks*, *64*, 59-63. (This is the paper for the FER-2013 dataset).
2. Beukelman, D. R., & Mirenda, P. (2013). *Augmentative and alternative communication: Supporting children and adults with complex communication needs*. Paul H. Brookes Publishing Company.
3. Krizhevsky, A., Sutskever, I., & Hinton, G. E. (2012). ImageNet classification with deep convolutional neural networks. *Advances in neural information processing systems*, *25*.