Neuro Semantic Interface

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Abstract

The Neuro Semantic Interface (NSI) is a complete and smart communication tool developed to help the Deaf community communicate smoothly with the hearing population.
The approached Android application allows two way communication, it converts sign language into text and speech also producing sign language output for given text using advanced computer vision, machine learning, and Generative AI. This system helps in real-time interaction by converting sign language to text and speech, and also provides text-to-sign language a generation and Android's Text-to-Speech (TTS) system, allowing hearing-impaired individuals to both express themselves and receive information in a preferred format.
Beyond basic translation, the NSI includes high-level semantic processing via Gemini AI, enabling an educational layer and context-aware features.
The system relies on Firebase Cloud Services for real-time data handling and user synchronization. Experimental results indicate high accuracy in gesture recognition and low latency on standard mobile devices. Ultimately, the Neuro Semantic Interface aims to improve user independence and social participation, transforming assistive technology from a basic tool into an intelligent interface that would allow easy and more efficient communication between person with disability and normal person .
Keywords: Sign Language Recognition, Android Application, Computer Vision, Deep Learning, Assistive Technology, Generative AI, Accessibility, Firebase.

1. INTRODUCTION

Good communication is very important it plays a crucial role is day to day lifestyle. However persons with hearing and speech problem find it more difficulty in hearing facing complex challenges.

For the Deaf and mute communities, sign language is the main way of communication, but most hearing people are not familiar with its complex structure. This disconnect often results in social exclusion, fewer job options, and limited access to key services like healthcare and education. Currently available technologies have provided with partial solution and they support very limited communication ability.

The rise of modern Artificial Intelligence (AI) and mobile computing offers the chance to create more accessible and affordable solutions

Mobile platforms like Android provide a widespread environment for deploying real-time assistive tools. Current research stresses the need for systems that are accurate, portable, and context-aware. The proposed Neuro Semantic Interface tackles these challenges by integrating sign recognition, speech synthesis, and Generative AI into one unified platform. By moving beyond simple gesture-to-word translations and adding semantic understanding, the NSI provides a more natural and fluid communication experience for everyone involved.

2. Literature Review

Recent studies have adopted few innovative approaches like vision-based. Deep learning models such as CNNs , RNNs and Transformers have shown some results in sign language translation.

Early research overly relied on specialized hardware, which was often inconvenient and expensive. Recent studies, such as the ML Based Sign Language Recognition System (2024) and Sign Language Interpretation Using Machine Learning and Artificial Intelligence (2024), illustrate the effectiveness of Convolutional Neural Networks (CNN) in extracting spatial features from images. Moreover, Neural Sign Language Translation (CVPR) emphasizes the importance of sequence modeling to understand the temporal dynamics of continuous signing, as opposed to just single gestures.

Research in the opposite direction—text-to-sign—has also made progress with the introduction of Text2Sign using Neural Machine Translation and GANs (2022).

Generative Adversarial Networks (GANs) have been used to create more realistic signing animations, though they need a lot of computational power. The following table provides a comparison of these methods with the proposed Neuro Semantic Interface framework.

Method	Accuracy	Features	Limitations
CNN	High	Gesture Recognition	Limited Context Understanding
GAN	High	Sign Generation	Large Training Data Requirements
Transformer	Very High	Translation Alignment	High Computational Cost
Proposed System	High	Bidirectional + AI Assistant	Continuous Optimization Needed

3. Methdology

The methodology of the Neuro Semantic Interface is divided into four distinct technical modules designed for the Android ecosystem. The primary **Sign Recognition Module** utilizes the camera to capture real-time video frames. These frames are processed using the **Media Pipe** framework, which extracts **21** 3D hand landmarks. This two way solution is superior to raw pixel analysis as it is robust to varying lighting conditions and background noise. The extracted landmark sequences are fed into a lightweight **CNN classifier** that identifies the gesture and outputs the corresponding text label.

Bidirectional Processing and Synthesis

The **Text-to-Sign Module** handles the reverse communication flow. When a user enters text, the system utilizes a mapping database to retrieve corresponding sign language representations, displaying them as synchronized images or animations. Simultaneously, the recognized text from gestures is passed to the **Android Text-to-Speech (TTS) engine**, converting digital text into audible speech to facilitate communication with hearing individuals who may not be looking at the device screen.

The **AI Assistant Module** integrates the **Gemini API** to provide a layer of intelligent interaction. This allows users to ask questions about sign language grammar, look up specific signs, or receive educational summaries. By hosting educational resources and tutorials, the system serves not just as a translator, but as a comprehensive learning platform. The integration of **OpenCV** ensures efficient image processing, maintaining a high frame rate for real-time responsiveness on mobile hardware.

4. GAP ANALYSIS

A comparative study was conducted between the Neuro Semantic Interface and traditional assistive communication methods such as human interpreters, text-based communication tools, and basic speech-to-text applications. The analysis shows that traditional systems mainly focus on simple message conversion, while the proposed system provides real-time, bidirectional, emotion-aware, and AI-supported communication.

The Neuro Semantic Interface reduces dependency on human interpreters, improves communication speed, supports both sign-to-text and text/speech-to-sign conversion, and adds emotional understanding through AI-based processing.

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GAP ANALYSIS: TRADITIONAL VS. NEURO SEMANTIC INTERFACE

Metric	Traditional System	Neuro Semantic Interface
Communication Mode	One-way or manual communication	Two-way real-time communication
Sign Language Support	Requires human interpreter	Camera-based gesture recognition
Text/Speech to Sign	Usually not available	Converts text/speech into 2D sign animation
Emotion Understanding	Emotion is usually ignored	Emotion detection included
AI Support	Limited or absent	Generative AI improves context and sentence clarity

5. FUTURE SCOPE

The future of Neuro Semantic Interface will have more focus on improving accuracy in translation , will support multiple sign language and make user interaction more advanced .A primary objective is the integration of **Indian Sign Language (ISL)** and other regional sign dialects to support a broader demographic. To improve the expressiveness of the sign generation module, the research team plans to transition from static images to **3D avatar animations**. These avatars will be able to convey non-manual markers, such as facial expressions and head tilts, which are essential for true linguistic accuracy in sign language.

Additional multi-modal enhancements include the integration of **AR/VR interfaces**, allowing users to practice sign language in immersive virtual environments. Wearable device integration, such as smartwatches, could provide haptic feedback or simplified gesture controls. From a software perspective, the team aims to implement **offline AI processing** using edge-based LLMs, ensuring that the translation features remain functional even in areas with poor internet connectivity. Emotion recognition will also be explored to add a layer of sentimental context to the synthesized speech and text outputs.

6. CONCLUSION

The project gives feasible solution for smart communication covering the gap between person with hearing problem and normal person by integrating combining gesture recognition, 2D sign language animation, text/speech conversion, emotion detection, Generative AI, Android Java/XML, and Firebase Realtime Database, the system supports real-time two-way communication between sign language users and non-signers.

The project reduces dependency on human interpreters and traditional text-based communication methods. It also improves communication quality by preserving both the meaning and emotional tone of messages. Overall, the Neuro Semantic Interface promotes accessibility, independence, social inclusion, and equal communication opportunities for differently-abled users.

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