BHAASHA VAHINI: A BRIDGE FROM SIGN LANGUAGE TO REGIONAL LANGUAGES

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Keywords:

Indian Sign Language (ISL), Real-Time Gesture Recognition, Speech Translation, Multilingual Support, React Native, Spring Boot, MySQL Database, Computer Vision, Deep Learning, OpenCV, TensorFlow, Natural Language Processing (NLP).

Introduction:

In a diverse and multilingual country like India, communication barriers pose significant challenges, especially for individuals who rely on Indian Sign Language (ISL) as their primary mode of expression. Despite growing awareness, the lack of real-time interpretation tools limits their ability to interact freely in everyday situations such as schools, hospitals, workplaces, and public services. This project addresses this critical need by developing an intelligent, accessible, and mobile-first translation system that converts ISL gestures into spoken language across various Indian regional languages.

The proposed system leverages cutting-edge technologies including computer vision, deep learning, and natural language processing (NLP). Through the use of TensorFlow for model training and OpenCV for real-time video processing, the solution is capable of recognizing complex ISL gestures with high accuracy. These gestures are then mapped and translated into corresponding speech using NLP pipelines, ensuring that users receive natural, context-aware spoken feedback in their preferred language.

To ensure widespread usability, the system is optimized for smartphones using React Native,

allowing users to access the application on both Android and iOS platforms. The backend, built on Spring Boot and supported by a MySQL database, manages user data, translation logs, and analytics, offering a scalable and secure infrastructure. Special emphasis has been placed on reducing latency to provide near-instantaneous communication, as well as making the system adaptive to various lighting conditions and environments.

Beyond translation, the project aims to promote digital inclusivity by empowering the hearing-impaired community with a reliable tool for independent communication. By breaking down language barriers and creating equal opportunities for interaction, this system contributes meaningfully to the broader goal of inclusive education, employment, and social integration in the digital age.

Main objectives of the project:

a. Build a system that accurately translates Indian Sign Language gestures into spoken language in real-time.
b. Train deep learning models to recognize a wide range of ISL gestures with minimal error, even in complex sequences.
c. Support translation into multiple Indian regional languages (e.g., Hindi, Kannada, Tamil) to cater to diverse user needs.
d. Create a responsive and user-friendly mobile application using React Native for Android and iOS platforms.
e. To develop a real-time scoring system that processes and evaluates answers immediately after submission.
f. To allow participants to log in using unique identifiers (e.g., USN) and access with a smooth, guided flow.
g. To offer insightful analytics, including performance reports, score breakdowns, and ranking comparisons.
h. To support educators, corporate trainers, and individuals in managing and tracking engagement effectively.
i. To ensure data security, privacy, and reliability throughout the process.

j. Bridge communication gaps for the hearing-impaired community, enhancing access to services, education, and daily interaction.
k. Design the system to learn from user feedback and expand the ISL gesture dataset for long- term model improvement and accuracy.

Methodology:

The development of the real-time Indian Sign Language (ISL) to speech translation system involves a multi-stage approach, combining machine learning, computer vision, and mobile development frameworks to ensure accurate, fast, and accessible translation.

l. Dataset Collection and Preprocessing

A large dataset of Indian Sign Language gestures is collected from publicly available sources and custom recordings. Each gesture video is labeled and preprocessed by extracting key frames, normalizing image data, and augmenting the dataset to improve model robustness under various lighting and background conditions.

m. Model Training using Deep Learning

A Convolutional Neural Network (CNN) or hybrid deep learning model (CNN + LSTM) is trained using TensorFlow to recognize dynamic hand gestures. The model learns spatial and temporal features from the video frames to accurately classify ISL signs.

n. Gesture Recognition and Mapping

The trained model processes live camera input from the mobile app using OpenCV, identifies the performed ISL gesture, and maps it to a corresponding word or phrase using a predefined ISL-to-text dictionary.

o. Natural Language Processing (NLP) Integration

Recognized text is passed through NLP modules to construct grammatically correct sentences. This ensures the spoken output is natural and contextually accurate.

p. Text-to-Speech Conversion

The processed text is converted to speech using text-to-speech (TTS) engines in regional languages, allowing the hearing-impaired user's gesture to be heard as voice in real-time.

q. Mobile Application Development

The front-end mobile interface is developed using React Native, providing cross-platform compatibility and an intuitive user experience. The app includes a live video feed, translation output display, and voice playback.

r. Backend Development and Database Integration

A Spring Boot-based backend handles user management, session logs, and analytics. MySQL is used to store user preferences, translation records, and model usage data.

s. Performance Optimization and Latency Reduction

The entire pipeline is optimized to ensure minimal delay from gesture input to speech output. Lightweight models and efficient frame sampling techniques are used for real-time processing on mobile devices.

t. Testing and Validation

The system is tested under various real-world conditions, including different lighting, backgrounds, and user hand shapes. Feedback is collected from hearing-impaired individuals and sign language experts to validate the model's accuracy and usability.

u. Deployment and Future Updates

The application is packaged and deployed on mobile platforms. The system is designed to support future updates such as additional sign gestures, offline support, and two-way communication features.

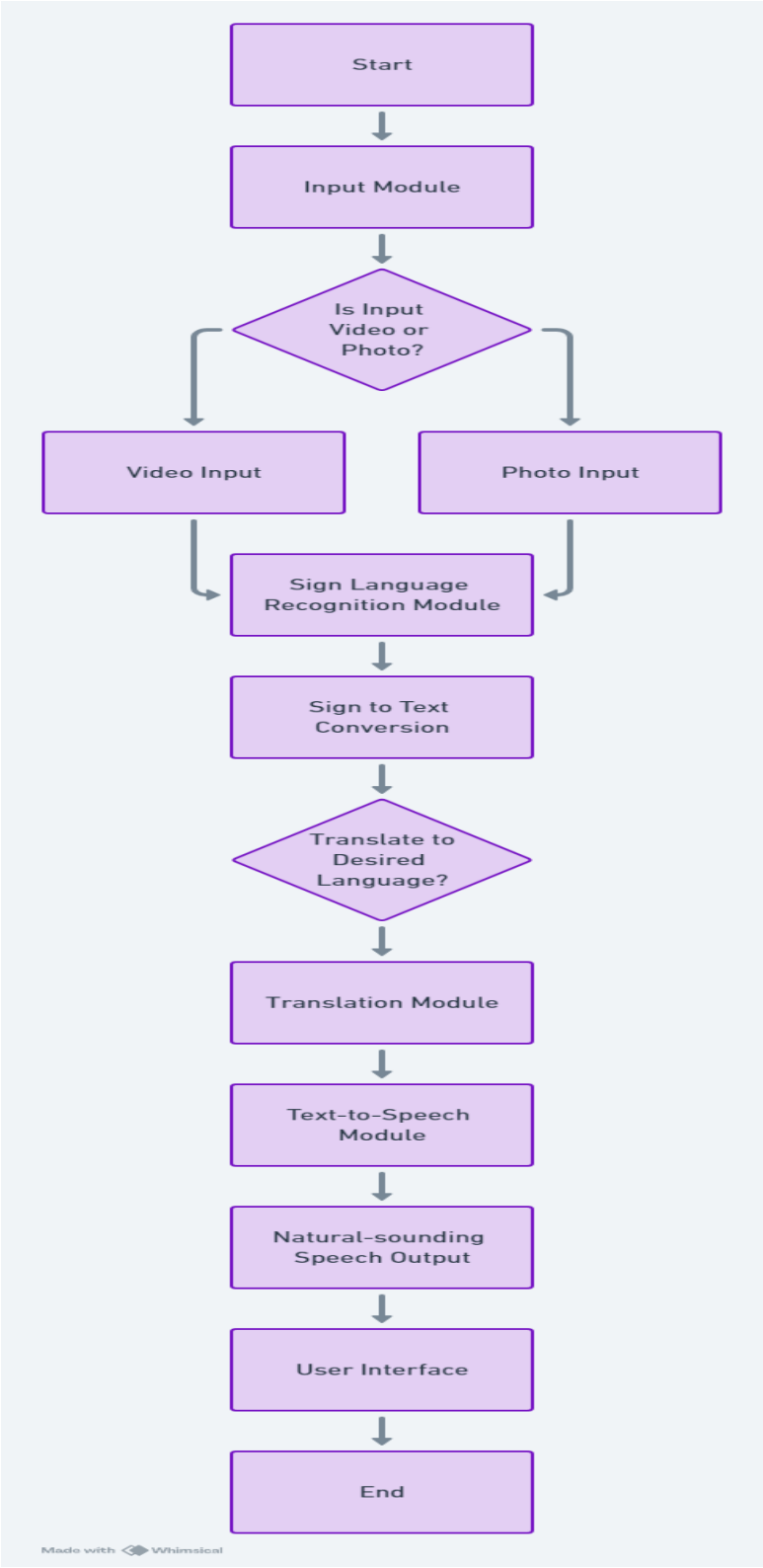

Figure 1. Data Flow Diagram

7. Results and Conclusions:

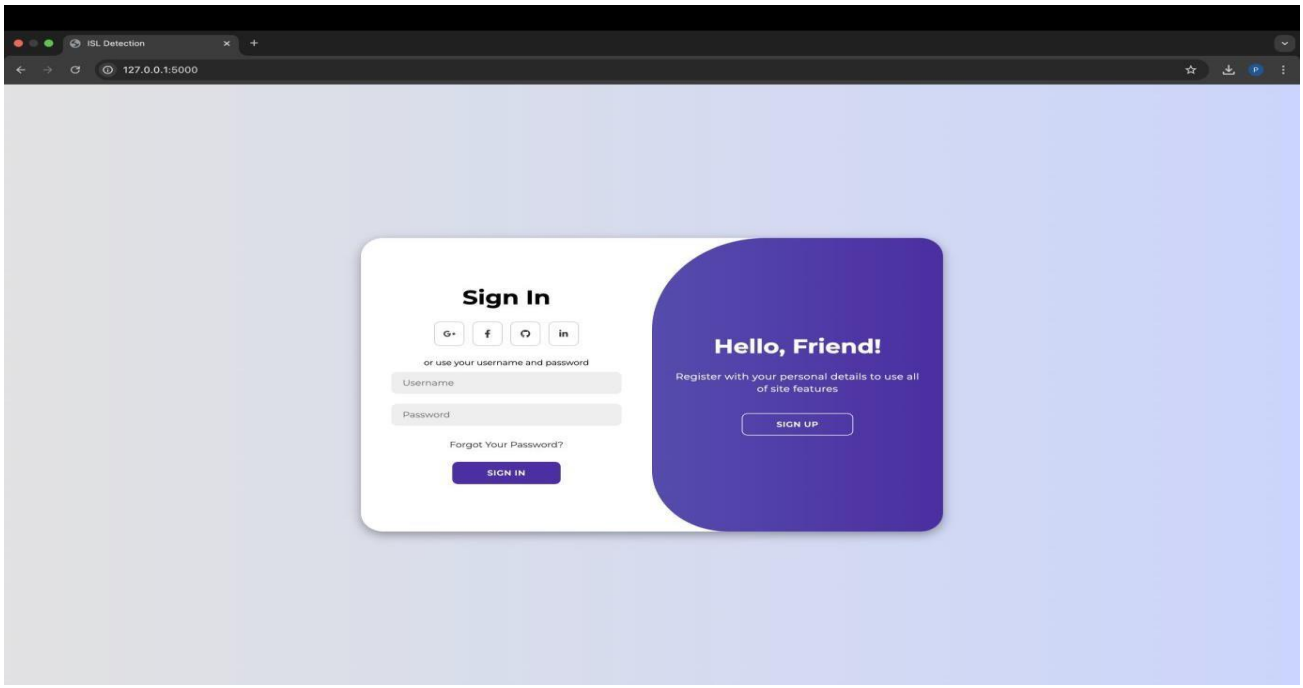

Figure 2. Sign In Page

The image displays a modern and elegant login interface designed for a web application. On the left, there is a clean and minimalist "Sign In" form, encouraging users to log in using their credentials. The form includes text fields for entering a username and password, along with a "Sign In" button prominently displayed below. Additionally, there are options to log in using social media platforms like Google, Facebook, and LinkedIn, represented by their respective icons at the top of the form.

On the right side, the interface features a contrasting purple section with a welcoming message: "Hello, Friend!" This side invites new users to register for the platform, encouraging them to sign up to access all available features. A "Sign Up" button is placed within this section to guide users toward the registration process.

The overall design is visually appealing, using a gradient background that transitions smoothly from light to dark shades of blue. Rounded corners and a shadow effect give the interface a polished, three- dimensional look. The use of white for the input fields and buttons enhances readability and

accessibility, while the purple accent adds a sense of sophistication. The layout is intuitive, creating a seamless user experience, with the sign-in and sign-up options clearly separated yet cohesively styled. The design also emphasizes responsiveness, ensuring compatibility across various devices and screen sizes.

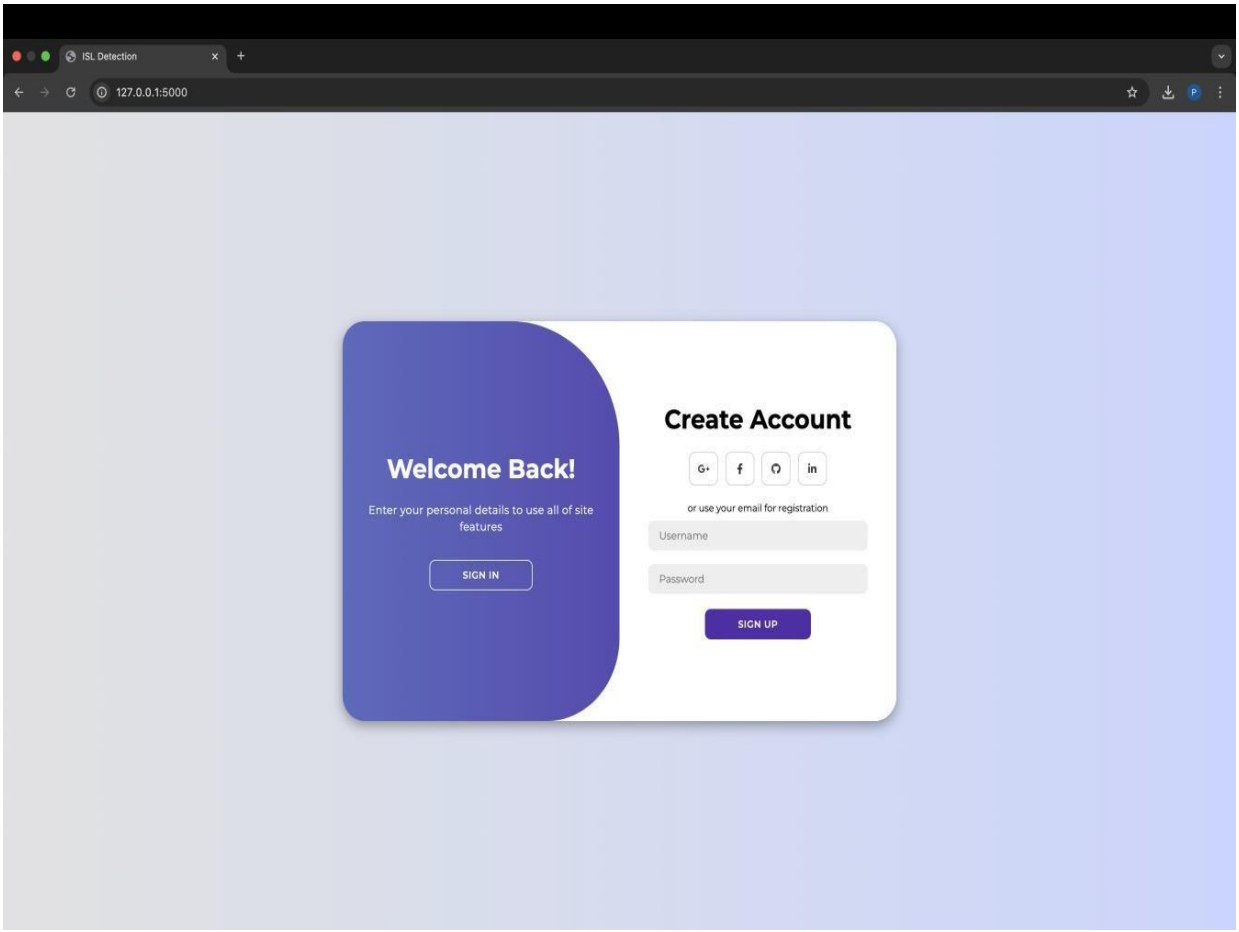

Figure 3. Create Account

The image shows a visually appealing user interface for a registration and login process, featuring a two-panel layout. On the left side, there is a purple panel with a welcoming message that reads, "Welcome Back!" It encourages returning users to sign in by clicking the "Sign In" button placed in the center. The design here is simple yet inviting, using a gradient purple background that contrasts well with the white text and button border. On the right side, there is a white panel titled "Create Account," aimed at new users. This section allows users to register by entering their username and password. Additionally, it offers options to sign up using social media platforms such as Google, Facebook, and LinkedIn, with their respective icons displayed above the input

fields. Below these fields is a "Sign Up" button, clearly visible for initiating the registration process.

The interface utilizes a smooth gradient background that transitions between light blue and white, creating a modern and professional look. Rounded corners for the panels and buttons give the design a softer and more approachable appearance.

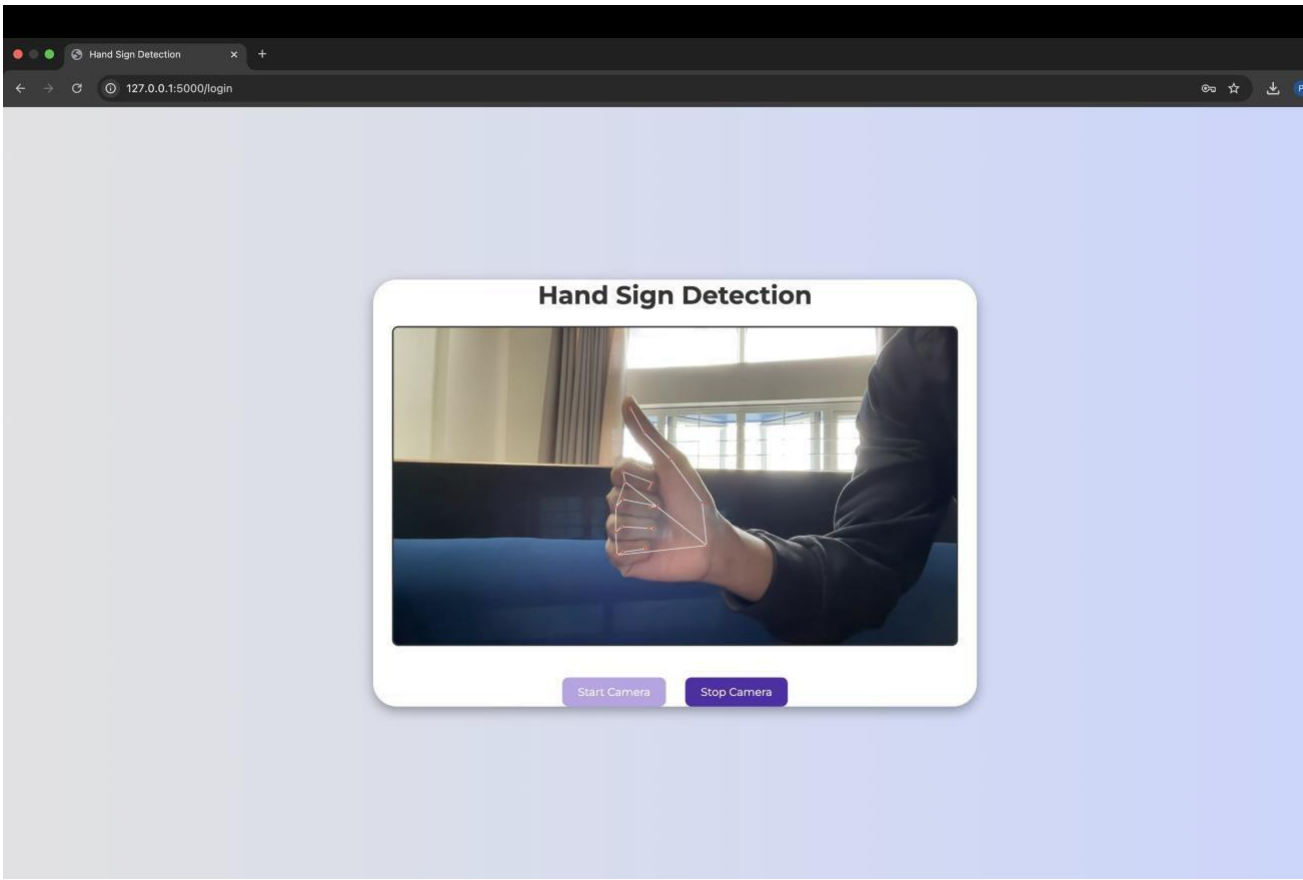

Figure 3. Hand Sign Detection

The image showcases a user interface for a "Hand Sign Detection" application, demonstrating its ability to detect hand signs and predict corresponding outputs. At the top of the interface, a bold title "Hand Sign Detection" clearly states the purpose of the application. Below it is a central frame displaying a live video feed. In this frame, the camera captures a hand showing a thumbs-up gesture, and a set of lines overlay the hand, representing the detection of key hand landmarks. These lines likely illustrate the model's ability to track hand positions and recognize gestures in real time. The surrounding environment in the video feed includes a couch, a window

with blinds, and natural light, indicating that the detection works in casual, real-world settings. Below the video feed, two buttons labeled "Start Camera" and "Stop Camera" are presented in a vibrant purple color, making them easily identifiable. These buttons enable users to toggle the camera functionality, providing control over when detection begins or ends. The overall design maintains a clean and professional appearance with rounded corners and a subtle gradient background.

Project Outcome & Industry Relevance:

The successful completion of this project resulted in the development of a real-time Indian Sign Language (ISL) to Speech translation system that bridges the communication gap between the hearing-impaired community and the hearing population. The system is designed to be mobile- first, lightweight, and user-friendly, making it accessible on widely-used smartphones. It achieves high gesture recognition accuracy, low response latency, and provides multilingual voice output, ensuring inclusivity across different regions of India.

From a technical standpoint, the project showcases the integration of machine learning, computer vision, natural language processing, and mobile app development, reflecting an interdisciplinary approach aligned with current industry demands. The use of technologies like TensorFlow, OpenCV, React Native, Spring Boot, and MySQL highlights the practical application of modern tech stacks in solving real-world problems.

In terms of industry relevance, this solution holds immense potential in the Assistive Technology (AT) sector. It can be adopted and further enhanced by companies working in healthcare tech, EdTech, public service platforms, and AI-driven accessibility tools. The system aligns with the United Nations' Sustainable Development Goals (SDG) on inclusive communication and education for persons with disabilities. With the rising focus on AI for social good, this project stands out as a scalable, impactful, and industry-aligned innovation that can be commercialized or integrated into larger platforms serving special

needs populations.

Additionally, this project opens pathways for future research and industrial collaboration in the areas of gesture-to-text/speech AI systems, smart interpreters, and multilingual accessibility frameworks. It demonstrates how technology can be harnessed to create a more inclusive society, making it highly relevant for both academia and industry stakeholders.

Working Model vs. Simulation/Study:

The project QuizWiz is a fully functional working model and not a mere simulation or theoretical study. It involves the complete development and deployment of an interactive and automated quiz management system that can be actively used by real users, such as educators, students, and corporate trainers. The project encompasses the creation of both frontend and backend components using a modern technology stack—React Native for the mobile user interface, Spring Boot for backend logic and RESTful services, and MySQL for persistent data storage.

The system enables real-time operations such as quiz creation from document uploads, question generation through automation, user registration, quiz participation using unique Quiz IDs, and automatic evaluation with result storage and analytics. Every module has been developed, integrated, and tested to ensure it functions as a practical, deployable product, demonstrating the implementation of real-world use cases rather than theoretical simulation.

Hence, QuizWiz qualifies as a complete working model, showcasing the practical application of software engineering principles, automation, and user-centric design in solving problems associated with manual quiz creation and assessment.

Project Outcomes and Learnings:

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Future Scope:

This project opens up multiple avenues for further development and

innovation. One of the most significant enhancements would be enabling two-way communication, where the system not only translates Indian Sign Language (ISL) into speech but also converts spoken language or text back into ISL using animated avatars. This would empower both hearing and hearing- impaired individuals to interact naturally and without barriers. Another important direction is the expansion of language support. While the current system supports a few regional languages, future versions can be extended to cover a wider range of Indian languages and dialects. This would make the application even more inclusive, allowing users from different linguistic backgrounds to benefit from the technology.

The system can also be integrated with wearable devices such as smart glasses or AR headsets. This would allow users to experience real-time translation in a more seamless ands-free manner, which is especially beneficial in dynamic environments like classrooms, hospitals, and public transportation. A major improvement could be the addition of an offline mode, where the model runs entirely on the device without needing an internet connection. This would make the system accessible to users in remote or rural areas with limited connectivity, ensuring that communication support is available anywhere and anytime.

Finally, the future scope includes implementing personalized learning and continuous model improvement. By collecting user feedback and adapting to individual signing styles, the system can become more accurate and user-friendly over time. These improvements will further strengthen its impact in the assistive technology space and pave the way for its adoption at a national and global scale