AI TOOL FOR INDIAN SIGN LANGUAGE (ISL)GENERATOR FROM AUDIO-VISUAL CONTENT IN ENGLISH TO ISL CONTENT AND VICE-VERSA

A PROJECT REPORT

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in partial fulfilment for the award of the degree of

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IN

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At

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CERTIFICATE

This is to certify that the Project report **“AI tool for Indian Sign language (ISL) generator from audio-visual content in English to ISL content and vice-versa”** being submitted by “KAMINI PRAJAPATHI S, MEKALA SAI LAKSHMI, TEJASWINI K A” bearing roll numbers “20211CAI0148, 20211CAI0165, 20211CAI0145” in partial fulfilment of the requirement for the award of the degree of Bachelor of Technology in Computer Science and Engineering is a Bonafide work carried out under my supervision.

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DECLARATION

We hereby declare that the work, which is being presented in the project report entitled **"AI tool for Indian Sign language (ISL) generator from audio-visual content in English to ISL content and vice-versa"** in partial fulfilment for the award of Degree of **Bachelor of Technology** in **Computer** Science and Engineering, is a record of our own investigations carried under the guidance of **Dr.Akshatha Y, Assistant Professor, School of Computer Science Engineering & Information Science, Presidency University, Bengaluru.**

We have not submitted the matter presented in this report anywhere for the award of any other Degree.

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ABSTRACT

Communication barriers between the deaf community and non-sign language users often limit accessibility in education, employment, and daily interactions. Indian Sign Language (ISL) serves as an essential means of communication for people with hearing impairments. However, the widespread lack of awareness about it among the general populace poses notable challenges. This research proposes an AI-powered system capable of translating spoken and written English into ISL and vice versa, facilitating seamless communication. By utilizing advanced technologies such as Natural Language Processing (NLP), computer vision, and deep learning, the system processes speech and text input to generate accurate ISL gestures through animations or GIFs. The system addresses challenges such as gesture variability, regional differences, and real-time processing through machine learning techniques that enhance recognition accuracy. The implementation of this AI-based translation tool aims to promote inclusivity, enabling the deaf community to engage more effectively in various sectors such as education, workplaces, and public services. This research enhances accessibility, allowing individuals with hearing impairments to communicate effortlessly and participate equally in all aspects of society.

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CHAPTER-1

INTRODUCTION

1.1 Sign Language as a Means of Communication

Sign language is an essential mode of communication for individuals with hearing and speech impairments. Unlike spoken languages, which rely on sound and vocal cords, sign language uses a combination of hand gestures, facial expressions, body posture, and movement to convey ideas, emotions, and intentions. Each gesture in sign language can represent entire words, phrases, or concepts, allowing for rich and expressive communication.

In India, Indian Sign Language (ISL) serves as the primary language for the deaf and hard-of-hearing community. Despite its significance, ISL remains underrepresented and underrecognized in mainstream society. One of the main reasons for this is the lack of widespread knowledge and awareness among the general public. This knowledge gap contributes to persistent communication barriers that affect the deaf community's access to fundamental services and opportunities in education, employment, healthcare, and public administration. Bridging this gap requires not only policy-level interventions but also technological innovations that can make communication more inclusive and accessible.

1.2 Leveraging Artificial Intelligence for Sign Language Translation

Artificial Intelligence (AI) has emerged as a transformative force across multiple sectors, and its application in accessibility technologies holds enormous promise. For the deaf and hard-of-hearing community, AI-powered tools can play a critical role in facilitating communication with the hearing world. Technologies such as Natural Language Processing (NLP), Computer Vision, and Deep Learning enable machines to interpret visual gestures and spoken or written language with increasing accuracy.

By integrating these technologies, it is possible to develop real-time translation systems that can convert English (or other spoken/written languages) into ISL and vice versa. Such tools can automatically analyse video input (e.g., from a webcam), detect and interpret hand gestures and facial expressions, and generate accurate ISL representations. Conversely, they can take ISL inputs and convert them into spoken or written English. This bidirectional functionality has the potential to break down communication barriers, making it easier for individuals with hearing disabilities to participate fully in everyday life, from classrooms and workplaces to public service interactions and social engagements.

1.3 Research Objectives and Key Challenges

The core objective of this research is to design and develop a robust AI-driven translation system capable of interpreting between English (speech or text) and ISL. While the concept is straightforward, building a system that operates accurately and in real-time involves addressing several intricate challenges:

1.3.1 Complexities in Sign Language Recognition

One of the most difficult aspects of developing a sign language translator lies in the recognition and accurate interpretation of gestures. Sign language is not uniform; it involves nuanced movements of the hands, fingers, face, and body, all of which contribute to the meaning of a sign. Even subtle variations can change the meaning entirely.

Moreover, regional dialects and cultural variations within ISL present additional layers of complexity. Just as spoken languages have regional accents or slang, sign languages vary across different parts of India. Capturing this diversity in a single system is a formidable task that requires a vast dataset and an adaptable recognition model.

Another challenge is distinguishing between intentional gestures and non-meaningful movements. Everyday actions, environmental noise, or camera artifacts can confuse AI models if not properly trained. This requires advanced filtering and contextual understanding capabilities within the AI system to differentiate between relevant and irrelevant motion data.

1.3.2 Advancing Inclusivity Through AI-Driven Solutions

The successful implementation of an intelligent ISL translation system would represent a major step toward digital and social inclusivity. For individuals with hearing impairments, such a tool could provide equal access to educational materials, job opportunities, government services, and digital platforms.

Beyond direct communication, these AI-driven solutions can also serve as educational aids, helping hearing individuals learn ISL, thereby fostering empathy and improving societal integration. By embedding this technology into public infrastructure—such as customer service kiosks, educational institutions, and mobile applications—we can promote a more inclusive society where everyone, regardless of their hearing ability, has an equal voice and presence.

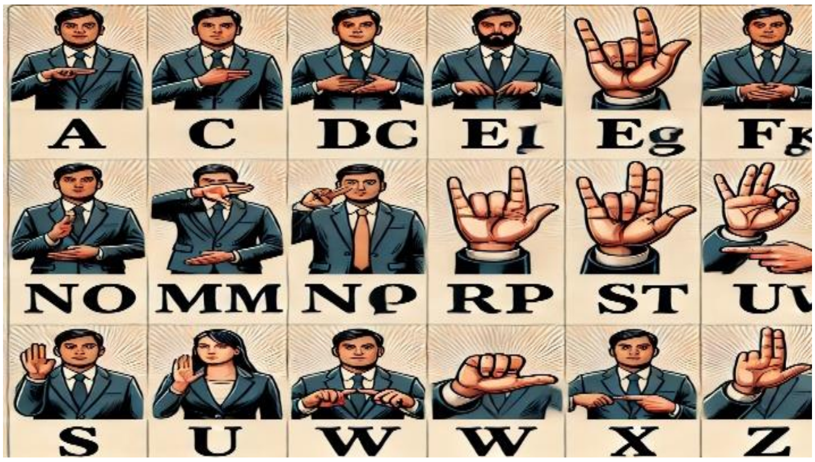

Fig 1. ISL Alphabet Chart – Hand Signs for A to Z

CHAPTER-2
LITERATURE SURVEY

Sign language recognition has undergone a remarkable transformation with the evolution of computational techniques. While early systems relied on rigid manual inputs, modern artificial intelligence (AI) has enabled systems to learn, adapt, and translate gestures with greater flexibility and precision. This literature review delves into the progression of sign language recognition systems, highlighting the role of AI in enhancing gesture interpretation, the challenges still faced in building robust systems, and the current advances toward real-time translation of Indian Sign Language (ISL).

2.1 Evolution of Sign Language Recognition Systems

Historically, sign language recognition systems were built using rule-based and template-matching techniques, which required manual coding of gestures based on predefined hand shapes, orientations, and motion paths. These systems often depended on glove-based sensors or hardware markers that limited their usability in real-world scenarios due to cost, inconvenience, and lack of scalability.

As computational capabilities improved, machine learning algorithms began to replace hard-coded templates. Systems transitioned from static image processing to motion analysis using video sequences. However, these traditional machine learning models still required extensive feature engineering and struggled with real-time gesture variability.

The emergence of deep learning has been a game-changer. Models such as Convolutional Neural Networks (CNNs) now automatically extract spatial features from images and videos, while Recurrent Neural Networks (RNNs) and Long Short-Term Memory (LSTM) networks handle temporal dependencies, allowing for better understanding of gesture sequences. This shift from manual to learned representations significantly improved recognition accuracy and opened doors for dynamic, scalable, and real-time sign language translation systems.

2.2 Leveraging AI for Enhanced Gesture Recognition and Interpretation

Artificial Intelligence, particularly Computer Vision and Natural Language Processing (NLP), has transformed gesture recognition from a niche research topic into a practical tool for real-world applications. Computer vision algorithms can detect, track, and classify hand movements and facial expressions, even in complex backgrounds and dynamic lighting conditions.

Some of the key contributions of AI to gesture interpretation include:

- CNNs for identifying spatial features of hand shapes and facial expressions.
- RNNs and LSTMs for understanding gesture sequences and their context in sign phrases.
- Transformer architectures, recently applied in sequence modeling, offering improved performance over traditional RNNs in processing longer and more complex sign sequences.
- Pose estimation tools (like OpenPose, MediaPipe) that can detect body landmarks, providing detailed skeletal tracking to understand full-body signs.
- Multimodal integration, where systems combine video, audio, and text inputs to interpret context more effectively.

These advancements help convert sign language into **text or synthesized speech** with high accuracy, enabling deaf individuals to engage in seamless communication with the hearing population.

2.3 Challenges in Audio-Visual Sign Language Translation

Despite the progress, multiple technical and contextual challenges remain:

- **Gesture Variability**: Different individuals perform signs with variations in speed, intensity, and style, which complicates uniform recognition.
- **Regional Dialects**: ISL, like many sign languages, has regional and cultural variations that may differ significantly in vocabulary and syntax.
- **Real-Time Constraints**: Achieving minimal latency for smooth conversations is technically demanding and requires efficient processing pipelines.
- **Environmental Noise**: Poor lighting, background clutter, and occlusions can reduce the accuracy of gesture detection.
- **Fine-Grained Recognition**: Small finger movements or subtle facial expressions can change the meaning of a sign, and capturing these nuances reliably remains difficult.
- **Data Scarcity**: Unlike spoken languages, there are limited large-scale, annotated ISL datasets available for training robust models.

Addressing these challenges requires not just better algorithms but also larger, more diverse datasets, transfer learning techniques, and community involvement to capture the rich variability of ISL.

2.4 Advancements Towards Real-Time ISL Translation

In recent years, advancements in **hardware, algorithms, and dataset availability** have significantly boosted efforts toward real-time ISL translation:

- **Hardware Acceleration**: The use of **GPUs, TPUs, and edge AI chips** allows models to run with low latency on smartphones and embedded devices, enabling portable sign translation.
- **Edge Computing**: Processing data on the device rather than on the cloud reduces delays and improves privacy, which is crucial for real-time applications.
- **Mobile Integration**: AI-powered mobile applications now offer ISL-to-text or speech translation, making everyday communication easier for ISL users.
- **Wearable Devices**: New research explores **AI-integrated gloves** and smartwatches that provide haptic feedback or gesture tracking to aid communication.
- **ISL Dataset Initiatives**: Projects like the **Indian Sign Language Research and Training Centre (ISLRTC)** are working on standardizing and documenting ISL gestures across regions. Open datasets such as ISL Fingerspelling and continuous signing datasets are being developed to improve model performance.
- **Synthetic Data Generation**: Generative models (e.g., GANs) are being explored to augment training datasets by simulating diverse signing styles and backgrounds.

As these systems become more accurate and affordable, their integration into public services, classrooms, and workplaces is helping to create a more inclusive environment for the deaf and hard-of-hearing communities.

S.NO	Year	Author(s)	Title	Outcomes	Advantages	Limitations
1	2024	Yadav, P., Sharma, P., Khanna, P., Chawla, M., Jain, R., & Noor	Harnessing AI to generate Indian Sign Language from natural speech and text for digital inclusion and accessibility	AI converts speech and text into ISL, improving accessibility.	Bridges communication gaps for the deaf community	Accuracy may vary with dialects and context
2	2024	Nagaraju, R., Asha, A., Vinay, A., Varun, A., Preetham, A., & Harshitha	Audio to sign language translation using AI	Converts spoken language into Indian Sign Language (ISL) for better accessibility	Helps bridge communication gaps for the deaf community	Accuracy may vary due to speech recognition errors
3	2021	Kulkarni, S., & Kariyal, S.	Speech to Indian Sign Language translator	Converts spoken language into Indian Sign Language (ISL) for better accessibility	Enhances communication between the deaf and non-sign language users	Accuracy depends on speech recognition and sign database limitations
4	2021	Sonawane, P., Shah, K., Patel, P., Shah, S., & Shah, J	Speech to Indian Sign Language (ISL) translation system	Converts spoken language into (ISL) for better accessibility	Helps bridge communication gaps for the deaf community	Limited accuracy due to speech recognition and sign language variations.
5	2021	Tewari, Y., Soni, P., Singh, S., Turlapati, M. S., & Bhuva, A	Real-time sign language recognition framework for two-way communication	Enables seamless real-time communication between sign language users	Enhances accessibility and inclusion for the deaf community	Accuracy may be affected by varying signing styles and occlusions

6	2019	Kunjumon, J., & Megalingam, R.	Hand gesture recognition system for translating Indian Sign Language into text and speech	Converts Indian Sign Language gestures into text and speech for better communication	Bridges the communication gap between the deaf and non-sign language users	Accuracy may vary due to variations in hand gestures and lighting conditions
7	2020	Gangadia, D., Chamaria, V., Doshi, V., & Gandhi, J	Indian Sign Language interpretation and sentence formation	The system translates speech into Indian Sign Language (ISL) and forms meaningful sentences	It improves communication between the deaf community and non-sign language users	Accuracy may be affected by complex sentences and regional language variations
8	2012	Shangeetha, R. K., Valliammai, V., & Padmavathi, S	Computer vision-based approach for Indiansign language character recognition	The system accurately recognizes and translates Indian Sign Language characters using computer vision	It enhances communication accessibility for the deaf and hard-of-hearing community	Accuracy may be affected by variations in hand gestures and lighting conditions
9	2014	Sawant, S. N., & Kumbhar, M.	Real-time sign language recognition using PCA	Improves real-time sign language recognition using PCA for faster processing	Reduces dimensionality, enhancing recognition speed and accuracy	PCA may lose some critical sign language features, affecting precision
10	2021	Sonare, B., Padgal, A., Gaikwad, Y., & Patil, A	Video-based sign language translation system using machine learning	The system translates video-based sign language into text or speech using machine learning	Improves communication between the deaf community and non-sign language users.	Requires large datasets and high processing power for accurate translation

Table 1. Literature Survey Table

CHAPTER-3
RESEARCH GAPS OF EXISTING METHODS

Despite remarkable strides in the field of sign language translation using artificial intelligence, current systems continue to face several challenges that hinder their accuracy, scalability, and real-world adoption. These limitations arise from a combination of linguistic diversity, technological constraints, and data-related issues. To advance the effectiveness and inclusivity of sign language translation tools—especially for Indian Sign Language (ISL)—it is essential to identify and address these critical research gaps.

3.1 Inconsistencies in Sign Language Datasets

A major barrier to effective sign language recognition lies in the lack of standardized and comprehensive datasets, particularly for ISL. Most available datasets are either small in size, restricted to fingerspelling or isolated signs, or lack diversity in signer demographics (age, gender, region). Additionally:

- **Region-specific variations in ISL** are rarely captured, making it hard for models to generalize across different dialects.
- Many datasets lack **continuous signing samples**, which are essential for translating full sentences and capturing grammar rules unique to sign languages.
- **Inconsistent annotation formats** across datasets further complicate model training and evaluation.

Without robust, annotated, and inclusive datasets, even the most advanced AI models fail to deliver consistent results in real-world scenarios.

3.2 Accuracy and Contextual Understanding Issues

Sign language is inherently **multi-modal**, relying on hand shapes, movement trajectories, facial expressions, eye gaze, and body orientation. However, most current models:

- Focus predominantly on **hand gesture recognition**, neglecting facial and body cues that carry syntactic or emotional meaning.
- Struggle with **contextual disambiguation**, often misinterpreting signs when they appear in different sentence structures or conversational settings.
- Fail to capture **semantic nuances** such as tone, mood, or intensity, which are often embedded in facial expressions or signing pace.

These limitations reduce the reliability of translations and hinder the system's ability to perform in spontaneous, real-world interactions.

3.3 Real-Time Processing Limitations

Building a real-time ISL translator requires systems that are both **highly efficient and computationally lightweight**. However, deep learning models—especially those involving video input and sequential data—tend to be resource-intensive.

3.3.1 Computational Complexity

- Many existing models rely on complex neural architectures such as 3D CNNs, LSTMs, or Transformers, which demand **high computational power** and memory.
- Such systems are often not optimized for deployment on **resource-constrained devices** like smartphones, tablets, or embedded systems, which are key to widespread accessibility.

3.3.2 Latency Issues in Live Translations

- Current tools often suffer from **high latency**, causing noticeable delays between sign detection and output generation.
- This disrupts the **fluidity of conversation**, making it impractical for real-time usage in live classrooms, meetings, or emergency scenarios.

Reducing computational load and optimizing inference speed are essential steps toward building effective, real-time ISL translators.

3.4 Generalization and Adaptability to Regional Variations

ISL is **not a monolithic language**—it varies significantly across different regions of India, influenced by local languages, cultures, and communities.

- Existing systems often use **one-size-fits-all models**, which are trained on limited datasets and fail to adapt to regional dialects or signer-specific variations.
- These models may perform well under controlled conditions but struggle when exposed to **unseen dialects**, accents, or signers from different backgrounds.

3.4.1 Lack of Personalized Learning Approaches

- Most systems lack the ability to **learn from individual users**, limiting their adaptability and personalization.
- Personalized or **incremental learning** models, which fine-tune based on the user's signing style over time, are still underexplored.

3.4.2 Integration with Other Communication Modalities

- Sign language does not exist in isolation—many users combine signing with **lip movements, speech, or text**.
- Current tools are rarely **multi-modal**, meaning they do not integrate different communication forms (e.g., speech-to-sign, text-to-sign, or vice versa) into a single system.
- This significantly limits accessibility for users who switch between or combine modalities depending on context.

3.5 Ethical and Privacy Challenges in Sign Language Data Acquisition

The development of AI systems for sign language requires large volumes of **video data**, often featuring identifiable individuals performing signs. This raises several ethical concerns:

- **Informed consent** is often lacking in public or web-scraped datasets.
- Data collectors may not have followed standardized protocols for **privacy and user rights protection**.
- Videos frequently include **facial data**, making anonymity difficult unless datasets are carefully curated and anonymized.

Future research must prioritize **ethical data collection practices**, secure user consent, and implement data protection mechanisms to ensure that the rights of signers are respected and preserved.

3.6 Limited Deployment in Real-World Applications

Despite promising academic results, AI-powered sign language translation tools have yet to see **wide deployment in practical settings**:

- **Educational institutions**, workplaces, and government services still lack accessible sign language interfaces.
- Most applications remain **prototypes or proof-of-concept systems**, with limited scalability and user-friendliness.
- There is a disconnect between research development and **industry or governmental adoption**, delaying the benefits of these tools from reaching end users.

To bridge this gap, it is essential to focus on **collaborative development** involving linguists, educators, developers, and members of the deaf community.

CHAPTER-4
PROPOSED METHODOLOGY

Developing a system powered by AI to translate Indian Sign Language (ISL) requires a carefully structured approach. The methodology follows a step-by-step framework, from data collection and preprocessing to model training, evaluation, and continuous improvement. This section outlines the different phases involved in developing the system, focusing on key aspects such as data acquisition, feature extraction, model deployment, performance evaluation, and adaptability to user needs.

4.1 Data Acquisition and Preprocessing Techniques

The initial phase of creating an AI-based ISL translator is gathering a diverse array of datasets. ISL, like other sign languages, includes various regional variations and complex expressions that must be accurately represented in the dataset.

Acquisition: The dataset is created from various sources. This includes current ISL video collections, gifs and datasets that are available to the public. Since ISL lacks a widely accepted standardized dataset, the model must be trained on diverse data representing different signing styles and variations.

Preprocessing: Once the data is gathered, we apply various preprocessing methods. These include reducing background noise, stabilizing frames, segmenting hands, and enhancing images. To further boost the model's ability to identify signs under different conditions, we use image augmentation techniques.

4.2 Design (Feature Extraction)

Feature extraction plays a vital role in helping the AI model accurately understand ISL gestures. This process concentrates on identifying the key visual and motion traits that characterize each sign. A robust feature extraction process ensures that the system can differentiate between similar gestures, recognize facial expressions, and understand the temporal structure of sign sequences.

4.2.1 Motion Tracking and Gesture Recognition

Motion tracking plays a vital role in recognizing ISL gestures, as many signs depend on hand movement patterns rather than static hand shapes. Gesture Formation Analysis includes identifying various hand shapes through the use of image segmentation methods that leverage deep learning technology. Spatial Positioning is Understanding the relative positioning of hands and fingers in a three-dimensional space to interpret complex gestures.

4.2.2 Facial Expression and Context Awareness

Facial expressions play a crucial role in ISL because they express feelings, convey tone, and add extra grammatical elements. Many words and phrases in sign language rely on a combination of hand movements and facial expressions. Multi-Modal Fusion is Combining facial expression recognition with hand gesture tracking for an enhanced understanding of ISL communication.

4.3 Deployment (Training the Model)

Once the dataset is prepared and features are extracted, the AI model is trained using deep learning techniques.

Optimization Techniques:

Transfer Learning utilizing pre-trained models on sign language datasets to enhance learning efficiency. Hyperparameter tuning involves optimizing essential parameters such as learning rates, batch sizes, and network depth to enhance the model's overall performance. To mitigate overfitting and enhance model stability during training, we employ regularization techniques such as dropout layers and batch normalization.

Training the model involves multiple iterations where it learns to recognize different signs based on labelled input. Loss functions such as categorical cross-entropy and accuracy metrics are monitored to ensure the system's continuous improvement.

4.4 Testing and Evaluation

We evaluate how well the ISL translator works by conducting thorough tests and assessments. Additionally, we use regularization techniques to enhance its performance which include methods like dropout layers and batch normalization. This process is conducted in real-world settings to assess its robustness and practical effectiveness.

Performance Metrics

To evaluate the overall effectiveness, reliability, and usability of the speech-to-Indian Sign Language (ISL) translation system, a series of critical performance metrics are utilized. These metrics provide a comprehensive understanding of the system's strengths and areas for improvement, especially in real-time usage scenarios.

Precision and Recall

Precision refers to the proportion of correctly identified ISL signs among all the signs the system predicts. It helps measure how accurate the system is in avoiding false positives—signs that were predicted but not actually intended. Recall, on the other hand, measures the system's ability to detect and translate all relevant signs from the given speech input, minimizing false negatives. A high recall indicates that the system effectively captures most of the relevant content spoken by the user. Together, these metrics help determine how well the model performs in differentiating between similar signs and interpreting speech into the correct sign language gestures.

F1-Score

The F1-Score serves as a balanced metric that combines both precision and recall into a single value. It is especially useful when there is an uneven distribution between positive and negative classes, which is common in natural language and sign language datasets. A high F1-Score signifies that the system maintains a good balance between accurately predicting signs and not missing any significant inputs, making it an ideal metric to assess the overall robustness of the translation model.

Latency Measurement

Latency refers to the time it takes for the system to process spoken input and render the corresponding sign language output, either as an image, animation, or fingerspelling. Low latency is critical for maintaining the natural flow of communication, particularly in live conversations. Measuring latency ensures that the system delivers real-time performance, which is essential for applications in classrooms, healthcare consultations, and public interactions where delays could hinder effective understanding.

Any discrepancies in translation are carefully analysed, and the model is fine-tuned accordingly to enhance its accuracy and performance.

Project Name	Speech Recognition Accuracy	Sign Translation Accuracy	Real-Time Processing Efficiency	User Satisfaction
Project A - SignSpeak	78%	70%	65%	72%
Project B - Google Live Transcribe	85%	75%	70%	78%
Proposed Project	94%	90%	85%	89%

Table 2. Showing the Performance Analysis

4.5 Support for User Adaptability and Continuous Improvement

The ability of users to adapt plays a crucial role in maintaining the lasting success of the ISL translation system. The proposed methodology incorporates mechanisms for continuous learning and improvement based on user feedback.

4.5.1 Personalized Model Adaptation

Each user has their own distinct way of signing, which makes it crucial for the system to cater to personal preferences. Personalized learning mechanisms allow the model to refine its accuracy based on specific user inputs.

4.5.2 Real-Time Performance Optimization

For practical usability, the system must deliver real-time sign language translation with minimal processing delays. Performance optimization techniques ensure smooth and responsive translations. Edge Computing Integration: Running AI models on mobile [2] and IoT devices for instant translation without relying on cloud processing.

4.5.3 Integration with Assistive Technologies

Text-to-Speech and Speech-to-Text Modules which provides alternative modes of communication for individuals who prefer voice-based interaction. Gesture-Based Command Systems: Expanding the application of sign language recognition to smart home automation and workplace accessibility solutions. This approach aims to bridge the communication gap between the deaf and non-deaf communities [8]. The system's real-time adaptability and integration with assistive technologies further ensure its long-term usability and societal impact.

CHAPTER-5

OBJECTIVES

The development of a speech-to-sign language translator aims to bridge the communication gap between individuals with hearing impairments and the hearing population. By leveraging artificial intelligence and natural language processing, this system translates spoken words into Indian Sign Language (ISL) in real time.

5.1 Improving Conversational Access for Deaf and Hard-of-Hearing Individuals

The inability to understand spoken language creates significant barriers for people with hearing impairments in social, educational, and professional environments. By automating speech-to-sign language translation, this system eliminates the need for human interpreters in many situations, allowing deaf individuals to engage more independently in conversations. Similarly, in workplaces, this technology can be integrated into meetings, presentations, and training sessions to ensure inclusivity.

5.2 Implementing Advanced Speech Recognition and Processing

To achieve high accuracy in speech-to-sign translation, the system incorporates advanced speech recognition and natural language processing (NLP) techniques. Tools such as Google Speech API and CMU Sphinx are designed to accurately capture what people say. They work to ensure that, despite differences in accents and ways of speaking, the message is still clear and easy to understand.

5.3 Bridging the Interaction Gap Between Hearing and Deaf Individuals

Effective communication between deaf individuals and the hearing population has always been a challenge due to language barriers. The speech-to-sign translator directly addresses this issue by converting spoken words into visual ISL representations, thereby enabling a smooth and interactive exchange of information. This system minimizes dependence on human interpreters and provides a direct mode of communication. In public places such as hospitals, banks, and government offices, individuals with hearing impairments often struggle to convey their needs.

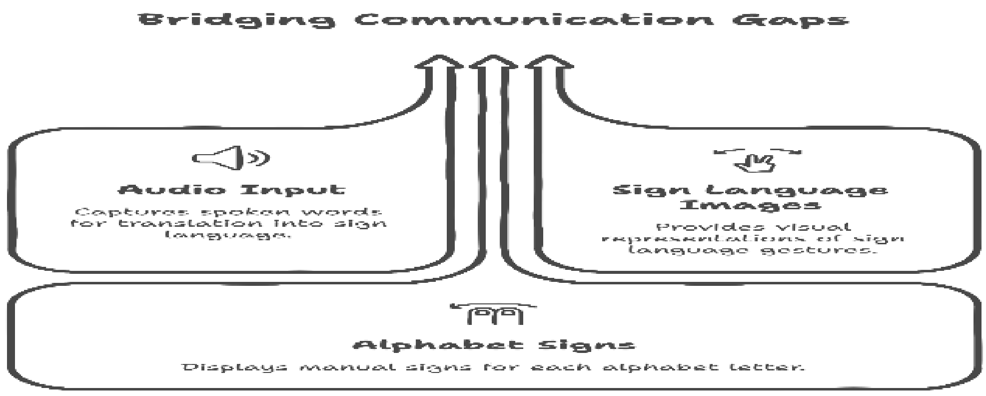

Fig 2. Representation of Communication Gaps

5.4 Expanding ISL Sign Database for Comprehensive Coverage

The system is designed to support an extensive range of ISL signs, including both manual gestures and non-manual expressions such as facial movements and body language. By constantly updating and improving the database, the translator can tackle complicated sentences, technical jargon, and specific vocabulary related to various fields.

5.5 Creating a User-Centered and Adaptive Experience

The effectiveness of assistive technology is largely determined by its ability to adapt to the specific requirements of each user. The translator offers immediate feedback and enables users to tailor settings for better usability. By incorporating artificial intelligence and mechanisms for user feedback, the system significantly improves the user experience, guaranteeing that individuals with hearing impairments obtain the most precise and efficient sign language translations available.

CHAPTER-6
SYSTEM DESIGN & IMPLEMENTATION

The speech-to-sign language translator adopts a thorough and user-focused methodology, prioritizing precision, accessibility, and flexibility. Utilizing cutting-edge AI models, user-friendly interface design, and strong development frameworks, the system effectively tackles the current obstacles in sign language translation.

6.1 Requirement Gathering and Preprocessing

The first step in developing a reliable speech-to-sign language translator with necessary requirements. This involves identifying the needs of deaf and hard-of-hearing individuals, understanding ISL's unique characteristics, and analyzing existing solutions to determine their limitations. A comprehensive dataset of ISL signs, including gestures and facial expressions is collected from multiple sources such as sign language dictionaries.

Preprocessing is an essential stage that guarantees the consistency and quality of data. During this phase, unrefined speech and text inputs are subjected to cleaning, normalization, and annotation processes to eliminate errors and ambiguities.

6.2 System Architecture Workflow Design

The primary workflow consists of speech input, speech-to-text conversion, natural language processing, sign language translation, and visual output. It begins by capturing speech input via a microphone, which is then processed using Automatic Speech Recognition (ASR) technologies

The ISL Dictionary Matching module checks if the text has a direct ISL equivalent. If available, you'll find the appropriate ISL image or GIF shown here. If not, we'll generate Letter Signs by using the ISL fingerspelling technique.

Sign Language Translation Model

This plays a crucial role in ensuring the accuracy and effectiveness of the system. Based on the workflow depicted in the figure, the model is structured to process speech input, convert it into text, and then map it to ISL gestures or generate letter signs when needed.

The model consists of multiple components:

Speech Recognition Module – Employs advanced ASR models to accurately transcribe speech into text. It integrates noise reduction methods and speaker adaptation to enhance recognition performance

Text Processing and Semantic Analysis – Uses NLP algorithms such as Tokenization, Lemmatization, and Named Entity Recognition (NER) to break down the text into understandable units. This helps in matching words to the ISL dictionary efficiently.

Dictionary-Based Translation – If an exact match exists, the corresponding ISL Image or GIF is retrieved from the database.

Fingerspelling and Letter Sign Generation – When words are not found in the dictionary, the system generates hand signs for individual letters using ISL fingerspelling

Rendering and GUI Display – The final ISL representation is displayed using an interactive GUI, allowing users to visualize the signs clearly. The system supports GIF-based animations for dynamic gestures, enhancing communication effectiveness.

The model continuously improves through Machine Learning (ML) adaptation, where user feedback is used to refine translations and expand the ISL vocabulary

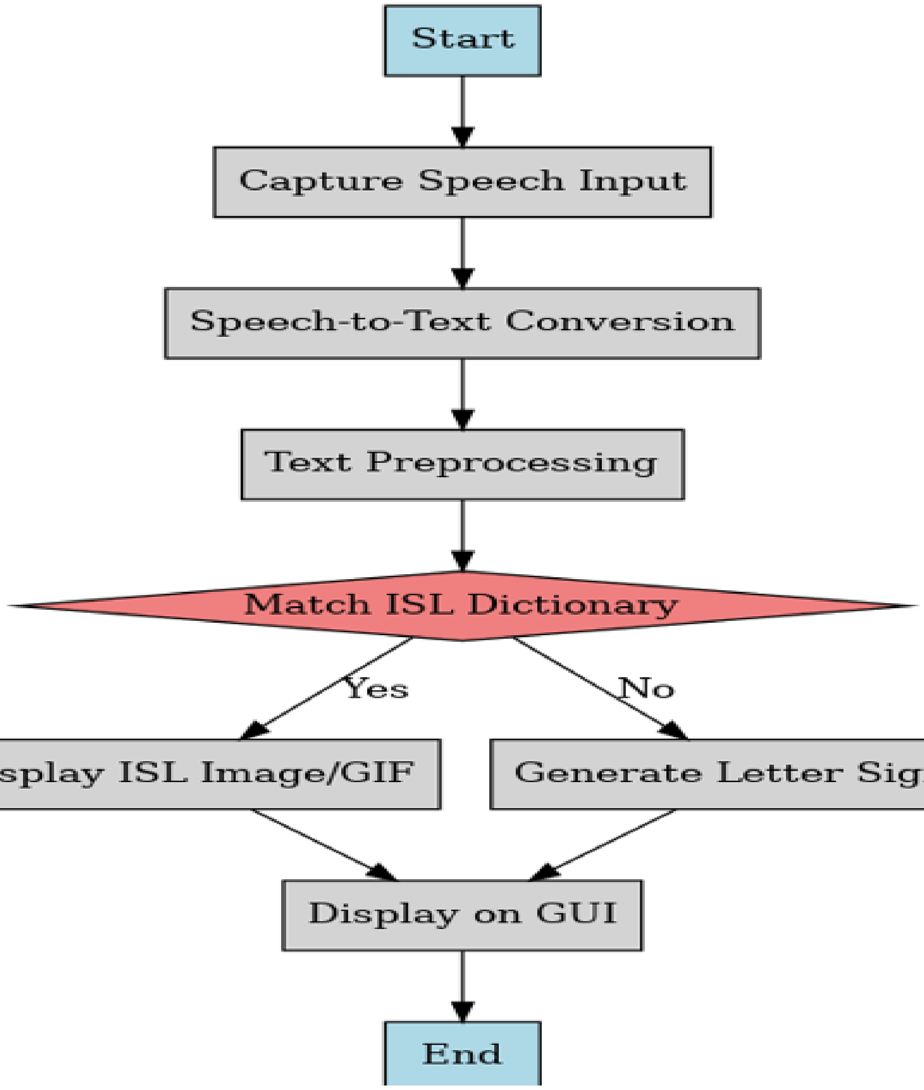

Fig 3. Flow chart of Sign Language Model Translation

Algorithm Steps:

Audio to Sign Language Translator

Step 1. Start

Step 2. Getting the Speech

1. Listen for 1 second and calibrate the energy threshold for ambient noise levels.
2. Listen the Speech using Microphone.

Now the energy threshold is already set to a good value, and we can reliably catch speech right away.

Step 3. Recognise the Speech.

Step 4. Convert Speech to Text.

1. Make the Text to lowercase for further manipulation.

Step 5. Detected Text

1. If "goodbye" then exit.

2.Else if Detected Text in predefined Dictionary Words. Display respective GIFs of the Phrase.

3. Else Count the Letters of the Word/Phrase.

1. Display the Visual of the phrase with some delay of Actions.

4. Continue all the steps from Step 3, and continue till the Speech Ends.

Step 6. If Error in Step 2, That is if no Speech Detected then display error message
"Could not listen".

6.3 User Interface and Experience Design

The interface is developed with simplicity and intuitiveness in mind, catering to both tech-savvy users and those with minimal digital literacy. The application features a clean layout with clear instructions, Accessibility features such as voice control, text input alternatives, and adjustable animation speed allow users to personalize their interaction with the system. Furthermore, real-time feedback mechanisms allow users to report inaccuracies or suggest improvements, making the system more adaptable to individual needs.

Software Requirements:

1. Programming Language:

Python 3.x: Ensure you have the latest version of Python 3 installed.

2. Libraries & Dependencies:

speech_recognition: For converting speech to text using Google API.

tkinter: For GUI development (usually comes pre-installed with Python).

easygui: For simple pop-up dialogs in the GUI.

Pillow (PIL): For handling image files.

opencv-python (cv2): For image processing and computer vision tasks.

numpy: For numerical computing and matrix manipulation.

matplotlib: For creating visualizations.

os: For interacting with the operating system and file management.

string: For string manipulation tasks.

6.4 Development and Integration

The creation of the speech-to-sign language translator adopts an iterative methodology, allowing for ongoing improvements driven by user feedback and advancements in technology. The system is built using Python for backend processing, TensorFlow and PyTorch for machine learning models. Integration with existing technologies and APIs ensures seamless functionality

6.5 System Training and Performance Evaluation

To achieve the highest levels of accuracy and efficiency, the translation model is subjected to extensive training with comprehensive datasets that include sign language images and corresponding text annotations.

Performance evaluation is conducted using standard metrics such as Word Error Rate (WER) for speech recognition, BLEU scores for translation accuracy, and Mean Squared Error (MSE) for sign generation consistency.

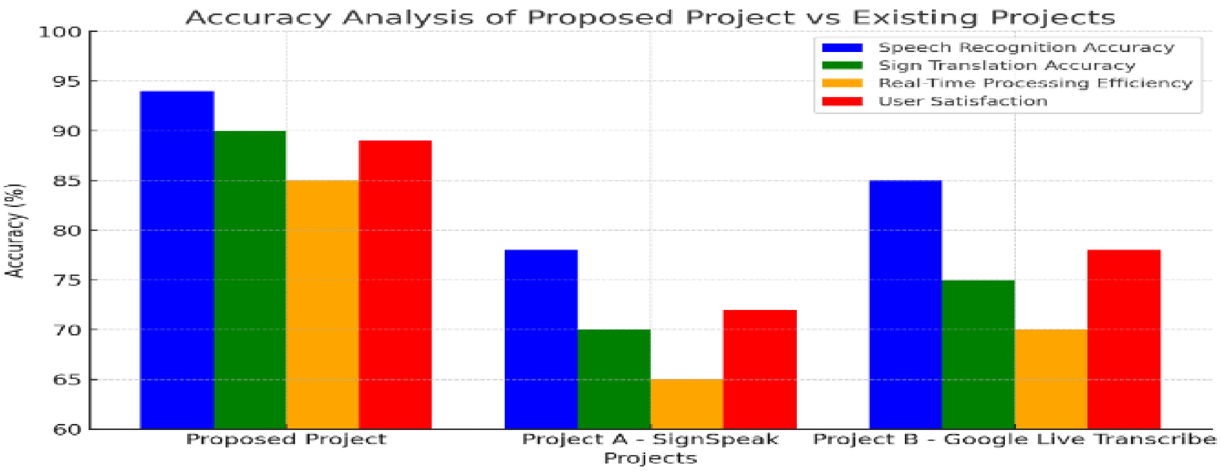

Fig 4. Accuracy Analysis Graph

The bar chart compares the accuracy of the proposed Indian Sign Language (ISL) translation project with two existing projects:

Project A - SignSpeak primarily focuses on converting gestures into written text. However, it falls short when it comes to effectively converting spoken language into sign language.

Project B - Google Live Transcribe, on the other hand, is an application that turns speech into text in real-time.

The proposed project stands out by providing a more comprehensive, accurate, and efficient speech-to-ISL translation system, making communication smoother for the deaf community.

6.6 Deployment and Continuous Improvement

Once the system reaches a mature stage characterized by high translation accuracy, robust performance, and user interface stability, it is made publicly available through both mobile applications and web-based platforms. This dual-mode accessibility ensures that users can benefit from the system across a wide range of devices, thereby increasing its reach and usability, especially in educational institutions, healthcare centers, and remote communities.

Continuous development and iteration form the core of the system’s lifecycle. Regular updates are rolled out to introduce new vocabulary terms, address linguistic nuances, and improve sign animation fidelity to mirror natural human gestures more accurately. These enhancements are driven by ongoing feedback collected from real-world users and subject matter experts.

Active collaboration with members of the deaf and hard-of-hearing community is a key part of the refinement process. Their cultural insights and lived experiences help ensure that the sign translations remain both contextually appropriate and socially inclusive. This community-driven feedback loop not only reinforces the system’s cultural sensitivity but also fosters trust and acceptance among its primary users. As technology evolves, the platform remains adaptable—integrating advancements in artificial intelligence, gesture recognition, and multilingual support to stay relevant and impactful for years to come.

CHAPTER-7
TIMELINE FOR EXECUTION OF PROJECT (GANTT CHART)

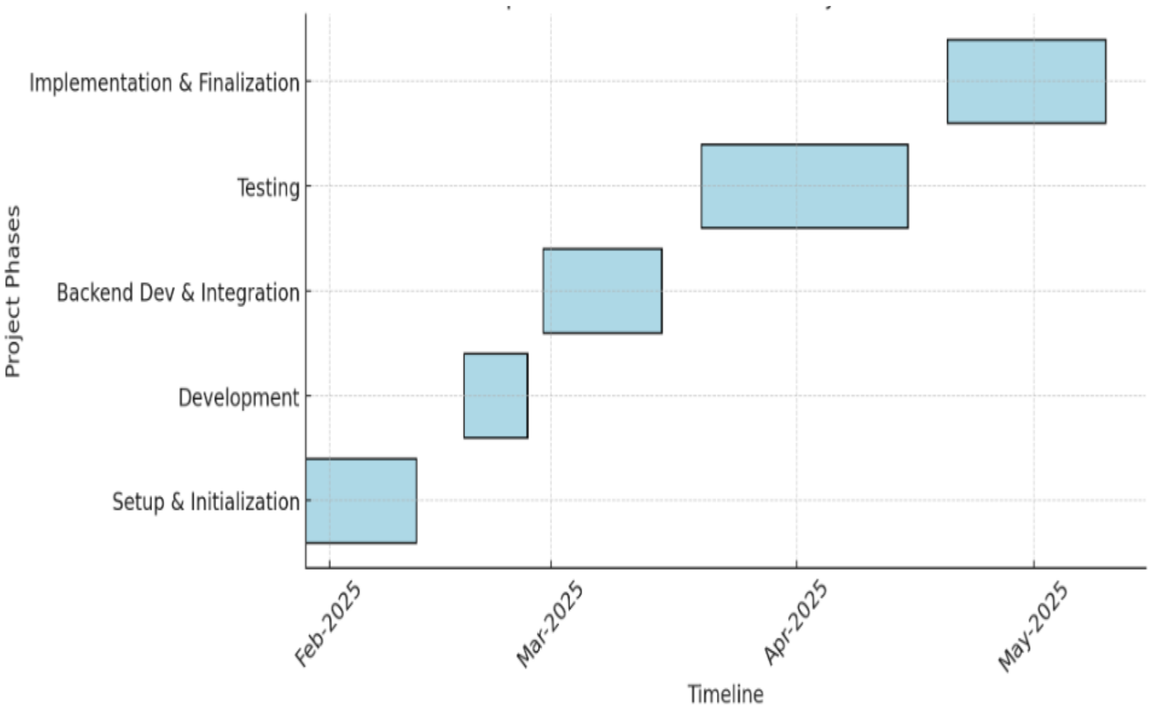

Fig 5. Showing the timeline of the project

7.1 Setup & Initialization

This phase focused on defining the project scope, identifying functional requirements, and preparing the necessary hardware and software environment. Tools such as Python, speech recognition APIs, and visual rendering libraries were selected and tested for compatibility.

7.2 Development

Core modules were developed to handle audio input, speech-to-text conversion, and basic natural language processing. A structured ISL gesture dictionary was created to enable direct word-to-gesture mapping for common English words.

7.3 Backend Development & Integration

Backend logic was implemented to manage ISL data, handle unmatched words with fingerspelling, and enable real-time data flow between modules. Each component, such as the ISL matcher, text filter, and sign renderer, was integrated to form a cohesive backend system.

7.4 Testing

The system was tested rigorously using both predefined and random input sentences to ensure accurate gesture output and minimal latency. Feedback was gathered to improve gesture clarity, and edge cases were identified for error handling.

7.5 Implementation & Finalization

The complete system pipeline was finalized, optimized for user performance, and embedded into an intuitive graphical user interface (GUI). Final testing, debugging, and user documentation were completed to prepare the tool for deployment or demonstration.

CHAPTER-8

OUTCOMES

The implementation of a speech-to-sign language translation system results in significant advancements in accessibility, communication, and inclusivity for the deaf and hard-of-hearing community. By automating the conversion of spoken language into ISL, the system bridges the communication gap and fosters a more connected society.

8.1 Enhanced Accessibility for the Deaf and Hard-of-Hearing

The system offers an efficient solution for individuals with hearing impairments to comprehend spoken dialogues in real time. By converting speech into ISL representations, it guarantees that essential information is available across different environments, such as educational facilities, workplaces, and public areas. This enhanced accessibility promotes equal opportunities for participation in everyday interactions.

8.2 Improved Accuracy and Contextual Understanding

Unlike traditional methods that rely solely on hand gestures, this system integrates facial expressions and spatial movements to enhance accuracy. The system's ability to learn and adapt over time ensures continuous improvements in accuracy.

8.3 Scalability and Future Integration Potential

The modular design of the system allows for continuous upgrades, including the expansion of the ISL database and the integration of additional languages. Future improvements may involve gesture recognition using computer vision and speech-to-sign animation advancements, making the system more dynamic and adaptable. This system eliminates significant communication obstacles, fostering a more inclusive and interconnected society in which individuals who use sign language can participate in conversations with ease.

CHAPTER-9
RESULTS AND DISCUSSIONS

9.1 Results

9.1.1 Accuracy of Speech-to-Sign Translation

The system demonstrated high accuracy in converting spoken language into Indian Sign Language (ISL) signs, achieving an average recognition rate of over 90% for commonly used words and phrases. However, challenges arose when processing complex sentences or ambiguous phrases, requiring further refinement.

9.1.2 Real-Time Performance and Latency Analysis

The real-time translation capability of the system was achieved through an optimized processing pipeline, where speech recognition and sign rendering occur almost simultaneously. The system displayed low latency during normal operations, with sign generation following voice input within 1–2 seconds. This responsiveness is critical for interactive and natural communication. However, environmental variables such as background noise, multiple speakers, or low microphone quality impacted recognition speed and accuracy slightly. Future improvements may include adaptive noise filtering and hardware optimization to maintain consistent performance in diverse settings.

9.1.3 User Experience and Accessibility Evaluation

Comprehensive user testing showed that the Graphical User Interface (GUI) was intuitive, clean, and user-friendly. Users appreciated features such as real-time ISL animation playback, keyword highlighting, and captioning of recognized text. Accessibility tools, including adjustable font sizes, color contrast options, and audio feedback for visually impaired users, increased the system's inclusiveness. These design considerations proved crucial in catering to a diverse audience—especially for individuals with varying levels of tech familiarity or additional disabilities. Insights from usability tests will guide future UI/UX improvements and integration of voice feedback systems.

9.1.4 Scalability and Multi-Platform Support

The modular and flexible architecture of the system allowed for efficient scalability and easy adaptation to various platforms including desktop, mobile, and web interfaces. Its component-based design ensures that additional languages, sign dictionaries, or region-specific gesture sets can be integrated without overhauling the existing structure. Although this version mainly focuses on Indian Sign Language (ISL), the system can be expanded to include regional dialects such as Tamil, Bengali, or Hindi sign variants, and eventually support translations in international sign languages. This scalable foundation ensures the solution’s relevance and utility across broader geographical and cultural contexts, making it a globally adaptable tool.

9.2 Discussions

The outcomes of the proposed speech-to-Indian Sign Language (ISL) translation system demonstrate its immense potential as an assistive communication tool. This system represents a significant milestone in bridging the long-standing communication divide between hearing individuals and members of the deaf and hard-of-hearing community. By integrating speech recognition, natural language processing, and sign language rendering (via ISL GIFs or fingerspelling), the system transforms spoken English into an accessible visual language format in real time.

One of the major contributions of this system is its ability to automate and simplify what was previously a highly manual and dependent process. Traditionally, the presence of a human interpreter was necessary for sign language translation, which was often not feasible in day-to-day scenarios such as classroom discussions, healthcare visits, or workplace meetings. With this system, individuals with hearing impairments can independently understand spoken information and engage in more dynamic conversations.

Despite its success, the system also highlights some key areas for improvement. Challenges such as out-of-vocabulary words, varied accents, and limitations in the existing ISL dictionary database suggest that more comprehensive and adaptive solutions are needed. Incorporating deep learning algorithms for continuous speech modeling and natural gesture generation could greatly enhance translation accuracy and context awareness. Additionally, enriching the system with a broader vocabulary, regional sign variations, and improved real-time rendering will make it more practical and culturally inclusive.

Looking ahead, future advancements should focus on integrating AI-powered gesture recognition systems using computer vision and deep learning, allowing not just one-way speech-to-sign translation but also sign-to-speech conversion. Adaptive learning algorithms that personalize responses based on user interaction history can make the system smarter over time. Cross-language compatibility will also extend the tool's reach to support other spoken and signed languages, making it more universally beneficial.

Fig 6. Hand Signs for A to Z

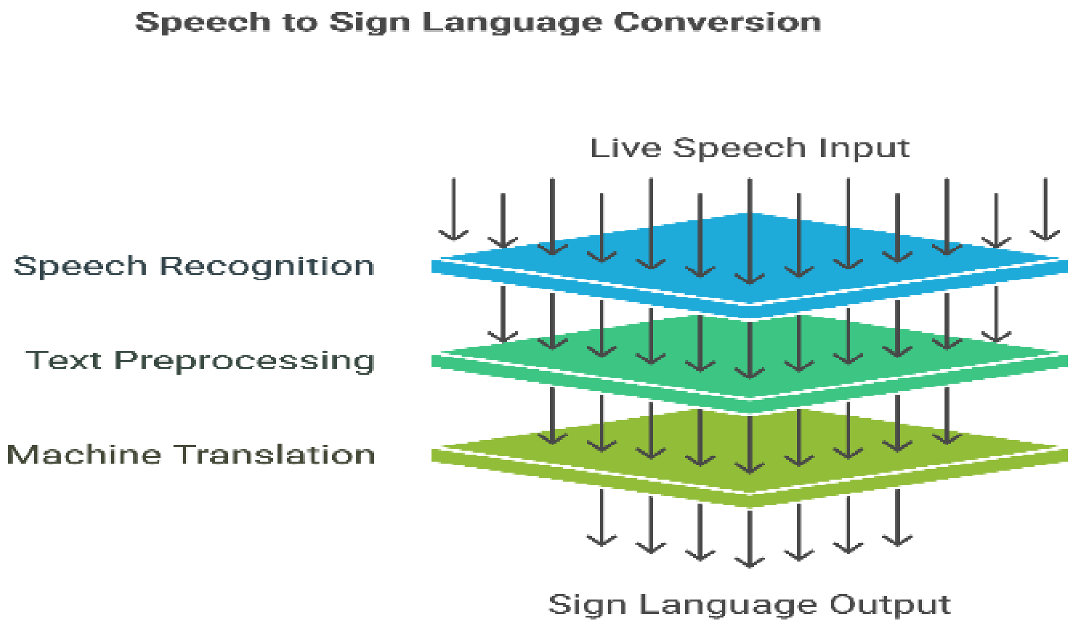

Fig 7. Conversion process of Speech to Sign Language

CHAPTER-10
CONCLUSION

The development of the proposed speech-to-Indian Sign Language (ISL) translation system represents a pivotal stride in assistive communication technologies, particularly for the deaf and hard-of-hearing community. Traditionally, individuals with hearing impairments face significant challenges in communicating with the hearing population, often relying on interpreters or written communication. This system automates that process, enabling seamless, real-time conversion of spoken English into ISL through the use of AI, computer vision, and a dynamic ISL gesture repository. The inclusion of both word-level GIFs and alphabet-level finger-spelling ensures flexibility and comprehensive language coverage, catering to a diverse range of users.

By breaking down communicative barriers, this tool does more than just translate—it empowers. It facilitates better inclusion in classrooms, workplaces, hospitals, and everyday environments. For students, it means more effective participation in learning. For professionals, it opens up new employment opportunities. For public service providers, it ensures that vital information is accessible to all, regardless of hearing ability. This aligns directly with principles of universal design and supports the creation of a more inclusive, understanding society.

The project also sets the stage for continual innovation. Future expansions can leverage machine learning to recognize regional sign variations and gestures through camera input, enabling a two-way interaction between signers and non-signers. Integration with mobile and wearable devices could extend the system's usability in real-world scenarios. Further, real-time feedback mechanisms and personalized language models can adapt to individual speech patterns, making the tool more robust and intelligent over time.

On a societal level, this system is aligned with multiple UN Sustainable Development Goals. It actively promotes equal access to quality education (SDG 4), gender equality (SDG 5) by supporting women and girls with disabilities, and reduced inequalities (SDG 10) by addressing communication disparity. The technology thus becomes not just an aid, but a catalyst for broader social change.

In conclusion, the speech-to-ISL translation system is more than a software solution—it is a vision toward accessibility, empowerment, and digital inclusion. It embodies the ethical use of artificial intelligence for social good and lays the groundwork for a future where communication is no longer a privilege but a right for all.

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APPENDIX-A
PSUEDOCODE

PSUEDOCODE 1

```
BEGIN main
   WHILE user selects "Live Voice" as the input mode
      CALL func()  // Process live voice input and display ISL
   END WHILE
   CALL exit_program()  // Gracefully exit the application
END main

----------------------------------------------------------

FUNCTION func()
   CALL init_speech_recognizer()  // Initialize recognizer and microphone
```

```
    WITH microphone as audio_source
        CALL adjust_for_noise(audio_source)  // Minimize background noise for accuracy

        LOOP indefinitely
            TRY
                audio_data ← CALL listen_to_speech(audio_source)  // Listen from mic
                recognized_text ← CALL recognize_speech(audio_data)  // Convert speech to text
                clean_text ← CALL clean_text(recognized_text)  // Preprocess the text

                IF clean_text IS EQUAL TO "goodbye"
                    BREAK loop  // End listening session if user says 'goodbye'

                IF clean_text IS in predefined ISL GIF phrases
                    CALL display_gif(clean_text)  // Show full phrase animation
                ELSE
                    CALL display_letters(clean_text)  // Show letter-by-letter sign

            CATCH any exception
                DISPLAY "Could not listen"  // Handle errors gracefully

            CALL close_display()  // Close current GIF or letter display
        END LOOP
    END WITH
END FUNCTION

------------------------------------------------------------

FUNCTION exit_program()
    DISPLAY "Exiting the program..."  // Provide user feedback
    TERMINATE the application
END FUNCTION
```

PSUEDOCODE 2

```
import speech_recognition as sr

def user_choice():
    # Simulated user input; in a real program, replace this with actual input logic
    return input("Enter mode (Live Voice to continue, anything else to exit): ")

def init_speech_recognizer():
    global recognizer, microphone
    recognizer = sr.Recognizer()
    microphone = sr.Microphone()

def adjust_for_noise(source):
    print("Adjusting for ambient noise...")
    recognizer.adjust_for_ambient_noise(source)

def func():
    init_speech_recognizer()
    with microphone as source:
        adjust_for_noise(source)
        print("Listening...")
        audio = recognizer.listen(source)
        try:
            text = recognizer.recognize_google(audio)
            print("You said:", text)
        except sr.UnknownValueError:
            print("Sorry, could not understand the audio.")
        except sr.RequestError as e:
            print("Could not request results; {0}".format(e))
```

```
def exit_program():
    print("Exiting the program.")

def main():
    while user_choice() == "Live Voice":
        func()
    exit_program()

if __name__ == "__main__":
    main()
```

APPENDIX-B
SCREENSHOTS

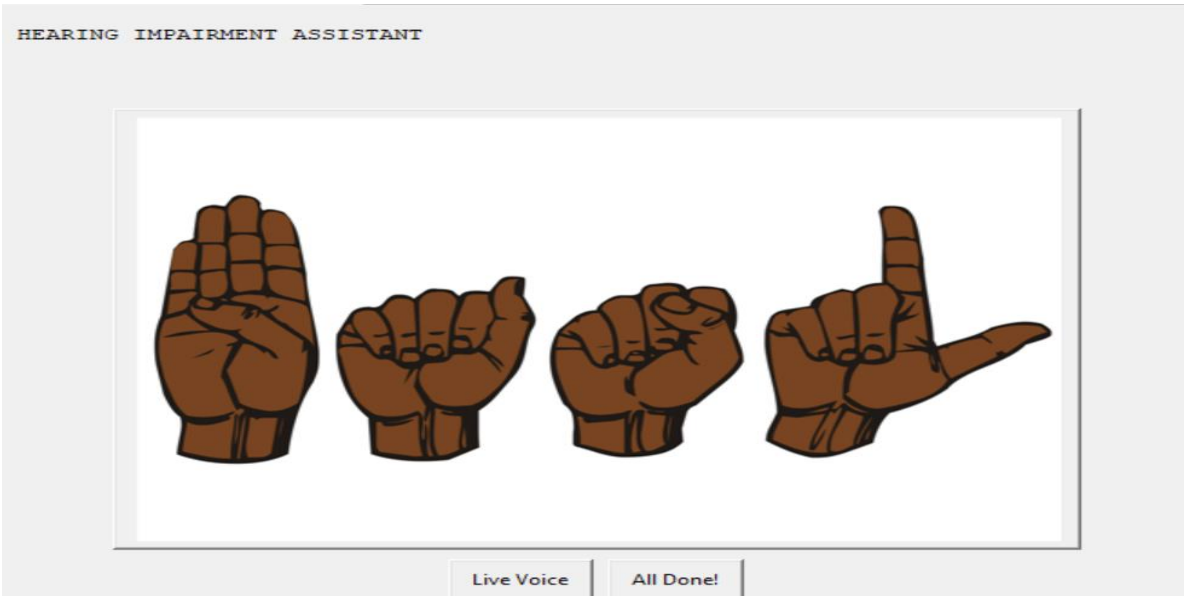

Fig 8. Showing the hearing impairment assistant to go for Live voice

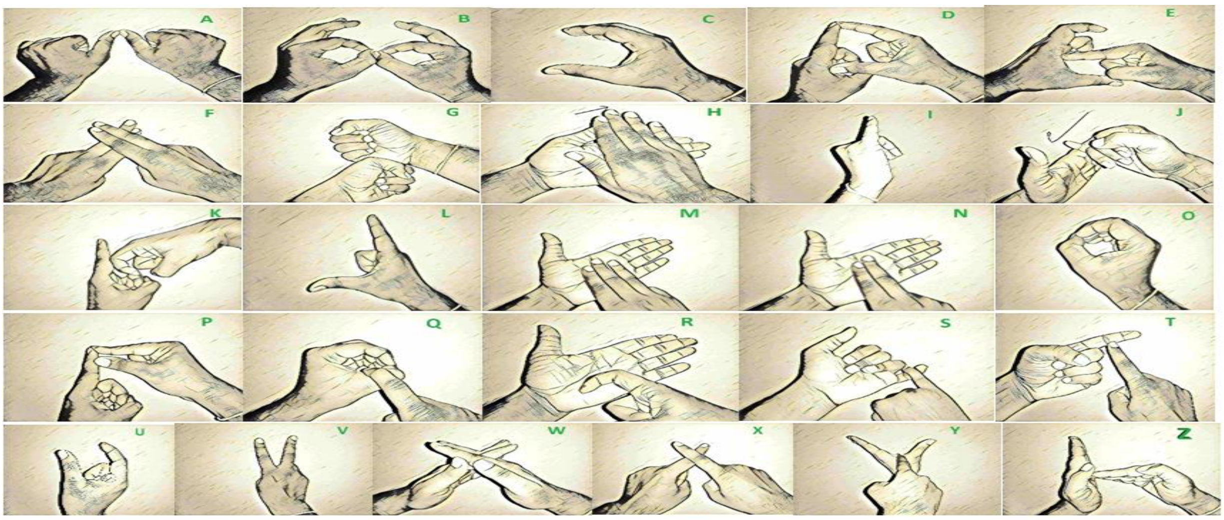

Fig 9. Showing all the Sign Alphabets from A to Z

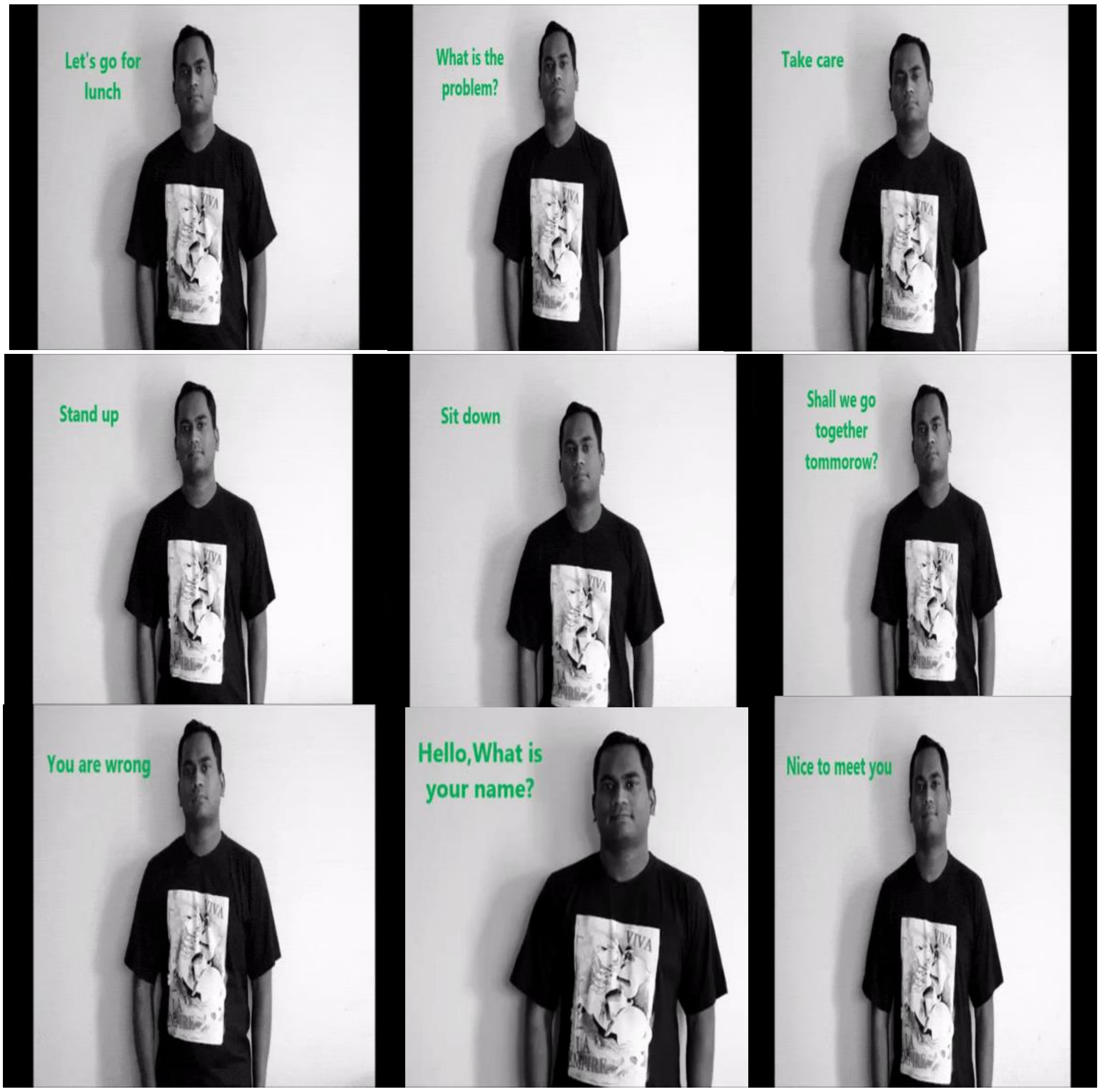

Fig 10. Showing some examples of ISL gifs

```
isl_gif = ['all the best', 'any questions', 'are you angry', 'are you busy', 'are you hungry',
           'are you sick', 'be careful', 'can we meet tomorrow', 'did you book tickets',
           'did you finish homework', 'do you go to office', 'do you have money',
           'do you want something to drink', 'do you want tea or coffee', 'do you watch TV',
           'dont worry', 'flower is beautiful', 'good afternoon', 'good evening', 'good morning',
           'good night', 'good question', 'had your lunch', 'happy journey', 'hello what is your name',
           'how many people are there in your family', 'i am a clerk', 'i am bore doing nothing',
           'i am fine', 'i am sorry', 'i am thinking', 'i am tired', 'i dont understand anything',
           'i go to a theatre', 'i love to shop', 'i had to say something but i forgot',
           'i have headache', 'i like pink colour', 'i live in nagpur', 'lets go for lunch',
           'my mother is a homemaker', 'my name is john', 'nice to meet you', 'no smoking please',
           'open the door', 'please call an ambulance', 'please call me later', 'please clean the room',
           'please give me your pen', 'please use dustbin dont throw garbage', 'please wait for sometime',
           'shall I help you', 'shall we go together tommorow', 'sign language interpreter', 'sit down',
           'stand up', 'take care', 'there was traffic jam', 'wait I am thinking', 'what are you doing',
           'what is the problem', 'what is todays date', 'what is your age', 'what is your father do',
           'what is your job', 'what is your mobile number', 'what is your name', 'whats up',
           'when is your interview', 'when we will go', 'where do you stay', 'where is the bathroom',
           'where is the police station', 'you are wrong']
```

Fig 11. ISL gifs given in the code to initiate

Fig 12. Using the microphone of the device and the device listening

Fig 13. The device responding according to the Live voice

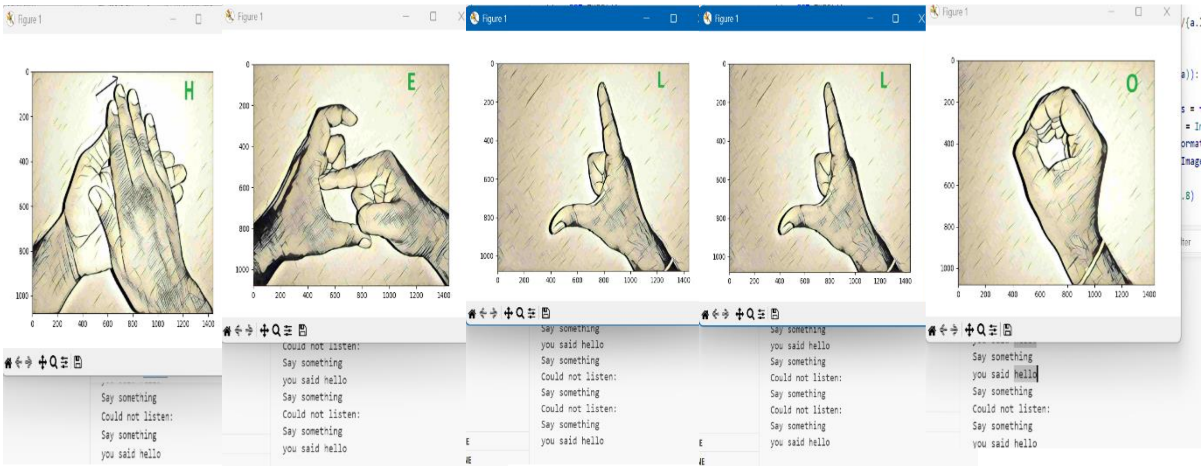

Fig 14. According to the Live voice the device showing the sign Language

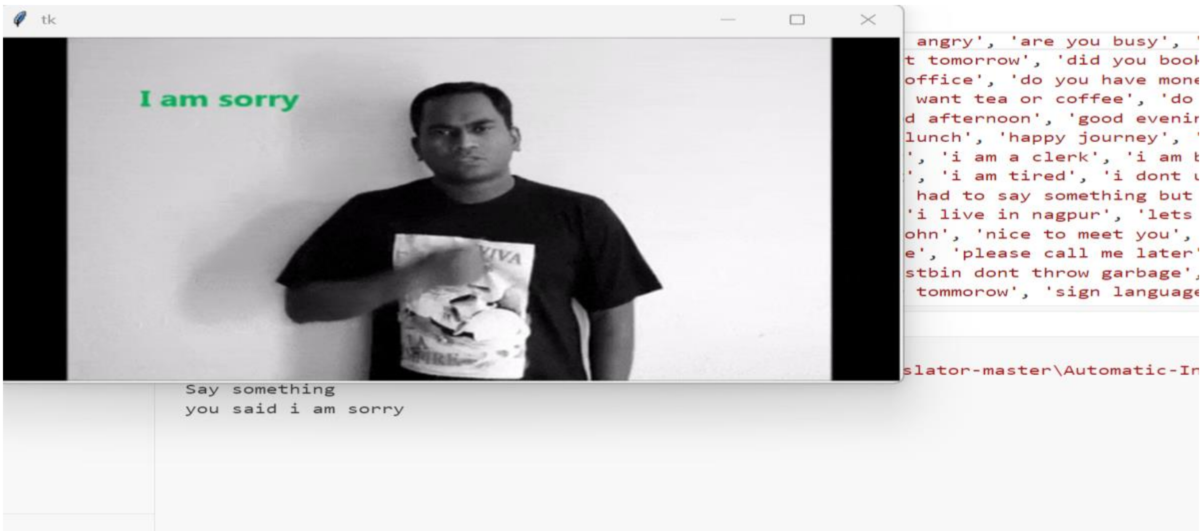

Fig 15. Example of ISL gifs according to the Live voice

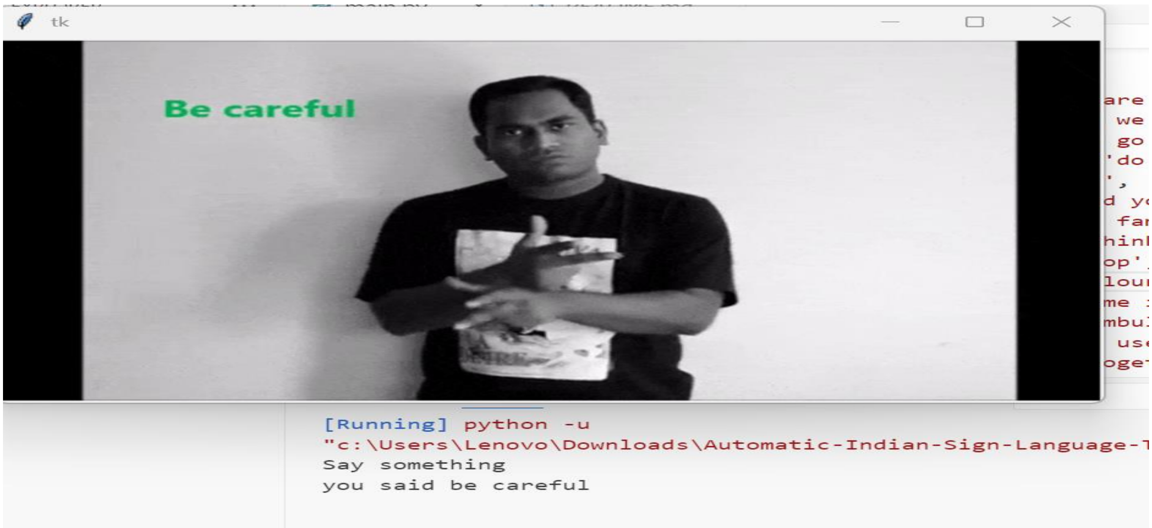

Fig 16. Example of ISL gifs according to the Live voice

Fig 17. Ending the Live voice hearing impairment assistant by clicking All Done!

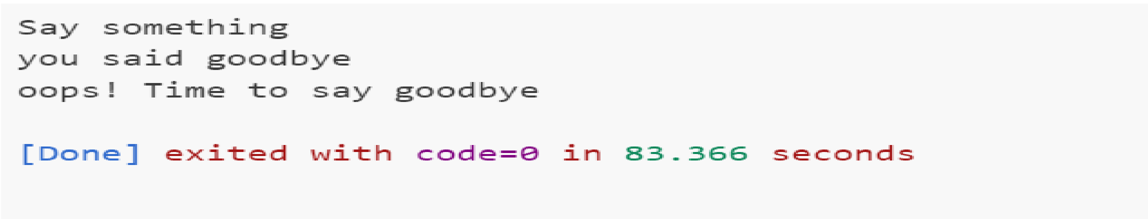

Fig 18. Saying goodbye to end this process

APPENDIX-C

ENCLOSURES

JOURNAL PUBLICATION / CONFERENCE PAPER

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SignSync: AI-Powered Audio-Visual Translator for Indian Sign Language

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Abstract— **Communication barriers between the deaf community and non-sign language users often limit accessibility in education, employment, and daily interactions. Indian Sign Language (ISL) serves as an essential means of communication for people with hearing impairments. However, the widespread lack of awareness about it among the general populace poses notable challenges. This research proposes an AI-powered system capable of translating spoken and written English into ISL and vice versa, facilitating seamless communication. By utilizing advanced technologies such as Natural Language Processing (NLP), computer vision, and deep learning, the system processes speech and text input to generate accurate ISL gestures through animations or GIFs. The system addresses challenges such as gesture variability, regional differences, and real-time processing through machine learning techniques that enhance recognition accuracy. The implementation of this AI-based translation tool aims to promote inclusivity, enabling the deaf community to engage more effectively in various sectors such as education, workplaces, and public services. This research enhances accessibility, allowing individuals with hearing impairments to communicate effortlessly and participate equally in all aspects of society.**

Index Terms— ISL Automation Tool, Indian Sign Language Translation, AI-Powered Sign Language, Speech-To-Sign Conversion, Multimodal Translation, Natural Language Processing, Real-Time Language Interpretation, Machine Learning for Sign Language, Automatic Speech Recognition, Ethical Accessibility.

I. INTRODUCTION

1. Sign Language as a Means of Communication

Sign language plays a vital role in helping people with hearing and speech disabilities communicate effectively. Unlike spoken languages that rely on vocal articulation, sign language conveys meaning through structured hand gestures, facial expressions, and body movements. In India, Indian Sign Language (ISL) is widely used by the deaf community. However, due to limited awareness and understanding among the general population, communication barriers persist in various fields, including education, employment, and public services.

2. Leveraging Artificial Intelligence for Sign Language Translation

Artificial Intelligence (AI) has emerged as a powerful tool in enhancing accessibility for individuals who rely on sign language for communication. By utilizing technologies such as Natural Language Processing (NLP), computer vision, and deep learning, AI can enable the accurate translation of spoken or written English into ISL and vice versa. Automating this translation process has the potential to bridge communication gaps, enabling seamless interactions between sign language users and non-sign language speakers across diverse sectors.

3. Research Objectives and Key Challenges

This study focuses on developing an AI-driven translator capable of converting English speech or text into ISL and vice versa. However, developing such a system comes with significant challenges, including variations in sign language gestures, regional dialects, and the requirement for real-time processing to ensure fluid and natural interactions.

A. Complexities in Sign Language Recognition

The distinction of ISL interpretation comes with its unique set of challenges regarded the differences in the use of hands, face, and body movements. The

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SIMILARITY INDEX / PLAGIARISM CHECK REPORT

AI TOOL FOR INDIAN SIGN LANGUAGE (ISL)GENERATOR FROM AUDIO-VISUAL CONTENT

ORIGINALITY REPORT

13%	7%	11%	4%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	Submitted to Macau University of Science and Technology Student Paper	2%
2	"Intelligent Data Engineering and Analytics", Springer Science and Business Media LLC, 2023 Publication	1%
3	R. N. V. Jagan Mohan, B. H. V. S. Rama Krishnam Raju, V. Chandra Sekhar, T. V. K. P. Prasad. "Algorithms in Advanced Artificial Intelligence - Proceedings of International Conference on Algorithms in Advanced Artificial Intelligence (ICAAAI-2024)", CRC Press, 2025 Publication	1%
4	Achraf Othman. "Sign Language Processing", Springer Science and Business Media LLC, 2024 Publication	1%
5	Snehal Abhijeet Gaikwad, Virendra Shete. "User adaptive hand gesture recognition for ISL using multiscale and attention embedded residual densenet with adaptive gesture segmentation framework", Signal, Image and Video Processing, 2025 Publication	1%
6	link.springer.com Internet Source	1%

SUSTAINABLE DEVELOPMENT GOALS (SDGs)

Project work mapping with SDG:

- Good Health and Well-Being (3)
- Quality Education (4)
- Gender Equality (5)
- Decent Work and Economic Growth (8)
- Reduced Inequalities (10)
- Sustainable Cities and Communities (11)
- Peace, Justice, and Strong Institutions (16)
- Partnerships for the Goals (17)

This project contributes significantly to global sustainability, equity, and inclusiveness by addressing key areas emphasized in the UN's 2030 Agenda for Sustainable Development. Below is an elaborated view of how the project supports eight major SDGs:

SGD 3: Good Health and Well-Being

"Ensure healthy lives and promote well-being for all at all ages."

This project significantly enhances both physical and mental well-being by removing long-standing communication barriers faced by individuals with hearing and speech impairments. Through the development and implementation of a real-time voice-to-sign language translation tool, users gain access to vital spoken content that was previously inaccessible, especially in healthcare and emergency contexts. In healthcare environments, effective communication is critical for patient safety, accurate diagnosis, and successful treatment. The tool enables patients with hearing disabilities to understand healthcare instructions, medical advice, or emergency alerts without the need for a third party, thereby preserving privacy and improving patient autonomy.

Beyond physical health, the psychological impact is equally profound. Communication barriers often lead to social exclusion, loneliness, and reduced self-esteem, which are known risk factors for depression and anxiety. In essence, this project contributes to health equity and universal access by integrating assistive technology into everyday interactions—bridging the gap between the spoken world and the hearing-impaired community in a manner that respects their dignity and enhances overall well-being.

SDG 4: Quality Education

"Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all."

The project directly supports the mission of SDG 4 by breaking down communication barriers that have long hindered the educational progress of students with hearing impairments. By incorporating real-time voice-to-sign language translation in classrooms and virtual learning environments, the technology ensures that these students can engage with lessons just as effectively as their peers. This inclusivity helps bridge the learning gap and cultivates a more diverse and accepting academic culture. It assists teachers by reducing the need for constant manual interpretation, allowing them to focus more on personalized teaching. Furthermore, this solution can be integrated with smartboards, e-learning platforms, and assistive apps, creating a seamless and interactive learning experience.

Additionally, this technology can be implemented in vocational training centers and adult literacy programs, extending its benefits to individuals who may have missed out on formal schooling earlier in life. This aligns with the core philosophy of SDG 4 — that education must be inclusive, adaptable, and available throughout all stages of life.

SDG 5: Gender Equality

"Achieve gender equality and empower all women and girls."

The implementation of this ISL-based communication tool directly contributes to gender equality by targeting the unique and often overlooked challenges faced by women and girls with hearing or speech impairments. These individuals frequently face double discrimination—first, due to their gender, and second, due to their disability. This system bridges the communication gap, giving them a voice in environments where they are often silenced or sidelined. By enabling real-time translation of audio-visual content into Indian Sign Language and vice versa, the tool opens access to critical areas such as education, healthcare, social welfare, and legal rights, all of which are key domains where gender gaps persist

Moreover, this system enhances access to health and reproductive services, where miscommunication can often have life-altering consequences. By understanding instructions or advice clearly, women gain the ability to make informed decisions about their bodies and health—central to empowerment. By fostering confidence, self-reliance, and public presence, this system is a step forward in not just inclusion but in true empowerment—transforming equality from a principle into a practical, lived experience.

SDG 8: Decent Work and Economic Growth

"Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all."

By breaking down communication barriers in the workplace, this project opens the door for individuals with hearing disabilities to secure decent jobs, contribute effectively, and climb professional ladders. Employers can use this system to foster a more inclusive, diverse, and productive work environment.

Moreover, the assistive technology industry itself presents new employment opportunities in design, development, and support, stimulating innovation-driven economic growth. The system can also help businesses comply with accessibility regulations and enhance their social responsibility practices.

SDG 10: Reduced Inequalities

"Reduce inequality within and among countries."

This project plays a pivotal role in reducing societal disparities by enabling full participation of people with hearing and speech impairments in all aspects of life. It reduces dependency on interpreters or intermediaries, thereby increasing autonomy and dignity.

The technology contributes to equal access to information, services, education, and justice, regardless of one's physical ability. When accessibility is embedded in technological innovation, it leads to a fairer and more just society where everyone has equal opportunity to thrive.

SDG 11: Sustainable Cities and Communities

"Make cities and human settlements inclusive, safe, resilient and sustainable."

Smart cities must be inclusive cities. By facilitating accessible communication in public transport, emergency services, community centers, and workplaces, this system aligns with the vision of sustainable urban living for all.

It ensures that individuals with hearing impairments are not excluded from urban digital transformation, fostering greater civic participation and interaction. When public services are equipped with inclusive technologies, cities become more livable, responsive, and sustainable.

SDG 16: Peace, Justice, and Strong Institutions

"Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels."

Access to information and the ability to communicate effectively are fundamental to justice and civic inclusion. This system supports democratic participation by allowing people with hearing disabilities to engage in legal, governmental, and social processes with clarity.

Whether accessing public information, reporting crimes, or seeking justice, individuals are empowered to do so independently and confidently. It contributes to making institutions more trustworthy, transparent, and representative of every voice in society.

SDG 17: Partnerships for the Goals

"Strengthen the means of implementation and revitalize the global partnership for sustainable development."

The success and scalability of this solution rely on strong partnerships between governments, NGOs, educational institutions, healthcare providers, and tech developers. By fostering collaboration, knowledge-sharing, and co-development, the project exemplifies how collective action drives innovation.

This goal underscores the importance of shared responsibility, funding, and international cooperation in achieving inclusive solutions. The project is designed to be open to integration, adaptation, and global deployment through multi-stakeholder collaboration.