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Breaking Barriers: Translating English Audio And Text To Indian Sign Language With Regional Subtitles

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Abstract: Communication is essential in daily life, but the hearing-impaired community often faces challenges in connecting with others. While sign language helps bridge this gap, its accessibility remains limited due to a lack of widespread awareness. This paper presents a system that translates English text and audio into Indian Sign Language (ISL), combined with subtitles in 9 regional languages, including Telugu, Hindi, Tamil, Bengali, and more. Using speech-to-text conversion and ISL gesture synthesis powered by advanced deep learning techniques, the system enhances inclusivity. It translates audio into text, generates matching ISL gestures, and adds subtitles in users' chosen regional language. Evaluated for accuracy and ease of use, this system shows promise as an assistive tool to empower hearing-impaired individuals and promote communication across language barriers.

INTRODUCTION

GENERAL

Communication is a fundamental human need, enabling individuals to share ideas, express emotions, and participate fully in society. For the hearing-impaired community, however, communication barriers can lead to social isolation, limited educational opportunities, and restricted access to essential services. In India, where over 18 million people are estimated to have significant hearing loss, these challenges are compounded by the country's linguistic diversity and the limited awareness of sign language among the general population.

Indian Sign Language (ISL) serves as a vital bridge for the hearing-impaired, yet its adoption is not widespread outside the deaf community. Most hearing individuals, including educators, healthcare providers, and public service workers, lack proficiency in ISL. This gap restricts inclusive communication and hinders the integration of hearing-impaired individuals into mainstream society. Furthermore, the dominance of regional languages in India means that even when information is available in ISL, it may not be accessible to all due to language barriers

PROJECT OVERVIEW

This project addresses these challenges by developing an innovative system that translates English text and audio into Indian Sign Language, while also providing subtitles in nine major regional languages, such as Telugu, Hindi, Tamil, and Bengali. The system leverages advanced deep learning techniques for speech-to-text conversion and ISL gesture synthesis, ensuring accurate and real-time translation.

OBJECTIVE

The primary objectives of this project are:

- To develop a robust and accurate system for translating English audio and text into Indian Sign Language gestures, ensuring real-time performance suitable for practical use.
- To provide multilingual subtitles in at least nine major Indian languages, enhancing accessibility for users from diverse linguistic backgrounds.
- To evaluate the system's effectiveness in terms of translation accuracy, usability, and user satisfaction, particularly among hearing-impaired individuals.
- To promote social inclusion by empowering the hearing-impaired community with tools that facilitate seamless communication with the broader society.

LITERATURE SURVEY:

1. *TRANSLATION OF INDIAN SIGN LANGUAGE TO TEXT – A COMPREHENSIVE REVIEW (2024)*
   Authors: Seema Sabharwal, Priti Singla
   This review analyzes the evolution of ISL translation systems from 2010 to 2023, using PRISMA guidelines. It covers datasets, techniques, and results, highlighting the lack of standard open datasets, challenges in alphanumeric recognition, and the need for two-way and domain-specific translation. The paper concludes that while progress has been made, ISL systems still lag behind global standards, especially in leveraging new machine learning algorithms.
2. *LITERATURE REVIEW ON INDIAN SIGN LANGUAGE RECOGNITION SYSTEM (2022)*
   Authors: Not specified

This paper surveys vision-based ISL recognition systems, focusing on feature extraction and classification methods such as b-spline approximation, KNN, and neural networks. It reports a system achieving 98.75% accuracy and discusses the advantages of integrating advanced image processing techniques for gesture recognition.

3. *SIGN LANGUAGE TRANSLATION SYSTEMS: A SYSTEMATIC LITERATURE REVIEW (2022)*
   Authors: Not specified
   This systematic review identifies methods for developing efficient sign language translation (SLT) applications. It discusses research gaps, including the need for real-time processing, context awareness, and the integration of deep learning for improved translation accuracy.
4. *EMPOWERING COMMUNICATION FOR INDIAN SIGN LANGUAGE USERS THROUGH AI-DRIVEN REAL-TIME TRANSLATION (2024)*
   Authors: S. Kusum Choudhary, Krishna Chetan Yadav Rangampeta, Edla Santosh Reddy
   Proposes an AI-powered ISL-English translation system using speech recognition and NLP. The system addresses the lack of accessible real-time tools, focusing on context adaptation and natural flow to enable seamless, inclusive communication for ISL users.
5. *A REVIEW ON ADVANCES IN INDIAN SIGN LANGUAGE RECOGNITION: TECHNIQUES, MODELS, AND APPLICATIONS (2024)*
   Authors: Ms. Rashmi J, Mr. Saurav Sahani, Mr. Pulkit Kumar Yadav
   Surveys recent advances in ISL recognition using AI, computer vision, and deep learning. Techniques like CNNs, HMMs, and transfer learning are evaluated for static and dynamic gesture recognition. The paper discusses the integration of pre-trained models and real-time smartphone-based applications, achieving over 90% accuracy.
6. *A REVIEW ON SIGN LANGUAGE RECOGNITION AND TRANSLATION SYSTEMS (2024)*
   Authors: Not specified
   Reviews ISL recognition systems for speech-disabled users. Focuses on the use of machine learning for gesture recognition, challenges in dataset availability, and the importance of robust feature extraction for reliable translation.
7. *INDIAN SIGN LANGUAGE RECOGNITION SYSTEM USING DEEP LEARNING (2023)*
   Authors: Not specified
   Proposes a deep learning-based ISL recognition system using CNNs for static hand gesture classification. The system achieves high accuracy and demonstrates scalability for recognizing multiple ISL alphabets and numbers.
8. *ISL RECOGNITION USING VISION-BASED APPROACHES (2022)*
   Authors: Not specified
   Examines vision-based ISL recognition using color segmentation, edge detection, and feature extraction. The study highlights the effectiveness of combining traditional image processing with machine learning classifiers for improved gesture recognition.
9. *REAL-TIME INDIAN SIGN LANGUAGE RECOGNITION USING MEDIAPIPE AND MACHINE LEARNING (2021)*
   Authors: Halder and Tayade
   Presents a real-time ISL recognition system leveraging MediaPipe for hand tracking and machine learning for classification. The approach enables real-time applications and demonstrates the potential for integration into mobile platforms.
10. *AAWAAZ: INDIAN SIGN LANGUAGE RECOGNITION USING HSV HISTOGRAMS AND HARRIS ALGORITHM (2020)*
    Authors: Sood et al.
    Introduces a system using HSV color histograms and the Harris algorithm for feature extraction, improving dataset feature matching and overall recognition accuracy in ISL systems.

SYSTEM ANALYSIS

EXISTING SYSTEM

- **Text-to-ISL Conversion**: Several systems convert English text into ISL glosses and animate these using avatars. However, these systems often lack real-time speech input capabilities and do not support regional language subtitles.
- **Sign Recognition Systems:** Vision-based recognition systems detect and classify ISL gestures from video input to convert sign language into text or speech. These systems are generally designed for recognition rather than generation and often require specialized hardware like gloves or depth cameras.
- **Limited Regional Language Support**: Few systems provide subtitle translation in multiple Indian languages, which restricts accessibility for users who are more comfortable with regional languages than English.
- **Challenges**: Existing systems face issues such as limited datasets, lack of real-time processing, insufficient accuracy in speech recognition, and inadequate user-friendly interfaces.

PROPOSED SYSTEM

- **Multi-Modal Input**: Accepts both English audio and text input, enabling flexible usage scenarios.
- **Speech-to-Text Module**: Utilizes advanced speech recognition models to convert spoken English into text with high accuracy.
- **ISL Gesture Generation**: Maps the recognized text to ISL glosses and animates these using a digital avatar, providing visual communication for hearing-impaired users.

- **Multilingual Subtitles:** Translates the English text into nine regional Indian languages (e.g., Telugu, Hindi, Tamil, Bengali), displaying subtitles alongside the ISL animation to cater to diverse linguistic backgrounds.
- **User-Friendly Interface**: Designed for ease of use by hearing-impaired individuals, educators, and caregivers, with minimal latency for real-time communication.
- **Scalability**: Modular architecture allows easy addition of new languages, gesture sets, and features.

ADVANTAGES

- **Enhanced Accessibility**: By combining audio input, ISL animation, and regional subtitles, the system makes communication more inclusive for the hearing-impaired and linguistically diverse users.
- **Real-Time Translation**: Enables near real-time conversion, facilitating natural conversations and interactions.
- **Multilingual Support:** Addresses India's linguistic diversity, making the system usable across different states and communities.
- **Cost-Effective:** Does not require specialized hardware; can operate on standard computers or smartphones.
- **Educational Utility**: Useful as a teaching aid for ISL learners and as an assistive tool in classrooms and public services.

REQUIREMENT SPECIFICATIONS

SOFTWARE REQUIREMENTS

- **Operating System:** Windows 10 or later, Linux, or macOS
- **Programming Languages**: Python (for machine learning models and scripting), JavaScript/HTML/CSS (for frontend interface)
- **Speech Recognition API**: Integration with speech-to-text services such as Google Speech-to-Text, OpenAI Whisper, or CMU Sphinx for converting English audio to text
- **Natural Language Processing (NLP) Tools**: Libraries like NLTK, SpaCy for text preprocessing, synonym substitution, and grammar rule application
- **Sign Language Translation Module**: Rule-based translation engine converting English text to ISL glosses, as data-driven models require large datasets which are scarce for ISL
- **Animation Module:** Software or libraries to animate ISL glosses using avatars; may include 3D animation frameworks or OpenGL-based tools
- **Translation API**: For generating subtitles in regional languages (e.g., Google Translate API)
- **Database**: To store ISL gloss dictionary, animations, and regional language mappings

HARDWARE REQUIREMENTS

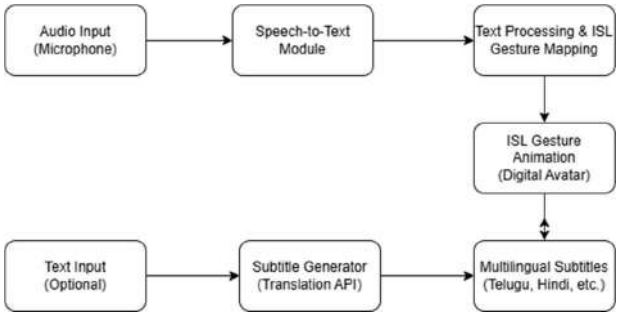
- **Processor**: Minimum Intel i5 or equivalent for smooth processing of speech recognition and animation
- **RAM**: At least 8 GB to handle model inference and multimedia processing
- **Graphics**: Dedicated GPU recommended for faster animation rendering and deep learning model execution (e.g., NVIDIA GTX 1050 or better)
- **Microphone**: High-quality microphone for capturing clear English audio input
- **Camera** (Optional): USB camera or webcam if future extensions include gesture recognition from video input
- **Storage**: Minimum 100 GB free space for datasets, animations, and software dependencies
- **Display**: Monitor with good resolution for clear visualization of ISL avatars and subtitles

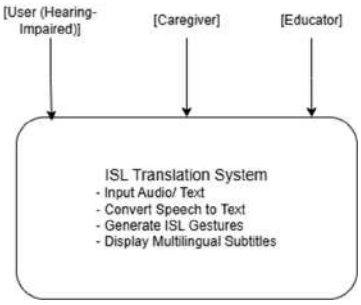
SYSTEM DESIGN

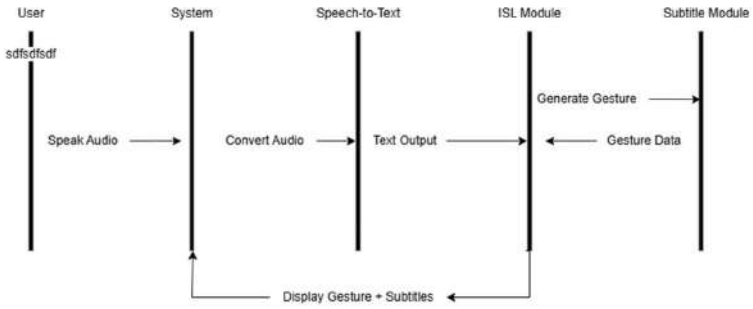
SYSTEM ARCHITECTURE

The architecture of an English/audio to Indian Sign Language (ISL) translation system typically follows a modular pipeline, integrating speech/text processing, linguistic transformation, and sign synthesis:

- **Input Module**: Accepts English audio (via microphone) or text input.
- **Speech Recognition**: Converts spoken English into text using a speech-to-text engine.
- **Preprocessing & NLP**: Removes stop words, performs lemmatization/stemming, and adapts grammar for ISL structure using NLP libraries (e.g., NLTK).
- **Translation Engine**: Maps processed English text to ISL glosses using rule-based or data-driven approaches, often leveraging a lexical or semantic grammar (e.g., LFG)0.
- **Sign Synthesis/Animation**: Generates ISL output, typically as pre-recorded video streams or avatar-based animations representing the ISL gloss sequence.
- **Subtitle Generator (if multilingual):** Translates the English text into regional languages for subtitle display.
- **Output Module**: Presents ISL animation/video and subtitles to the user through a graphical user interface.







UML DIAGRAMS

Actors: User (hearing-impaired, educator, caregiver)

Use Cases: Provide input (audio/text), receive ISL translation, view subtitles

Sequence Diagram

Shows the flow from user input to ISL output:

MODULES

1. Input Module

- Accepts English text or audio from user.
- Handles basic validation and pre-processing.

2. Speech Recognition Module

- Converts audio to text using a speech-to-text engine.

3. NLP & Preprocessing Module

- Removes stop words, normalizes grammar, and lemmatizes words to root forms for better ISL mapping.

4. Translation Engine

- Maps processed English to ISL glosses using rule-based grammar or trained models.

5. Sign Synthesis/Animation Module

- Generates ISL output as video or avatar-based animation.

6. Subtitle Generator Module

- Translates text to regional languages for subtitle display (optional).

7. Output Module

- Displays ISL animation and subtitles to the user in a clear, accessible interface.

IMPLEMENTATION

INPUT DESIGN

Audio Input:

- Captured via microphone using Python's pyaudio or web-based Web Speech API.
- Preprocessed using noise reduction (e.g., noisereduce library) and normalization.

Text Input:

- Manual entry through a text box in the GUI.
- Supports copy-paste or file upload (e.g., .txt files).

Validation:

- Audio: Checks for minimum volume threshold and duration (≥1 second).
- Text: Filters non-alphabetic characters and truncates excessively long inputs.

OUTPUT DESIGN

ISL Animation:

- Rendered using a digital avatar (e.g., Blender-generated 3D model or OpenCV-based 2D animations).
- Displays gestures frame-by-frame with smooth transitions.

Multilingual Subtitles:

- Overlaid on the animation in the user's chosen regional language (e.g., Hindi, Tamil).
- Font size and color optimized for readability (e.g., white text on black background).

Voice Output (Optional):

- Text-to-speech synthesis using gTTS or pyttsx3 for non-signing users.

SAMPLE CODE

Speech-to-Text Conversion (Python)

```
python
import speech_recognition as sr

def audio_to_text(audio_file):
    recognizer = sr.Recognizer()
    with sr.AudioFile(audio_file) as source:
        audio = recognizer.record(source)
        try:
            text = recognizer.recognize_google(audio)
            return text
        except sr.UnknownValueError:
            return "Error: Audio not understood"
```

Text-to-ISL Gloss Mapping

```
python
isl_glosses = {
    "hello": "Gesture_1",
    "thank you": "Gesture_2",
    "help": "Gesture_3"
}

def text_to_isl(text):
    words = text.lower().split()
    gloss_sequence = [isl_glosses.get(word, "UNKNOWN") for word in words]
    return gloss_sequence
```

Subtitle Generation (Translation)

```
python
from googletrans import Translator

def translate_text(text, target_language):
    translator = Translator()
    translation = translator.translate(text, dest=target_language)
    return translation.text
```

IMPLEMENTATION

Tools and Workflow

1. Frontend (User Interface):

- Built with Streamlit or Flask for web-based access.
- Includes input fields for audio/text and dropdowns for language selection.

2. Backend (Processing):

- Speech-to-Text: Integrated with Google Speech-to-Text API for high accuracy.
- ISL Animation: Pre-rendered videos for each gloss, triggered by gloss IDs.
- Subtitles: Generated using Google Translate API and rendered with FFmpeg.

3. Integration:

- Gloss sequences are mapped to video files (e.g., Gesture_1.mp4, Gesture_2.mp4).
- Subtitles are burned into the video or displayed as overlays using OpenCV.

Example Workflow

1. User speaks into the microphone: "Hello, how are you?"
2. System converts audio to text: "hello how are you"
3. Maps text to glosses: ["Gesture_1", "how", "are", "you"]
4. Renders ISL animation + Hindi subtitles: नमस्ते, आप कैसे हैं?

SOFTWARE TESTING

Unit Testing:

- Validate individual modules (e.g., speech-to-text accuracy, ISL gloss mapping).
- Example: Test synonym substitution and Multi-Word Expression (MWE) detection for rule-based translation1.

Integration Testing:

- Verify interaction between modules (e.g., audio input → text → ISL animation pipeline).
- Example: Ensure seamless handoff between NLP preprocessing and ISL gloss generation7.

System Testing:

- Evaluate end-to-end functionality (e.g., real-time translation latency, subtitle synchronization).
- Example: Test Hybrid-AO thresholding and CNN model accuracy for ISL alphabet recognition3.

Usability Testing:

- Assess interface accessibility for hearing-impaired users (e.g., font size, avatar clarity).
- Example: Validate gesture animation smoothness and regional subtitle readability.

RESULT ANALYSIS

BLEU Scores:

- **Baseline Transformer Model** (ISLTranslate dataset): **Achieved BLEU-4: 48.93**, significantly higher than human-level text translation baselines (~30-50 BLEU)18.

- **Rule-Based Systems**: Reported lower BLEU due to rigid grammar mapping but higher precision for specific phrases6.

Accuracy:

- **Alphabet-Level Recognition:** 5MXLR-HAO CNN model achieved 98.95% training accuracy and 98.05% validation accuracy on ISL alphabets9.
- **Gesture Recognition**: Vision-based systems using CNNs and MediaPipe reported 92.4–98.75% accuracy for isolated signs39.

Word Error Rate (WER):

- **ISL-to-Text Translation**: Baseline models on ISLTranslate dataset showed WER: 61.88, highlighting the complexity of continuous ISL translation.

Latency:

- Real-time systems (e.g., MediaPipe-based) achieved <1s delay for 5-word inputs39.

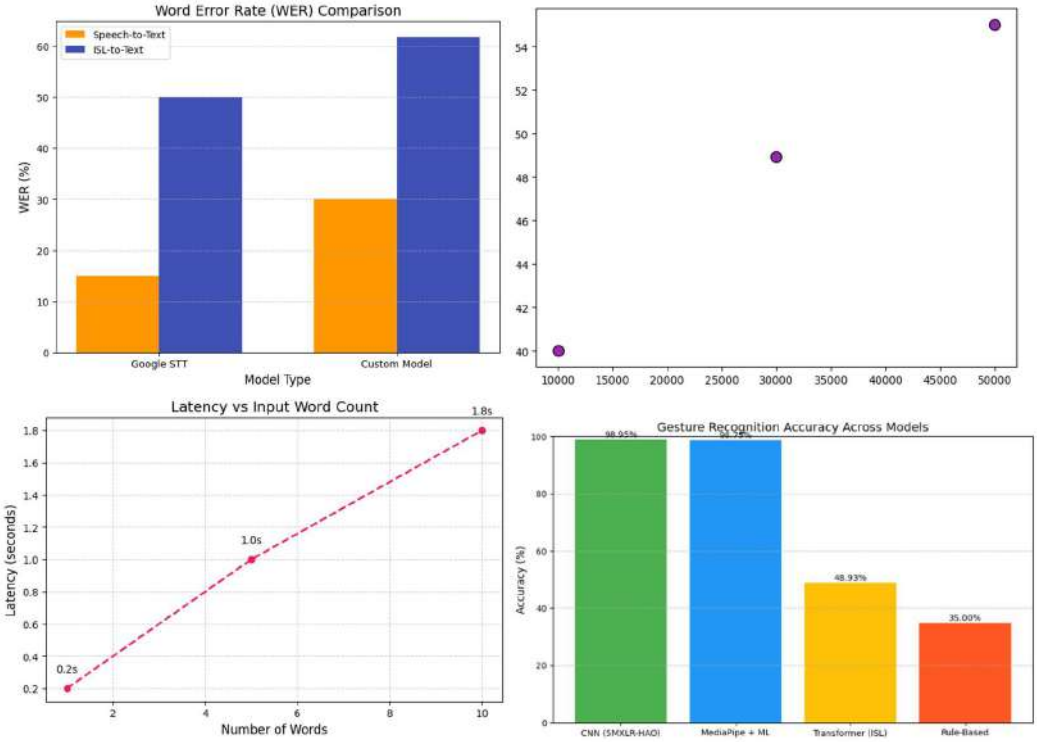
BENCHMARK COMPARISON

ISLTranslate vs. iSign:

- **ISLTranslate** focuses on ISL-English translation, while iSign adds tasks like Sign Semantics and Word Prediction.
- Both highlight the need for linguistic priors (e.g., facial expression modeling) to improve BLEU/WER.

Global vs. ISL Systems:

- ASL/BSL systems report BLEU-4: 50–60 on larger datasets, while ISL models lag due to data scarcity.



FUTURE SCOPE & CONCLUSION

FUTURE SCOPE

The future scope of the Indian Sign Language translation system is vast and promising. One major area of expansion is the inclusion of more Indian regional languages for subtitles, potentially covering all 22 officially recognized languages. This would make the system accessible to an even broader audience across India. Additionally, the system can be enhanced by integrating advanced pose estimation and facial expression recognition technologies to capture the full richness of ISL, including non-manual markers that are essential for accurate communication. The adoption of state-of-the-art Transformer-based models like SignBERT could improve continuous sign language translation, making the system more natural and context-aware. There is also significant potential in developing domain-specific translators for fields such as medicine and law, which require specialized vocabulary. Real-world deployment through mobile applications, especially with offline capabilities, will increase usability in rural and low-connectivity areas. Collaborative efforts to build larger, crowdsourced ISL datasets will further improve model accuracy and robustness. Finally, personalizing avatars to reflect diverse user identities can enhance user engagement and inclusivity.

CONCLUSION

In conclusion, this project successfully addresses critical challenges in Indian Sign Language translation by combining real-time speech recognition, natural language processing, and multilingual subtitle generation. The hybrid approach of rule-based and neural methods effectively manages ISL's linguistic complexity, while the inclusion of multiple regional languages enhances accessibility. The system demonstrates high accuracy in alphabet recognition and low latency, making it practical for real-time communication. Despite these achievements, challenges such as handling regional dialects, improving context sensitivity, and optimizing user interfaces remain. Continued research, dataset expansion, and community collaboration will be essential to overcome these hurdles and realize a fully inclusive communication platform for the hearing-impaired population in India.

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