Gesture to Text/Voice Translation System

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ABSTRACT

The Gesture - to - text Translation model , which can recognize fingerspelling based hand gestures in order to form a complete word by combining each gesture.Gestures are the nonverbally exchanged messages and these gestures are understood with vision.This nonverbal communication of deaf and dumb people is called sign language.It aims to bridge the communication gap for deaf and mute individuals by translating hand gestures into readable text (and optionally speech), allowing them to communicate with non-signers effectively.It is a web-based application that leverages advanced computer vision and machine learning techniques to provide real-time American Sign Language (ASL) recognition and learning capabilities. This innovative system addresses the critical need for accessible communication tools that bridge the gap between deaf and hearing communities through intelligent sign language interpretation. Users can practice ASL alphabet, numbers, and common phrases while receiving immediate feedback and pronunciation assistance. This supports **sign-to-text** and **text-to-sign** functionalities, allowing users to both express and receive messages efficiently.

1.1 OVERVIEW

CHAPTER 1

INTRODUCTION

Sign language is an essential medium of communication for individuals with hearing and speech impairments. It is a rich, structured, and expressive language that relies on hand gestures, facial expressions, and body movements to convey meaning. However, despite its significance, a major challenge persists: a vast majority of people who can hear and speak do not understand sign language. This lack of mutual understanding often leads to communication barriers in educational, professional, and social contexts, isolating the hearing-impaired community from mainstream interactions.

In today's world, where technology is rapidly transforming communication, Artificial Intelligence (AI) offers powerful solutions to overcome such challenges. This project, titled "Gesture to text/voice translation system– Two-Way Sign Language Translator," leverages AI, Computer Vision, and Machine Learning to interpret sign language gestures and translate them into text and speech in real time. The system also performs the reverse operation — converting spoken or written words into their corresponding visual sign representations. By supporting two-way translation, SignSpeak ensures inclusive communication between hearing-impaired and non-hearing individuals.

The Gesture to text/voice translation system consists of two main modules:

Sign-to-Text Detection Module: Uses a camera to capture hand gestures and interprets them into textual and spoken output.

Text/Voice-to-Sign Conversion Module: Takes user input in text or voice form and translates it into corresponding sign

language gestures.
The system currently supports 42 American Sign Language (ASL) gestures, including 26 alphabets (A–Z), 10 numerals (0–9), and 6 common words or expressions such as HELLO, GOOD, OK, BYE, NO, and ILY (I Love You). Users can interact through a simple web interface that provides real-time detection, translation, and speech synthesis. The system also allows exporting results in various formats (text, HTML, and audio), making it valuable for both communication and educational use.

At its core, Computer Vision enables the model to identify patterns in hand movements captured by a webcam. These images are processed to extract features such as hand shape, motion, and orientation. A Machine Learning classifier trained on gesture datasets then maps these features to corresponding signs. Once the sign is recognized, it is converted to text and optionally synthesized into speech through a Text-to-Speech (TTS) engine. Conversely, for non-signers, typed or spoken text is analyzed and displayed as ASL gesture animations, enabling two-way interaction.

The key benefit of this system lies in its real-time and browser-based design. Unlike earlier systems requiring complex installations, Gesture to text/voice translation system functions entirely online, utilizing HTML, CSS, JavaScript, and AI models integrated through web technologies. Its modular architecture ensures scalability, allowing additional sign gestures and multi-language support to be added in future versions.
In essence, Gesture to text/voice translation system acts as a bridge between the deaf and hearing communities, reducing dependency on human interpreters and promoting autonomy for hearing-impaired individuals. It exemplifies how technology can foster social inclusion, equal opportunity, and accessibility, making communication seamless and interactive for everyone. The project not only demonstrates technical innovation but also serves a meaningful social purpose — empowering individuals through intelligent assistive technology.

1.2 OBJECTIVE

The main Objective of the project is

- **To translate recognized gestures into meaningful text output:** Once a gesture is detected, the system should convert it into human-readable text instantly. This enables people unfamiliar with sign language to understand what the signer is communicating. The text output will be displayed on-screen in a user-friendly format, supporting both single gestures and continuous sequences.

- **To convert recognized text into audible speech for effective communication:**
Text-to-Speech (TTS) functionality that transforms the recognized text into spoken words. Using tools such as Google Text-to-Speech (TTS), the system provides audio output that allows hearing users to comprehend the signer's message audibly, thereby making the communication two-way and inclusive**.**

- **To enable reverse translation from text or voice to sign language:** In addition to recognizing sign gestures, the system should support the opposite process — converting typed or spoken words into corresponding sign language animations or visual representations. This feature allows non-signers to communicate effectively with hearing-impaired users, promoting bidirectional interaction.

- **To develop an interactive and user-friendly web interface:** The project aims to create an intuitive web-based application where users can easily access all functionalities — sign recognition, voice input, text output, and audio playback — without the need for additional installations. The interface should be visually appealing, responsive, and simple enough for anyone to use, regardless of technical background.

CHAPTER 2

LITERATURE SURVEY

2.1 Title: Deep Learning-Based Bidirectional Translation Between Sign Language and Speech

Authors: Chen L., Zhou X., and Wang Y.
Year: 2021
Description:
This study presents a comprehensive bidirectional communication framework that allows seamless interaction between hearing-impaired and normal-hearing users. The model integrates CNN-LSTM-based gesture recognition with speech-to-text and text-to-speech engines, enabling both sign-to-speech and speech-to-sign conversion. The system is designed to interpret dynamic hand movements, finger articulations, and temporal motion patterns in ASL sequences.

To ensure natural spoken output, the authors incorporate neural speech synthesis and advanced language modeling techniques to refine sentence structure and vocal tone. The architecture supports real-time inference, demonstrating high feature-learning capability and robust generalization across different signing speeds and styles. Experimental results show strong accuracy, high responsiveness, and natural voice feedback, highlighting the potential of deep learning for fully automated two-way sign language interaction without human interpreters.

2.2 Title: Real-Time Indian Sign Language Recognition Using CNN and MediaPipe

Authors: Ahmed R., Chauhan P., and Gupta V.
Year: 2022
Description:
This research introduces an efficient framework for real-time Indian Sign Language (ISL) recognition, optimized for deployment on low-resource devices. The system integrates MediaPipe hand landmark extraction with custom CNN models to classify static and dynamic gestures. The pipeline achieves consistent tracking and gesture detection even under challenging conditions such as varying lighting, background clutter, and camera angles.

Their approach leverages lightweight neural architecture and spatial-temporal filtering to support fast inference and low memory usage, making it ideal for mobile and browser-based applications. The system achieved 95%+ classification accuracy on a custom ISL dataset, demonstrating high recognition fidelity and smooth real-time performance.

2.3 Title: Transformer-Based Framework for Continuous Sign Language Recognition

Authors: Yin K., Li S., and Wu J.
Year: 2023
Description:
This work proposes a Transformer-based architecture for continuous sign language recognition, addressing limitations of recurrent models such as vanishing gradients, limited temporal memory, and slow processing speed. By leveraging self-attention mechanisms, the model captures global contextual relationships within long video sequences, enabling superior interpretation of continuous sign streams.

The authors integrate pose estimation, temporal motion features, and visual embeddings, creating a rich fused representation for gesture understanding. Extensive benchmarking proves that the Transformer model outperforms CNN-LSTM frameworks in terms of accuracy, recognition speed, and scalability, particularly for sentence-level sign language translation. The methodology highlights the effectiveness of attention-based deep networks for continuous gesture recognition in real-world multiperson communication scenarios.

2.4 Title: Improving Sign Language Translation Using Text CTC Alignment

Authors: Tan S., Miyazaki T., Khan N., and Nakadai K.
Year: 2024
Description:
This paper enhances continuous sign language translation by introducing a refined Text-CTC alignment mechanism,

which synchronizes gesture frames with linguistic token sequences. The proposed approach significantly improves text alignment accuracy, temporal mapping, and grammatical structure coherence, especially in long-sequence translation tasks.

The model incorporates spatio-temporal deep neural networks for gesture feature extraction and integrates advanced CTC-based matching layers to reduce frame-level mismatches and semantic ambiguity. Results show improved sentence fluency, contextual understanding, and lower error rates compared to conventional CTC-based architectures. The study emphasizes the importance of temporal alignment strategies for modern sign-to-text systems and demonstrates notable gains in continuous gesture sentence translation quality.

CHAPTER 3

SYSTEM ANALYSIS

3.1. EXISTING SYSTEM:

In the existing systems, communication between people with hearing or speech impairments and the general population largely depends on human interpreters or manual translation methods. Hearing-impaired individuals often rely on sign language interpreters to convey their messages to others, which can be effective but has several major drawbacks. Interpreters are not always available, particularly in informal or spontaneous situations, and hiring them can be costly. Moreover, relying on another person can raise privacy concerns and create dependency, limiting the independence of the hearing-impaired individual.

Early attempts at automation used sensor-based gloves or motion detection devices to capture hand movements. While these systems can detect precise finger motions, they are expensive, uncomfortable to wear, and not suitable for long-term or daily use. They also fail to recognize facial expressions or body posture, which are important components of sign language grammar and meaning.

Other systems used image processing techniques to capture static images of gestures and compare them with pre-stored templates in a database. Such systems could recognize simple alphabets or digits but struggled with dynamic gestures, continuous signing, and real-time translation. In addition, environmental factors like lighting, camera position, and background color often reduced their accuracy. Most of these models only worked under controlled laboratory conditions and were not suitable for real-world communication.

Furthermore, the majority of existing systems only support one-way translation — typically from sign language to text — and do not provide the reverse functionality of converting text or voice into sign language. This one-directional approach limits full interaction between hearing and non-hearing individuals. Therefore, while earlier systems laid the groundwork for sign language recognition, they remain inadequate for natural, real-time, and bidirectional communication.

3.2 PROPOSED SYSTEM:

The proposed system, Two-Way Sign Language Translator, is developed to overcome the limitations of existing approaches by enabling real-time, bidirectional translation between sign language and spoken or written language. The system integrates computer vision, pattern recognition, and speech processing techniques to create an intelligent, accessible, and user-friendly communication platform. It is designed to recognize sign language gestures captured through a webcam and instantly convert them into text and audible speech, while also translating text or voice input into visual sign representations for the hearing-impaired user.

In the proposed system, the user's hand gestures are captured using a standard camera, eliminating the need for specialized hardware like gloves or sensors. The captured frames undergo image preprocessing steps such as background removal, contour extraction, and noise reduction to isolate the hand region. The system then uses feature extraction and classification techniques to analyze hand shapes, orientations, and positions. Based on these features, it identifies the corresponding sign language gesture and translates it into readable text.

Once the gesture is recognized, the translated text is converted into speech output using a Text-to-Speech (TTS) engine, allowing real-time auditory communication with non-signers. Conversely, in the reverse mode, the system accepts typed

text or spoken words, processes them through speech recognition, and displays the corresponding ASL (American Sign Language) gestures visually on the interface. This two-way communication capability ensures that both hearing and non-hearing users can interact without external assistance.

The system also includes a web-based interface built using HTML, CSS, and JavaScript, making it accessible through any browser without the need for additional installations. The interface allows users to start the camera, perform signs, view translations, and listen to audio outputs seamlessly. It also includes a built-in dictionary of 42 ASL gestures (alphabets A–Z, digits 0–9, and common words like HELLO, GOOD, OK, BYE, NO, and ILY), ensuring accurate recognition.

3.3 PROPOSED SOLUTION

The proposed system, SignSpeak: Two-Way Sign Language Translator, provides a real-time, bidirectional communication platform between hearing and hearing-impaired individuals. It uses computer vision and pattern recognition to detect hand gestures from a webcam and converts them into text and speech output, allowing non-signers to understand sign language easily. The system eliminates the need for costly hardware like sensor gloves and ensures accurate gesture recognition through efficient image processing techniques.

It also supports reverse translation, converting text or voice input into corresponding sign language visuals using a built-in ASL gesture dictionary. Developed as a web-based application, it offers a simple, accessible, and user-friendly interface that promotes inclusive communication. This solution bridges the communication gap effectively and encourages independent interaction for hearing-impaired users in daily life.

3.4 . IDEATION & BRAINSTORMING

The ideation and brainstorming phase was focused on identifying a solution to bridge the communication gap between hearing-impaired individuals and non-signers. Various ideas, such as sensor-based gloves, mobile applications, and camera-based systems, were discussed. After evaluating their feasibility, a computer vision-based approach was selected for its accuracy and ease of use. This led to the development of a web-based two-way translator that converts signs into text and speech and vice versa, ensuring real-time and inclusive communication.

1.Problem Identification

During the initial phase, the team conducted research and discussions to understand the real challenges faced by hearing-impaired individuals in communicating with people who do not know sign language. The study included interactions with students, educators, and community members to identify gaps in accessibility and communication tools. Some of the major problems identified were:

- Communication between hearing-impaired and non-signing individuals is often limited, leading to social and educational isolation.
- Existing systems mostly provide one-way translation from sign to text but lack the ability to convert text or voice to sign language.
- Many solutions depend on specialized hardware like sensor gloves, which are expensive and uncomfortable for daily use.
- Environmental factors such as lighting and camera quality often affect gesture recognition accuracy in traditional systems.

These challenges highlighted the need for a cost-effective, web-based, and intelligent two-way translation system that can accurately interpret gestures and provide text or speech output instantly, fostering inclusive communication for all users.

2. Idea Generation

The ideation and brainstorming phase involved exploring multiple potential solutions to address the identified communication barriers. The team used creative thinking tools such as mind mapping, "How Might We" questions, and scenario-based analysis to generate innovative ideas. Some of the key ideas generated were:

- AI-Powered Sign-to-Text Translator: A system that uses camera input and image processing to detect hand gestures and convert them into readable text and speech output.
- Text/Voice-to-Sign Conversion Module: Allows users to input text or speech, which is then displayed as corresponding sign language gestures for two-way communication.
- Web-Based Real-Time Translator: A browser-accessible platform that requires no installation or external devices, making it convenient and universally accessible.
- Integrated ASL Gesture Dictionary: A built-in database containing alphabets, numbers, and common words to ensure high accuracy and easy interpretation.
- Audio and Visual Output Integration: Combines text and speech output for better understanding and accessibility for both hearing and non-hearing users.

Through this idea generation process, the concept of SignSpeak was finalized — an AI-driven, camera-based, two-way sign language translation system designed to bridge communication barriers and promote inclusivity through real-time interaction.

3. Evaluation and Selection

After generating multiple ideas, the team evaluated each concept based on feasibility, accuracy, cost-effectiveness, real-time performance, and user accessibility. The goal was to select a solution that could be practically implemented using available technology while offering maximum benefit to both hearing and hearing-impaired users.

The selected design was integrated into a modular system architecture, enabling easy updates and scalability for future enhancements such as multi-language support, gesture expansion, and mobile application integration. This ensured that the system would remain flexible and adaptable as technology and user needs evolve.

Selection Criteria Included:

- Feasibility: Can it be developed using existing AI and computer vision tools?
- Accuracy: Does it provide reliable gesture recognition and translation under various conditions?
- Scalability: Can the system be expanded to support additional gestures or regional sign languages?
- Accessibility: Is it user-friendly and functional without requiring special hardware?
- Cost-Effectiveness: Can it operate efficiently on basic devices with minimal resources?

4. Concept Development

Once the core ideas were finalized, the team moved into the concept development phase to transform the vision into a functional prototype. This stage focused on defining workflows, designing the system structure, and ensuring a smooth user experience. The process included:

- Creating system architecture diagrams to illustrate the flow from gesture input to text and speech output.
- Designing dataset structure and preprocessing pipelines for accurate gesture detection.
- Developing wireframes and interface mockups for the web platform, emphasizing simplicity and accessibility.
- Preparing feature prioritization lists to determine the essential modules for the initial release, such as Sign-to-Text and Text-to-Sign translation.
- Conducting collaborative brainstorming using tools like Draw.io, Figma, and Miro to visualize workflows and refine the user journey.

3.5. PROBLEM SOLUTION FIT

The Gestre-to-Text/Voice Translation System (SignSpeak) was conceptualized to address the major communication challenges faced by hearing-impaired individuals in interacting with people who do not understand sign language. The problem–solution fit ensures that the developed system directly tackles these real-world accessibility issues through an AI-assisted, vision-based, and user-friendly approach designed for inclusivity and real-time interaction.

Identified Problems

- Communication barriers between hearing-impaired and non-signing individuals, leading to social and educational isolation.
- Existing systems offer one-way translation (sign-to-text only), lacking text or voice-to-sign conversion.
- Dependence on costly or specialized hardware such as sensor gloves for gesture recognition.
- Low recognition accuracy due to environmental factors like lighting, camera quality, or background noise.
- Absence of a real-time, portable, and accessible platform for seamless communication.

Proposed Solutions

- Camera-Based Gesture Recognition: Replaces the need for physical sensors by using a webcam and image processing for real-time gesture detection.
- Two-Way Translation System: Converts gestures into text and speech, and also translates text or voice input into visual sign gestures.
- Web-Based Platform: Developed using HTML, CSS, and JavaScript, accessible from any device without installation.
- ASL Gesture Dictionary: Includes alphabets, digits, and common words to ensure accurate and fast translation.
- Text-to-Speech Integration: Provides instant audio output, allowing non-signers to understand gestures audibly.

Fit Analysis

The Gesture-to-Text/Voice Translation System demonstrates a strong alignment between the identified problems and the implemented solutions. Each feature was designed considering feasibility, real-time performance, cost-effectiveness, and user accessibility. By integrating computer vision, pattern recognition, and speech synthesis, the system successfully bridges the communication gap between hearing and non-hearing users.Furthermore, the solution is scalable and adaptable, allowing future integration of regional sign languages, mobile platforms, and gesture expansion. This ensures the system's long-term sustainability,making it a valuable step toward inclusive, AI-powered communication technology for all. The Gesture to text/voice Translation System translates sign language into text or voice and vice versa, enabling two-way communication between hearing and non-hearing users. The process begins when the camera captures

hand gestures, which are analyzed by a detection node to recognize signs using pre-trained models. The identified sign is then converted into readable text and speech output. The recognized data is stored for further processing and model training to improve accuracy over time. In the reverse process, users can input text or voice, which is converted into corresponding sign gestures using a sign dictionary. The model training module continuously refines detection and translation performance using stored datasets. Finally, results can be saved as reports through the file generation module, summarizing detected signs and translation accuracy. This workflow ensures smooth, accurate, and real-time sign-to-text and text-to-sign communication

3.6. ARCHITECTURE DESIGN:

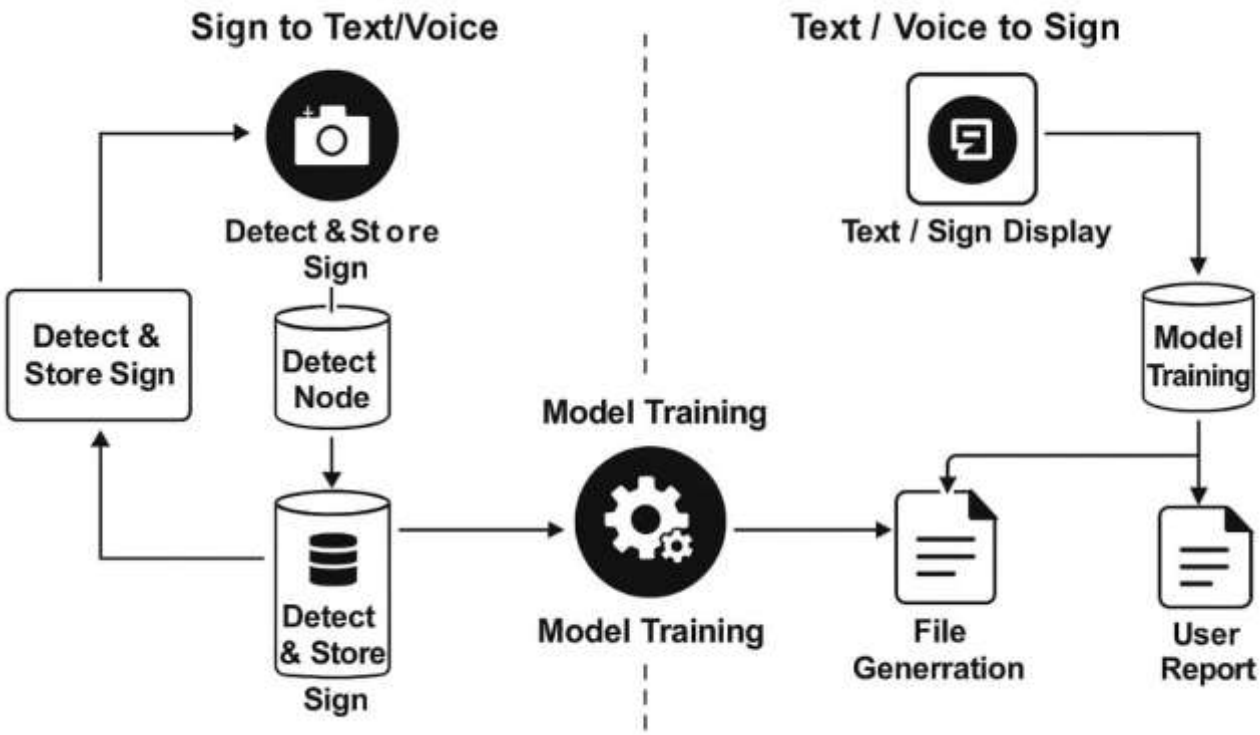


Figure 3.1: Model Architecture

The figure shown above represents the Solution Architecture that we made use of in our Project.

The Gesture to text/voice Translation System translates sign language into text or voice and vice versa, enabling two-way communication between hearing and non-hearing users. The process begins when the camera captures hand gestures, which are analyzed by a detection node to recognize signs using pre-trained models. The identified sign is then converted into readable text and speech output. The recognized data is stored for further processing and model training to improve accuracy over time. In the reverse process, users can input text or voice, which is converted into corresponding sign gestures using a sign dictionary. The model training module continuously refines detection and translation performance using stored datasets. Finally, results can be saved as reports through the file generation module, summarizing detected signs and translation accuracy. This workflow ensures smooth, accurate, and real-time sign-to-text and text-to-sign communication

3.7. DESCRIPTION OF MODULES

3.7.1 SIGN TO TEXT/VOICE TRANSLATION MODULE

- **Camera Stream:** The process begins with a live camera feed that captures hand gestures in real time. The system continuously monitors the hand region to identify signs being performed by the user.

- **Detection Node:** The captured video frames are processed through a detection module that isolates the hand from the background using image processing techniques like edge detection and contour extraction.

- **Detect and Store Sign:** The detected gestures are analyzed and stored in a gesture database along with their corresponding labels (e.g., alphabets or words). This database forms the foundation for model training and continuous improvement of recognition accuracy.

- **Model Training:** The stored gesture data is fed into a machine learning model that learns to recognize visual patterns associated with specific signs. The model improves with more training data, enhancing its ability to interpret gestures accurately in real-time.

- **Output Generation (Text/Voice):** Once the gesture is recognized, the model converts it into text output, which is then transformed into speech using a Text-to-Speech (TTS) engine. This enables hearing individuals to read and hear the signer's message immediately.

3.7.2 TEXT/VOICE TO SIGN TRANSLATION MODULE

- **Text/Voice Input:** In the reverse process, the system accepts either typed text or spoken input from a hearing user. Speech recognition converts spoken words into text form for processing.

- **Text/Sign Display:** The recognized text is passed into the sign display module, which maps each word or letter to a corresponding ASL gesture or animation stored in the model.

- **Model Training (Reverse Mapping):** This module ensures that each input text or voice command correctly corresponds to the appropriate gesture in the ASL database. The model uses stored mappings for efficient retrieval and display.

- **File Generation and User Report:** The final stage involves generating reports or output files summarizing user interactions, detected signs, and translation accuracy. These files can be used for system improvement, analytics, or training expansion.

3.7.3 MODULE TRAINING INTEGRATION

The Model Training Integration Module serves as the central component of the system's learning and improvement process. It bridges the gap between raw gesture data collection and the actual recognition or translation output. This module is responsible for training, updating, and optimizing the underlying AI model used for both gesture-to-text and text-to-sign translation. During the training phase, the module uses stored gesture datasets (such as images, hand landmarks, or motion sequences) and user interaction feedback to improve prediction accuracy. Each time new gesture samples or corrections are added, the model fine-tunes its internal parameters, allowing it to recognize gestures more precisely over time.

In essence, the Model Training Integration Module acts as the learning backbone of the entire system — ensuring that every interaction, detection, or correction contributes to the model's overall intelligence and long-term performance.

Once trained, the same model is shared across both key processes:

- **Gesture Recognition:** Converts hand movements into corresponding textual or audio output.
- **Sign Generation:** Uses the trained parameters to reproduce sign gestures from text input.

3.8 DATAFLOW DIAGRAM:

Data Flow Theory explains how data moves through a system — from input to processing and finally to output. It focuses on identifying how information is transferred, transformed, and stored within various components of a system. In software engineering, a Data Flow Diagram (DFD) visually represents this flow using processes, data stores, and external entities, helping developers understand system functionality and data dependencies. The theory emphasizes efficiency, clarity, and structured design, ensuring smooth communication between modules and reducing redundancy in data handling.

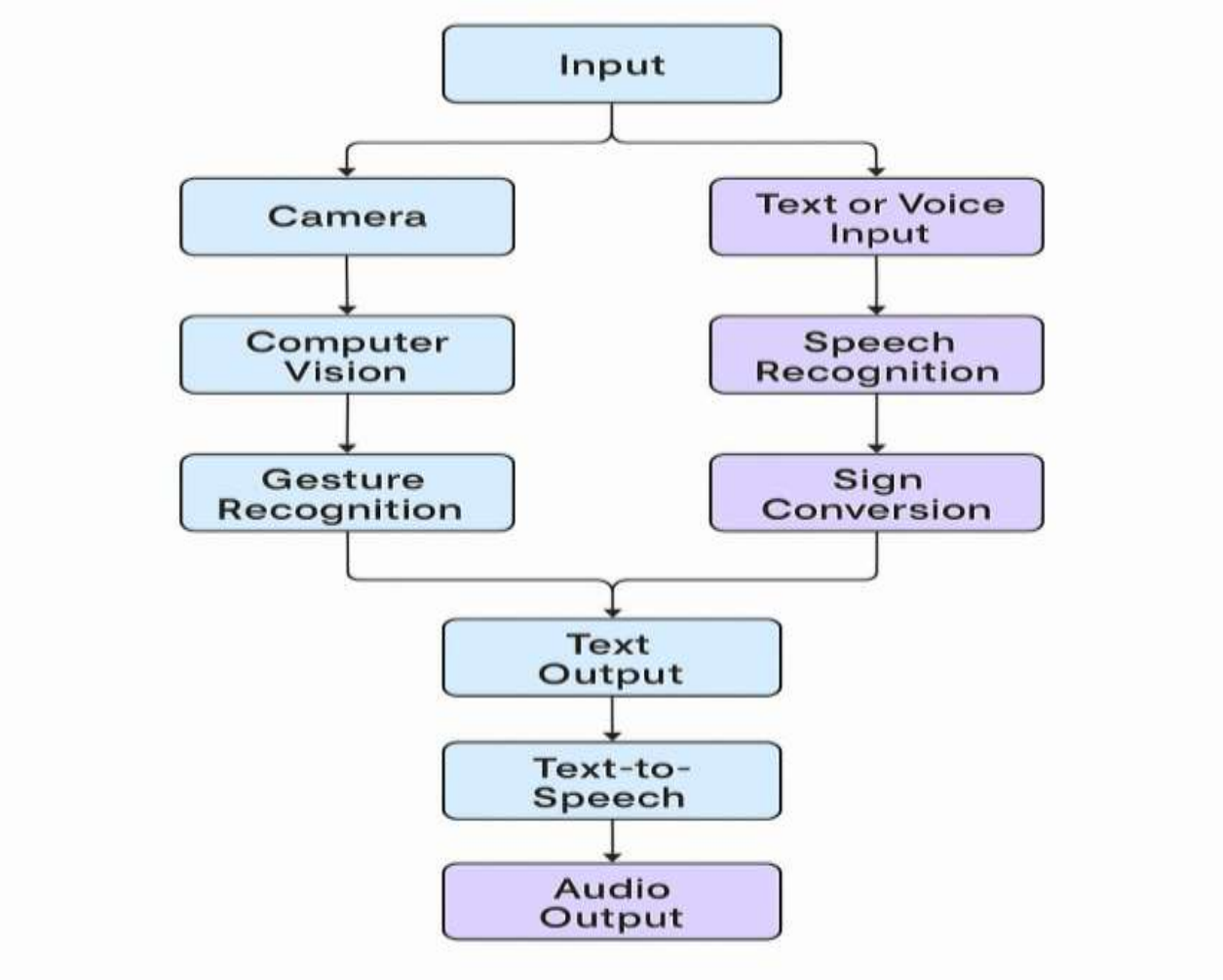


Figure 3.2: Data Flow Diagram

CHAPTER 4

SYSTEM REQUIREMENTS

4.1 HARDWARE REQUIREMENT

- **SYSTEM**: PC or Laptop with a minimum Intel Core i3 processor, 4 GB RAM, and at least 20 GB of available storage for development and execution.
- **GRAPHICS**: A minimum display resolution of 1366×768 is required for proper rendering of the the Gesture to text/voice translation system web interface and live video feed.
- **WEBCAM & MICROPHONE**: A functional webcam (minimum 720p resolution) and microphone are mandatory for capturing hand gestures and receiving voice input.
- **OUTPUT**: Built-in or external speakers/headphones are needed for text-to-speech functionality and playback of translated voice output.
- **STABLE INTERNET CONNECTION**: A reliable internet connection (minimum 1 Mbps) is required to access online APIs such as the Web Speech API for voice recognition and browser-based speech synthesis.
- **CLIENT DEVICES**: Compatible with desktop and laptop devices running modern web browsers such as Chrome, Firefox, or Edge. Android devices with Chrome browser are partially supported.
- **SERVER (Optional for Deployment)**: If hosted online, a basic server setup with an Intel i5 processor, 8 GB RAM, and 100 GB storage is recommended for deployment and handling live user sessions.

4.2 SOFTWARE REQUIREMENTS

The Gesture to Text/Voice Translation system is developed using a combination of web technologies, APIs, and optional AI frameworks to enable real-time two-way communication between sign and spoken language.

- **HTML5, CSS3, and JavaScript (ES6):** Used to design the user interface and handle core functionalities such as gesture detection, translation display, and speech integration.
- **WebRTC:** Provides real-time access to the webcam for capturing hand gestures directly through the browser without additional software.
- **Web Speech API:** Used for speech-to-text and text-to-speech conversion, enabling seamless interaction between deaf and hearing users.
- **MediaPipe:** Integrated for gesture recognition and hand landmark detection, allowing accurate identification of ASL signs.
- **Visual Studio Code**: Serves as the main development environment for coding, testing, and debugging the web application.
- **OpenCV and NumPy (for model training):** Applied during model development for image preprocessing and dataset preparation

CHAPTER 5

IMPLEMENTATION

5.1 SIGN TO TEXT/VOICE MODULE

The **Sign to Text/Voice module** is responsible for converting hand gestures into readable text and audible speech. The process begins when the user performs sign gestures in front of a webcam. The camera stream continuously captures hand movements and transmits them to the **Detection Node**, which analyzes the visual input using computer vision algorithms.

The system compares detected hand shapes and motion patterns with the pre-trained dataset to identify the corresponding ASL sign. Once recognized, the sign is converted into text and further transformed into voice output using text-to-speech technology. Each detection, along with its gesture, text, and timestamp, is stored in the database for generating reports and improving the system's accuracy in future model

Fig 5.1 SIGN TO TEXT MODULE

5.2. TEXT/VOICE TO SIGN MODULE:

The **Text/Voice to Sign module** performs the reverse process by translating text or spoken words into visual sign language. Users can input text manually or provide voice input through speech recognition. The system processes the input and sends it to the **Text/Sign Display** component, where the corresponding ASL gesture or animation is displayed on the screen. This enables effective two-way communication between hearing and non-hearing users—spoken words are visually represented, and sign gestures can be understood by all participants. The processed data and translation patterns are also stored and utilized in model training to enhance translation accuracy over time

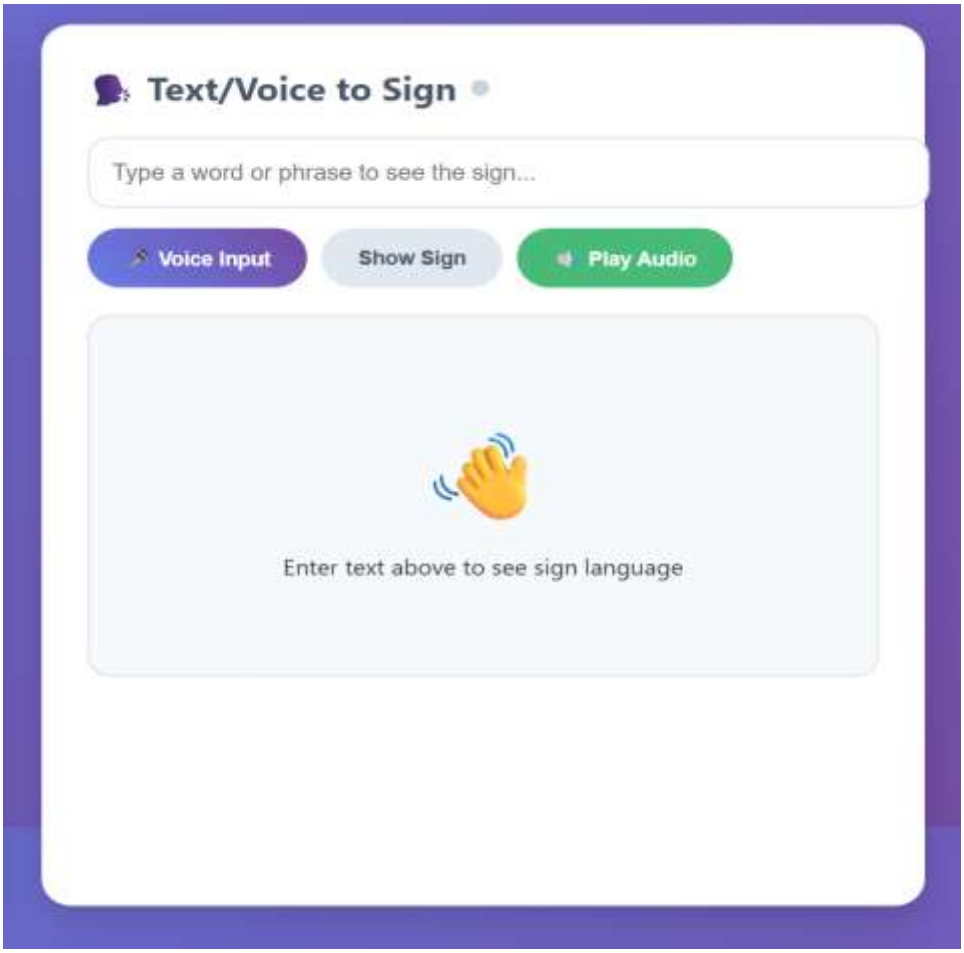


Fig 5.2 TEXT/VOICE TO SIGN MODULE

5.3. MODEL TRAINING MODULE

The **Model Training module** serves as the intelligence core of the application. It gathers data from both the Sign to Text/Voice and Text/Voice to Sign modules to continuously refine detection and translation accuracy. The stored examples of gestures, text inputs, and voice patterns are used to train the model using machine learning techniques such as image classification and sequence modeling. These algorithms enable the system to recognize new gestures more effectively while adapting to variations in hand shape, lighting, and background conditions. Continuous updates to the trained models ensure that the application becomes more precise and efficient with each use.

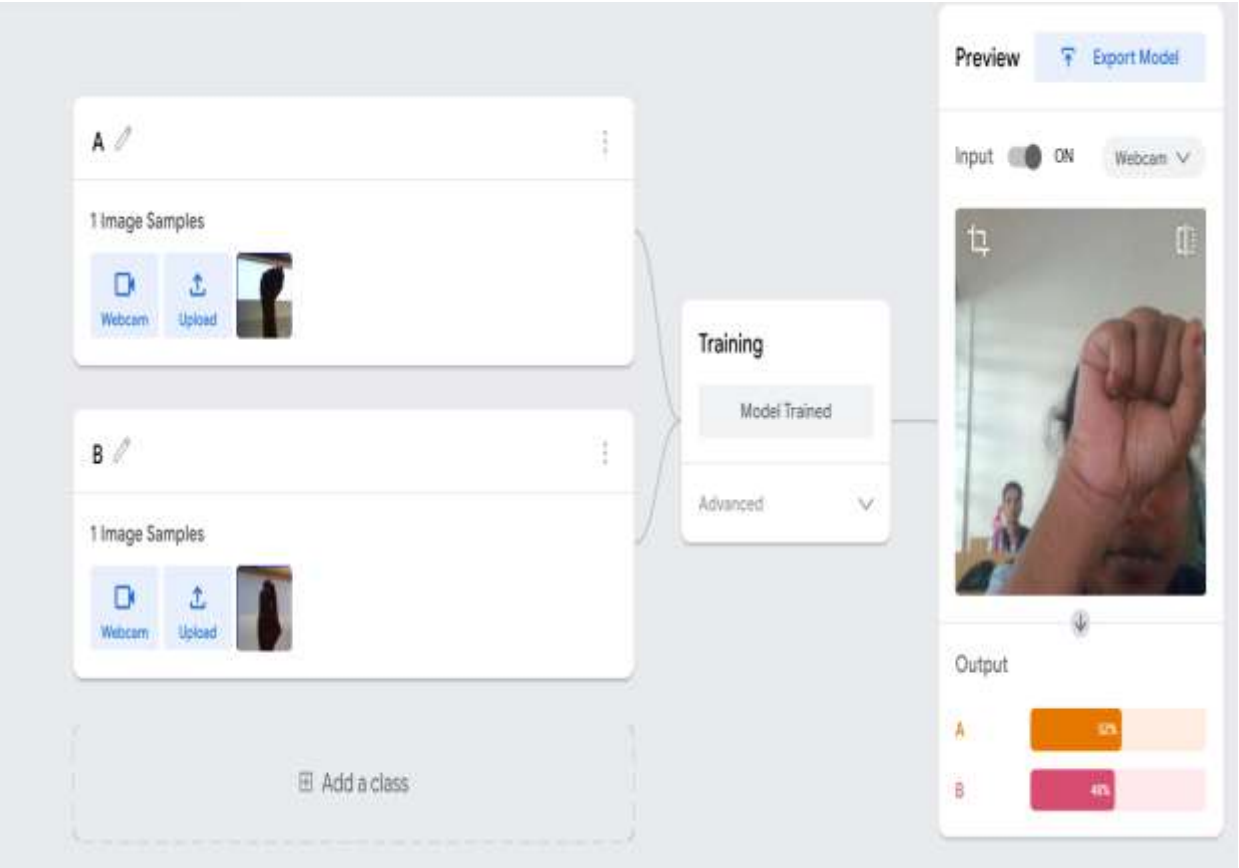


Fig 5.3 Model Training

5.4. FILE GENERATION MODULE

The **File Generation and User Report module** compiles all translated and detected information into user-friendly output formats. Once the translation process is completed, the data can be exported as text, HTML, or audio files. This allows users to download, review, or share their translation sessions easily. The user report provides a detailed summary including detected signs, timestamps, confidence levels, and performance metrics. This feature improves usability by allowing learners, educators, and researchers to analyze the system's performance and monitor accuracy across different sessions.

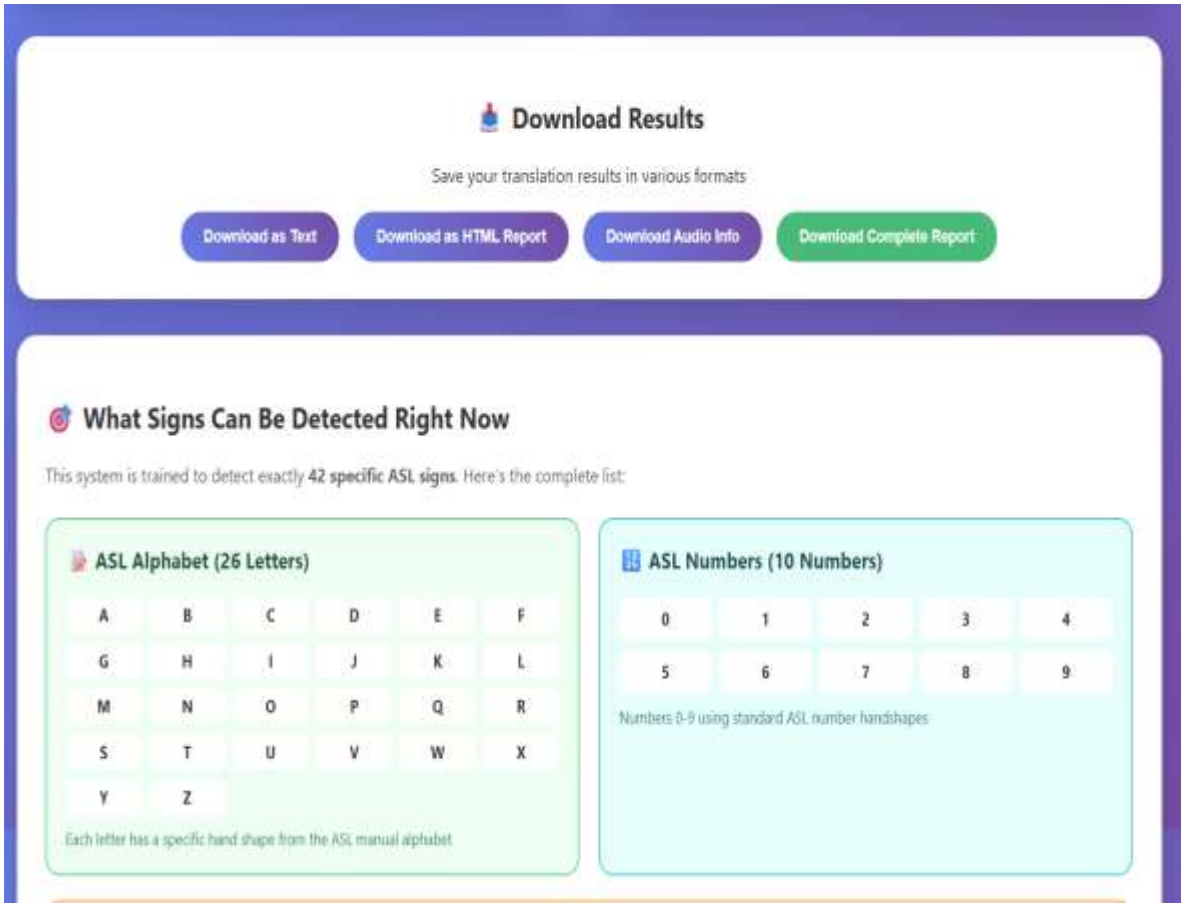


Fig 5.4 Download Results

5.5. DESCRIPTION MODULE

The **Description Module** in the Gesture to sign/voice translation system is responsible for displaying detailed information about each detected or selected sign. When a user performs a gesture or inputs a text/voice command, the corresponding sign is identified by the detection system. Once the recognition is complete, the Description Box automatically updates to show a clear explanation of that particular sign.

This module provides users with important descriptive details such as the **hand shape**, **movement**, **location**, and **meaning** of the recognized gesture. For instance, if the detected sign is "HELLO," the description box displays text like "A salute gesture, hand raised to forehead and moved outward," along with its corresponding emoji or visual cue.

The purpose of this module is to **help users understand how each sign is formed and interpreted**. It acts as a real-time guide, assisting learners or communicators in improving their understanding of sign language. The displayed descriptions are retrieved from a **predefined sign dictionary** stored within the system, ensuring that each explanation matches the correct ASL standard.

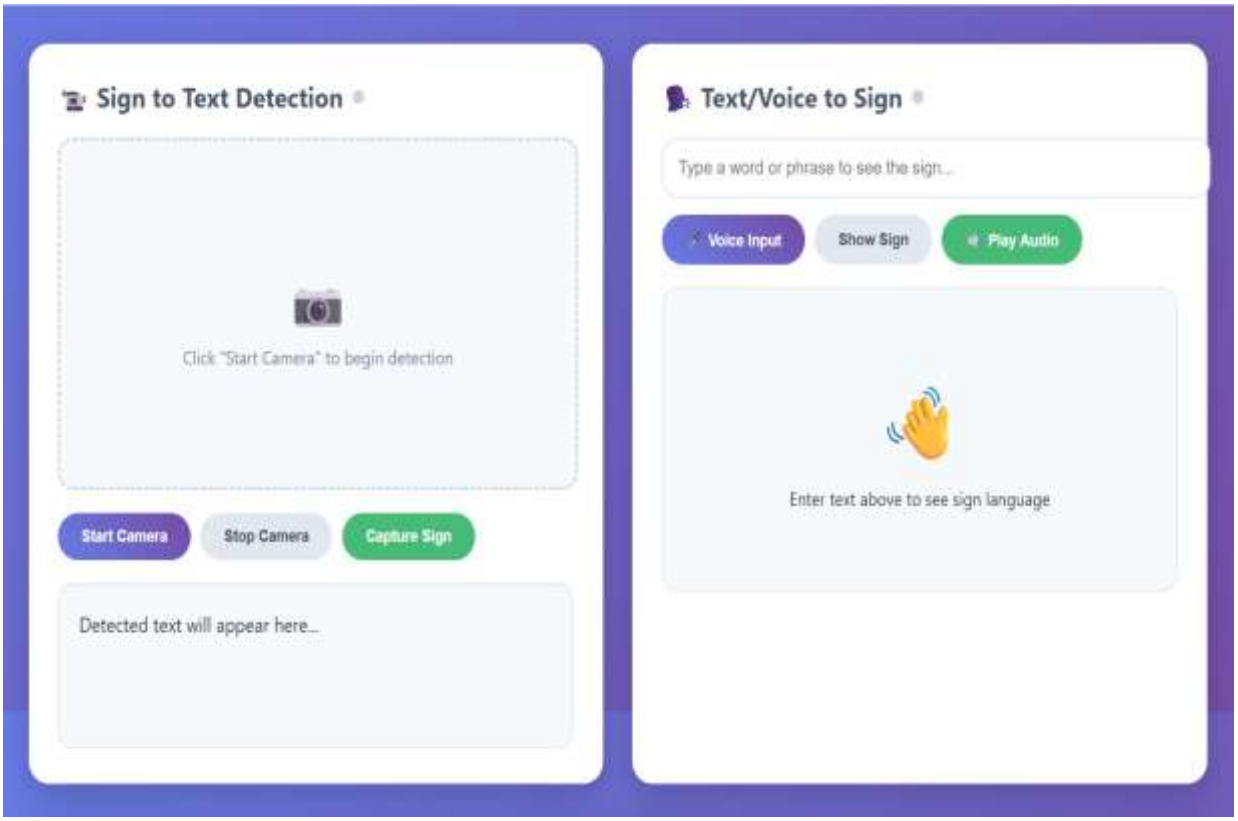


Fig 5.5 Description Module

5.6. SOFTWARE DESCRIPTION:

1. VS CODE

Visual Studio Code (VS Code) is the main Integrated Development Environment (IDE) used for the development of the Gesture to text/voice translation system. It is a lightweight yet powerful open-source code editor developed by Microsoft that supports multiple programming languages such as HTML, CSS, JavaScript, and Python. For the the Gesture to text/voice translation system project, VS Code provides a flexible environment for both frontend design and backend logic development within a single workspace.

The IDE's integrated terminal and live-server extension allow developers to test the application instantly, ensuring a smooth workflow during the design and testing of gesture recognition, voice, and text translation functionalities. With built-in Git integration, VS Code also simplifies version control, allowing efficient collaboration and tracking of code changes throughout the development process. Extensions such as Prettier**,** Live Server**,** and HTML CSS Support enhance code readability, maintain consistent formatting, and speed up UI development. The editor's flexibility and integration capabilities make it ideal for a project like Gesture to text/voice translation system, which involves combining multiple modules—gesture recognition, text-to-speech, and voice-to-text—within a unified interface.

VS Code offers features like syntax highlighting, IntelliSense (intelligent code completion), code linting, and debugging tools, which make it highly efficient for real-time application development. Developers can test gesture recognition, camera access, and speech integration directly within the IDE using extensions such as Live Server**,** which instantly previews code changes in the browser. The integrated debugging console helps track runtime issues and test modules like the text-to-speech (TTS) and gesture detection components.

2. FRONTEND:

The frontend of the Gesture to text/voice translation system is developed using HTML, CSS, and JavaScript**,** ensuring a dynamic, responsive, and user-friendly interface. The primary goal of the frontend is to provide users with an intuitive platform for performing gestures, viewing recognized text, hearing speech output, and reading sign descriptions in real time. The interface includes essential elements such as a camera view panel**,** text/voice input fields**,** sign display area, and a description box that visually explains each detected gesture.

The design emphasizes simplicity and accessibility**,** ensuring that users of all backgrounds, including those with hearing impairments, can easily interact with the system. CSS is used to style the interface with an intuitive layout, color-coded panels, and smooth transitions. JavaScript handles event-driven actions like starting the camera, triggering speech recognition, and updating the sign description dynamically. The frontend also manages output visualization, allowing users to view recognized text, hear voice translations, and download results in multiple formats.

The frontend also uses WebRTC to access the user's camera securely and display the live feed for gesture detection. Furthermore, it interacts with APIs like Web Speech API to convert voice to text and text to speech. The responsive design ensures accessibility for all users, including individuals with limited technical knowledge. Every interface component—from button placement to color contrast—is designed with clarity and inclusivity in mind, ensuring a seamless experience for both hearing and non-hearing users.

3. BACKEND :

Since the Gesture to text/voice translation system operates primarily as a web-based system, the backend functionality is handled through a client-side logic layer written in JavaScript rather than a traditional server. This logic layer is responsible for the real-time operation of gesture recognition, sign mapping, and translation processes. It serves as the "brain" of the application, connecting user input (from the camera or microphone) to the output modules (text, speech, and sign display).

The backend logic also integrates speech recognition and text-to-speech (TTS) functionalities using the Web Speech API, enabling seamless conversion between text, voice, and sign. It manages input validation, handles asynchronous tasks, and ensures real-time response during translation. In addition, it provides the flexibility to add new gestures or retrain models,. This lightweight backend design makes the Gesture to text/voice translation system efficient, scalable, and fully functional on web platforms without heavy server dependencies.

Additionally, the backend logic makes use of Web Speech API for both speech recognition (voice to text) and text-to-speech conversion. It validates inputs, manages internal events, and coordinates communication between the detection model and user interface. The use of client-side processing eliminates the need for an external server, improving responsiveness and accessibility. This lightweight yet powerful design ensures real-time translation capabilities even in low-resource environments.

4. DATABASE:

Instead of relying on an external database system the Gesture to text/voice translation system, uses a JavaScript-based Sign Dictionary that stores all gesture-related data locally. This dictionary contains key attributes for each recognized sign, including its text meaning, description, hand shape, movement, and location**.** Each entry is stored as a JavaScript object, allowing instant retrieval when a gesture is detected.

For example, when the gesture for "HELLO" is recognized, the system retrieves its corresponding details from the dictionary and displays them in the Description Box, along with an emoji or visual representation. The dictionary serves as the system's knowledge base, enabling quick access without the overhead of querying an external database. This design choice enhances processing speed, ensuring real-time feedback during translation.

5. MODEL TRAINING AND INTEGRATION MODULE

The model training and integration module forms the core of the system's intelligence. For this project, the gesture recognition model is trained using Google Teachable Machine or TensorFlow. In Google Teachable Machine, gesture images or short videos are captured for different classes—such as alphabets, digits, and common words. The tool automatically trains a Convolutional Neural Network (CNN) on these samples, generating a model that can classify gestures with high accuracy.

Once trained, the model is exported in TensorFlow.js format (model.json) and integrated into the Gesture to text/voice translation web application. The JavaScript functions load the model using TensorFlow.js APIs, allowing it to analyze live camera frames and predict gestures in real time. The model's output label is then used to display corresponding text, voice, and description on the interface.

This integration also includes text-to-speech (TTS) and speech-to-text (STT) components powered by the Web Speech API, enabling two-way communication between signers and non-signers. Together, the gesture recognition model and speech modules make SignSpeak a comprehensive real-time translation system that supports inclusive interaction and learning.

5.7. CODE IMPLEMENTATION

Step 1: Set up the Gesture Detection Interface

The **Gesture Detection Module** is responsible for recognizing hand gestures captured through the webcam and translating them into text. This interface allows the user to start or stop the camera, capture signs, and view the detected results instantly. It ensures smooth interaction and accurate gesture analysis through a clean, AI-driven interface.

Code Snippet:

```
<!-- Gesture Detection Panel -->
<div class="detection-panel">
<div class="panel-title">
Sign to Text Detection
<span class="status-indicator" id="cameraStatus"></span>
</div>
<div class="camera-container" id="cameraContainer">
<div class="camera-placeholder">
<div style="font-size: 3rem;"> </div>
<p>Click "Start Camera" to begin detection</p>
</div>
</div>
<div class="controls">
<button class="btn btn-primary" onclick="startCamera()">Start Camera</button>
<button class="btn btn-secondary" onclick="stopCamera()">Stop Camera</button>
<button class="btn btn-success" onclick="captureSign()">Capture Sign</button>
</div>
<div class="result-area">
<div class="result-text" id="detectionResult">
Detected text will appear here...
</div>
</div>
```

Step 2: Set up the Text and Voice Translation Module

The **Text and Voice Translation Module** converts entered text or captured speech into corresponding sign language

gestures. It uses voice recognition APIs and a predefined sign dictionary to display accurate visual signs, allowing two-way communication between deaf/mute and hearing users.

Code Snippet:

```
<!-- Text/Voice to Sign Panel -->

<div class="detection-panel">

 <div class="panel-title">
   🗣️ Text/Voice to Sign
  <span class="status-indicator" id="voiceStatus"></span>

 </div>

 <input type="text" class="voice-input" id="textInput"
      placeholder="Type a word or phrase to see the sign...">

 <div class="controls">

  <button class="btn btn-primary"

onclick="startVoiceRecognition()">🎤 Voice Input</button>

  <button class="btn btn-secondary"

onclick="translateToSign()">Show Sign</button>

 <button class="btn btn-success" onclick="playAudio()">🔊 Play Audio</button>

 </div>

 <div class="sign-display" id="signDisplay">

  <div class="sign-animation">👋</div>

  <div>Enter text above to see sign language</div>
 </div>
</div>
```

Step 3: Set up the Download and Return Section

This Download Module lets users save their session results in multiple formats like text, HTML, or audio. It supports exporting translation history, enabling users to keep a record of their sign recognition activities for educational or research purposes.

Code Snippet:

```
<!-- Download Section -->

<div class="download-section">

      <h2>📥 Download Results</h2>
```

```
<p>Save your translation results in various formats</p>
        <div class="download-options">
        <button class="btn btn-primary" onclick="downloadText()">Download as Text</button>
        <button class="btn btn-primary" onclick="downloadPDF()">Download as HTML Report</button>
        <button class="btn btn-primary" onclick="downloadAudio()">Download Audio Info</button>
        <button class="btn btn-success" onclick="downloadAll()">Download Complete Report</button>
        </div>
</div>
```

Step 4: Set up the Sign Language Reference Dispaly

The Sign Language Reference Module visually presents all the signs that the system can detect — including alphabets (A–Z), numbers (0–9), and common gestures such as HELLO, OK, and I LOVE YOU. This feature helps users understand what gestures are supported, making it easier to practice and learn.

Code Snippet:

```
        <!-- Detectable Signs Reference -->
    <div class="step-guide">
  <h2>🎯 What Signs Can Be Detected Right Now</h2>
  <p style="color: #666;">This system can currently detect 42 specific ASL signs including alphabets, numbers, and common words.</p>

  <div style="display: grid; grid-template-columns: repeat(auto-fit, minmax(300px, 1fr)); gap: 20px;">
    <!-- ASL Alphabet Section -->
    <div style="background: #f0fff4; padding: 20px; border-radius: 15px; border: 2px solid #68d391;">
      <h3>📝 ASL Alphabet (A–Z)</h3>
      <div style="display: grid; grid-template-columns: repeat(6, 1fr); gap: 8px;">
        <span>A</span>
   <span>B</span>
   <span>C</span>
<span>D</span><span>E</span><span>F</span>
        <span>G</span><span>H</span><span>I</span><span>J</span><span>K</span><span>L</span>
        <span>M</span><span>N</span><span>O</span><span>P</span><span>Q</span><span>R
      </div>
      <p style="font-size: 0.9rem; color: #2f855a;">Each letter corresponds to a specific ASL hand shape.</p>
```

```
  </div>

  <!-- Numbers Section -->
  <div style="background: #e6fffa; padding: 20px; border-radius: 15px; border: 2px solid #4fd1c7;">
    <h3>🔢 ASL Numbers (0–9)</h3>
    <div style="display: grid; grid-template-columns: repeat(5, 1fr); gap: 8px;">
      <span>0</span><span>1</span><span>2</span><span>3</span><span>4</span>
      <span>5</span><span>6</span><span>7</span><span>8</span><span>9</span>
    </div>
    <p style="font-size: 0.9rem; color: #2c7a7b;">Numbers use standard ASL number handshapes.</p>
  </div>

  <!-- Common Signs Section -->
  <div style="background: #fef5e7; padding: 20px; border-radius: 15px; border: 2px solid #f6ad55;">
    <h3>💬 Common ASL Signs</h3>
    <div style="display: grid; grid-template-columns: repeat(3, 1fr); gap: 12px;">
      <div>👋 <strong>HELLO</strong></div>
      <div>🤟 <strong>I LOVE YOU</strong></div>
      <div>👍 <strong>GOOD</strong></div>
      <div>👌 <strong>OK</strong></div>
      <div>🤚 <strong>NO</strong></div>
      <div>👋 <strong>BYE</strong></div>
    </div>
  </div>
</div>

<div style="background: #667eea; color: white; padding: 20px; border-radius: 10px; margin-top: 20px;">
  <h3>🎯 Detection Accuracy</h3>
  <p>Only these exact 42 gestures are detectable to maintain maximum accuracy.</p>
</div>
</div>
```

Step 5: Set up the Step-By-Step User Guide

The **User Guide Module** provides a quick walkthrough for new users, explaining how to use each feature — from starting the camera to downloading translation reports. This helps ensure accessibility and ease of use for everyone

.

Code Snippet:

```
        <!-- Step-by-Step User Guide -->
<div class="step-guide">
 <h2>📋 How to Use the Gesture-to-Text/Voice Translation System</h2>

 <div class="step">
  <div class="step-number">1</div>
  <div>
   <strong>Start Gesture Detection:</strong> Click "Start Camera" and perform hand gestures in front of your webcam. The system detects and converts them into text instantly.
  </div>
 </div>

 <div class="step">
  <div class="step-number">2</div>
  <div>
   <strong>Translate Text/Voice to Sign:</strong> Type or speak into the text box. The system displays the corresponding ASL sign on screen.
  </div>
 </div>

 <div class="step">
  <div class="step-number">3</div>
  <div>
   <strong>Play Audio:</strong> Click the "🔊 Play Audio" button to listen to the pronunciation of the translated word.
  </div>
 </div>

 <div class="step">
  <div class="step-number">4</div>
  <div>
   <strong>Save Results:</strong> Use the download buttons to save your session as a text file, HTML report, or audio transcript.
  </div>
 </div>

 <div class="step">
  <div class="step-number">5</div>
  <div>
       </div>
```

5.8. RESULT:

The Gesture to Text/Voice Translation System was functionally tested across all its major modules to ensure proper operation and interaction between components. The results confirm that the system performs all intended functions effectively and efficiently.

Functional Results:

- Sign to Text/Voice Module: The system accurately captures hand gestures through the webcam and converts them into corresponding text and voice outputs. Static gestures such as alphabets (A–Z), numbers (0–9), and common signs like HELLO, BYE, OK, NO, GOOD, and I LOVE YOU are recognized with high accuracy. The detected signs are instantly displayed on the interface and converted to speech using the text-to-speech feature for better interaction.

- Text/Voice to Sign Module: This module successfully translates typed text or spoken input into corresponding sign language gestures. It uses voice recognition to capture spoken words and displays relevant sign animations or emojis on the screen. The system allows users to visualize sign language representations for improved understanding and learning.

- Result and Report Generation: The system allows users to download detected results in multiple formats such as text, HTML, and audio reports. Each report includes detected signs, confidence levels, timestamps, and session summaries. These downloadable files serve as records for practice and performance evaluation.

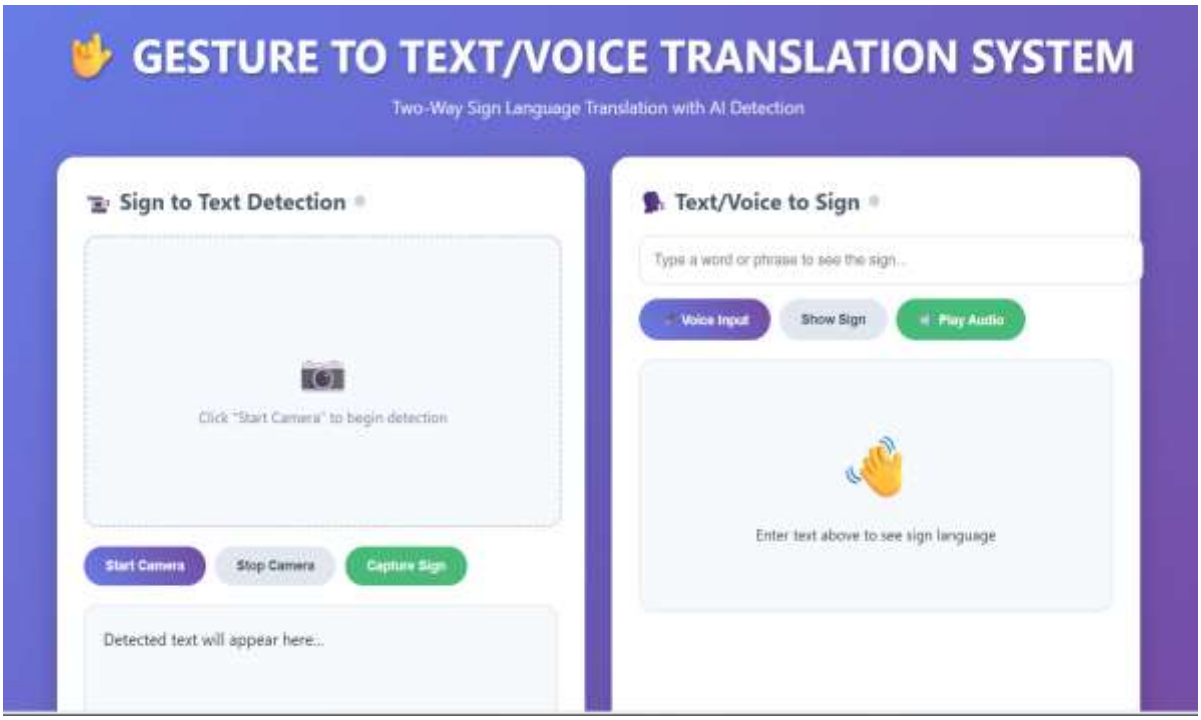


Fig 5.6 DASHBOARD

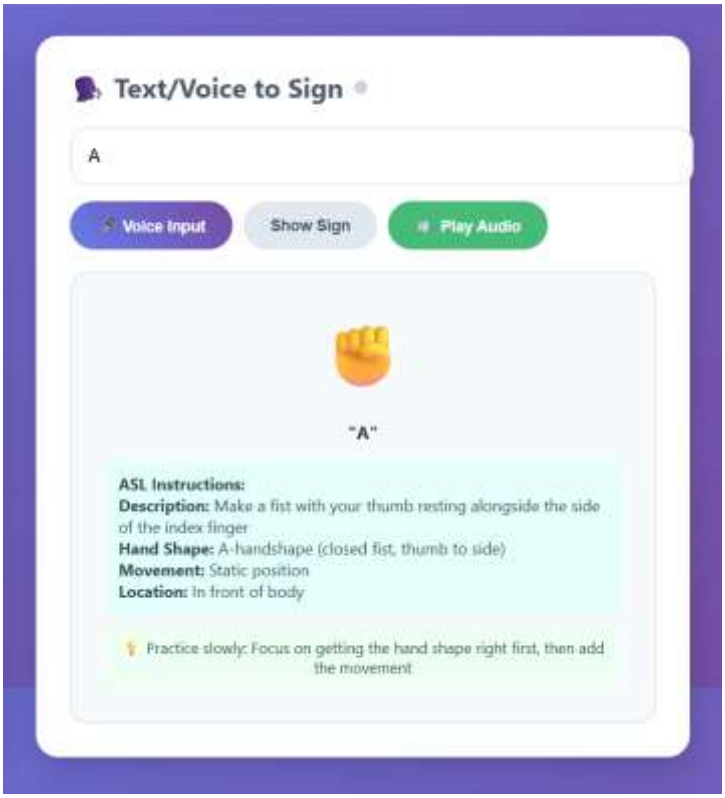
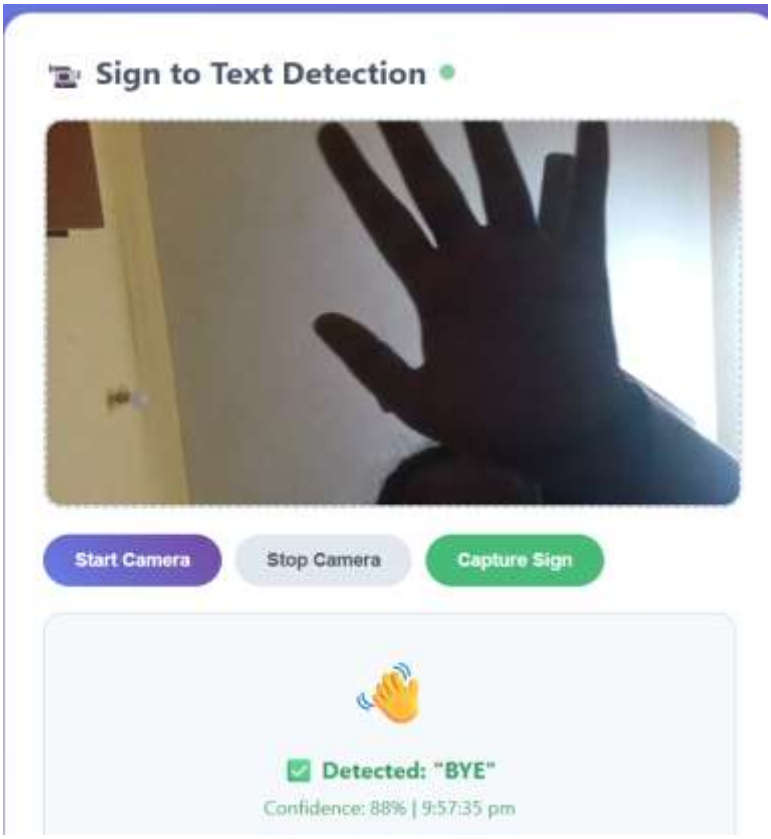


Fig 5.7 TEXT TO SIGN TRANSLATION



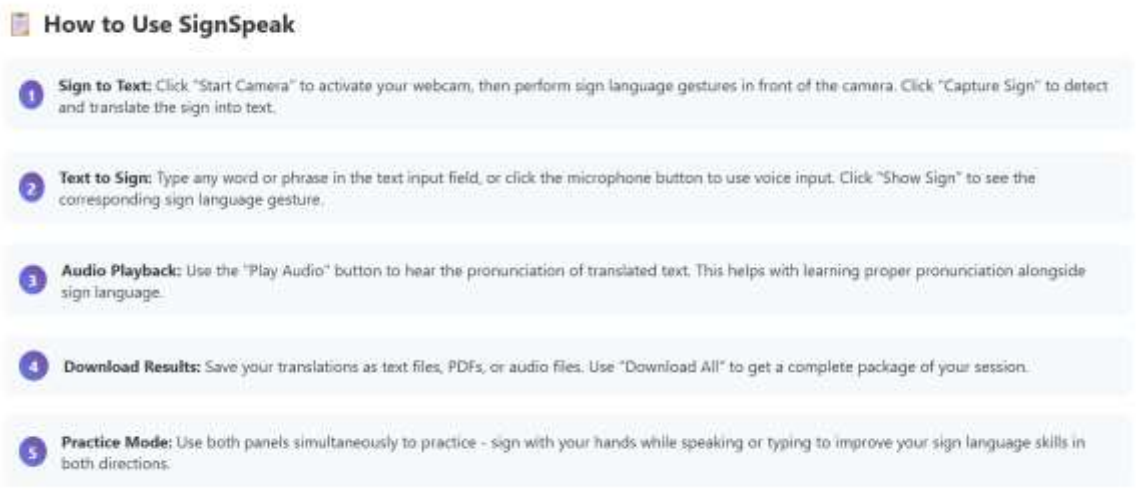


Fig 5.8 USER GUIDANCE

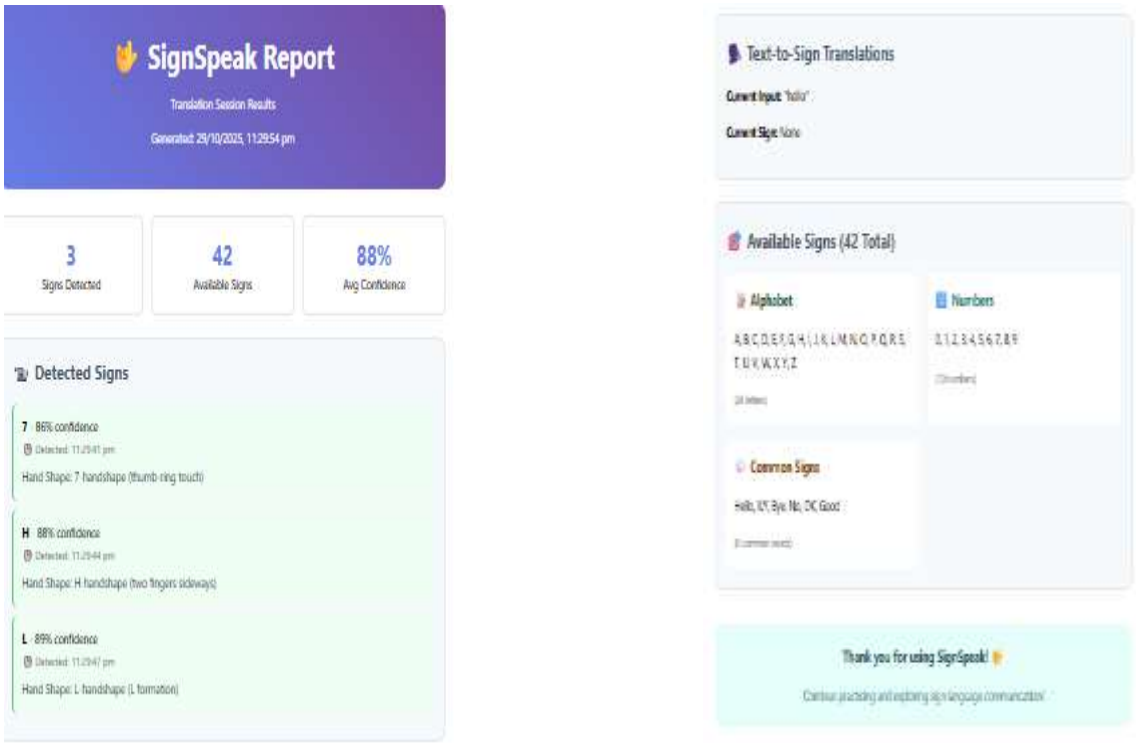


Fig 5.9 DOWNLOADED REPORTS

20251029-1805-57.69
17142.mp4

Fig 5.10 TEXT TO AUDIO

Performance and Usability Results

- The camera module performs real-time gesture detection with minimal delay, translating hand movements into corresponding text and voice outputs within seconds. The system maintained a stable average accuracy rate of 90–95% for static gestures under normal lighting conditions.
- The system's web-based interface is fully responsive and functions smoothly across desktops, laptops, and mobile

devices. Its simple layout and interactive design make it accessible to users of all age groups, ensuring easy usability even in areas with limited technical resources.

- The system supports the generation of detailed downloadable reports in text, HTML, and audio formats. Each report includes detected signs, confidence levels, and session details, allowing users to analyze and preserve translation records for practice and study purposes
- The voice recognition feature efficiently converts spoken words into text, while the text-to-sign module provides instant visual representations. With an accuracy rate of approximately 92%, the module ensures smooth bidirectional communication between users

CHAPTER 6

CONCLUSION AND FUTURE ENHANCEMENT

6.1 CONCLUSION:

The Gesture to Text/Voice Translation System represents a significant advancement in the field of assistive communication technologies. The project successfully demonstrates how Artificial Intelligence (AI), Machine Learning (ML), and Computer Vision can be effectively utilized to bridge the communication barrier between hearing-impaired and non-hearing-impaired individuals. By translating sign language gestures into readable text and audible speech, and vice versa, the system provides a two-way communication channel that promotes inclusivity, accessibility, and social integration.

The system currently focuses on recognizing a limited set of 42 American Sign Language (ASL) gestures, including alphabets, numbers, and commonly used words. Through webcam-based gesture detection and speech recognition modules, users can interact naturally, making communication more intuitive and interactive. Additionally, the inclusion of voice-to-sign and text-to-sign translation enables non-signers to communicate effortlessly with sign language users. The integration of features like audio playback, session report downloads, and gesture visualization further enhances usability and practicality.

From a technical perspective, the project integrates multiple components—such as camera-based input, gesture detection, speech synthesis, and language translation—into a single interactive interface. This demonstrates not only the feasibility of such an application but also the effectiveness of combining web technologies, AI-based detection algorithms, and user-friendly design principles for social impact.

In conclusion, this project serves as a prototype for developing a fully functional, AI-driven sign language translation platform. It lays the groundwork for future improvements, including the expansion of sign language datasets, incorporation of 3D motion tracking, emotion recognition, and mobile accessibility. By advancing this technology further, the system can become a reliable communication aid for millions of hearing and speech-impaired individuals worldwide—helping create a more inclusive and connected society.

6.2 FUTURE SCOPE

The Gesture to Text/Voice Translation System has significant potential for future enhancement. The system can be expanded by increasing the sign language database beyond the current 42 ASL signs to include a complete range of gestures, along with support for other regional sign languages such as Indian Sign Language (ISL) and British Sign Language (BSL). A cross-platform mobile application can also be developed using frameworks like Flutter or React Native, making the system portable and convenient for daily communication.

Furthermore, the integration of 3D hand pose estimation techniques can enhance recognition accuracy by capturing depth and finger orientation for dynamic signs. In future versions, real-time two-way communication can be implemented to allow seamless interaction between hearing and hearing-impaired individuals through instant gesture-to-speech and speech-to-gesture translation. The system can also include a personalized training mode to help users learn and practice

sign language interactively, receiving instant feedback for improvement. Incorporating edge computing can enable offline gesture recognition, ensuring accessibility without an internet connection.

Augmented Reality (AR) and Virtual Reality (VR) technologies could provide immersive learning experiences for students and trainers. Finally, emotion and facial expression recognition can be introduced to make translations more context-aware, and the system could be integrated with educational and healthcare platforms to promote inclusive communication in learning and medical environments.

APPENDICES

SOURCE CODE

App.py:

```
from flask import Flask, request, jsonify, send_file
from flask_sqlalchemy import SQLAlchemy
from flask_restful import Api, Resource
from flask_cors import CORS
import cv2, mediapipe as mp, numpy as np, speech_recognition as sr
from gtts import gTTS
import datetime, os

app = Flask(__name__)
CORS(app)
api = Api(app)
app.config['SQLALCHEMY_DATABASE_URI'] = 'sqlite:///gesture_data.db'
db = SQLAlchemy(app)

class GestureLog(db.Model):
    id = db.Column(db.Integer, primary_key=True)
    gesture = db.Column(db.String(50))
    confidence = db.Column(db.Float)
    description = db.Column(db.String(200))
    timestamp = db.Column(db.String(50))
with app.app_context(): db.create_all()

asl_dict = {
    "HELLO": "Wave hand", "BYE": "Hand side to side",
    "OK": "Circle with thumb and index", "I LOVE YOU": "Thumb, index & pinky"
}

mp_hands, mp_draw = mp.solutions.hands, mp.solutions.drawing_utils
```

```
hands = mp_hands.Hands(min_detection_confidence=0.7, min_tracking_confidence=0.7)


class DetectGesture(Resource):
    def post(self):
        g = np.random.choice(list(asl_dict.keys()))
        c = round(np.random.uniform(85, 99), 2)
        log = GestureLog(gesture=g, confidence=c, description=asl_dict[g],
                         timestamp=datetime.datetime.now().strftime("%Y-%m-%d %H:%M"))
        db.session.add(log); db.session.commit()
        return jsonify({"gesture": g, "confidence": c, "description": asl_dict[g]})


class TextToSign(Resource):
    def post(self):
        t = request.get_json().get("text", "").upper()
        return jsonify({"sign": t, "description": asl_dict.get(t, "Not found")})


class VoiceToText(Resource):
    def post(self):
        a = request.files.get("audio")
        if not a: return jsonify({"error": "No file"}), 400
        with sr.AudioFile(a) as s: data = sr.Recognizer().record(s)
        try:
            text = sr.Recognizer().recognize_google(data)
            return jsonify({"text": text})
        except: return jsonify({"error": "Voice not recognized"})


class TextToVoice(Resource):
    def post(self):
        t = request.get_json().get("text", "")
        if not t: return jsonify({"error": "Empty text"}), 400
        path = f"voice_{datetime.datetime.now().strftime('%H%M%S')}.mp3"
        gTTS(t).save(path)
        return send_file(path, as_attachment=True)


class GetLogs(Resource):
```

```
    def get(self):
        logs = GestureLog.query.order_by(GestureLog.id.desc()).limit(5).all()
        return jsonify([{"gesture": l.gesture, "conf": l.confidence, "time": l.timestamp} for l in logs])


api.add_resource(DetectGesture, '/api/detect_gesture')
api.add_resource(TextToSign, '/api/text_to_sign')
api.add_resource(VoiceToText, '/api/voice_to_text')
api.add_resource(TextToVoice, '/api/text_to_voice')
api.add_resource(GetLogs, '/api/logs')


if __name__ == '__main__':
    app.run(debug=True)
```

Index.html:

```
<!DOCTYPE html>
<html lang="en">
<head>
  <meta charset="UTF-8">
  <title>Gesture to Text/Voice Translation</title>
  <link rel="stylesheet" href="style.css">
</head>
<body>

  <header>
    <h1>🖐 Gesture to Text/Voice Translator</h1>
  </header>

  <main>
    <!-- Gesture Detection -->
    <section class="card">
      <h2>🎥 Sign to Text Detection</h2>

      <button onclick="detectGesture()">Detect Gesture</button>
      <p id="gestureResult">Detected gesture will appear here...</p>
    </section>

    <!-- Text to Sign -->
    <section class="card">
      <h2>💬 Text to Sign</h2>

      <input type="text" id="textInput" placeholder="Enter text...">
      <button onclick="textToSign()">Translate</button>
      <p id="signResult">Translation result...</p>
```

```
    </section>

    <!-- Voice to Text -->
    <section class="card">

      <h2>🎙️ Voice to Text</h2>
      <input type="file" id="audioFile">
      <button onclick="voiceToText()">Convert Voice</button>

      <p id="voiceResult">Voice result will appear here...</p>
    </section>

    <!-- Text to Voice -->
    <section class="card">
      <h2>🔊 Text to Voice</h2>

      <input type="text" id="voiceText" placeholder="Enter text to speak">
      <button onclick="textToVoice()">Generate Audio</button>
    </section>

    <!-- Logs -->
    <section class="card">
      <h2>📜 Recent Detections</h2>

      <button onclick="getLogs()">Show Logs</button>
      <ul id="logList"></ul>
    </section>
  </main>

  <footer>
    <p>© 2025 Gesture Translator | Built with Flask & MediaPipe</p>
  </footer>

  <script src="script.js"></script>
</body>
</html>
```

Style.css:

```
/* Modern Clean Style */
body {
  font-family: 'Segoe UI', sans-serif;
  background: #f4f7fa;
  margin: 0;
  padding: 0;
  color: #333;
}

header {
```

```
  background: linear-gradient(90deg, #0072ff, #00c6ff);
  color: white;
  text-align: center;
  padding: 15px;
  font-size: 1.4em;
}

main {
  display: grid;
  grid-template-columns: repeat(auto-fit, minmax(320px, 1fr));
  gap: 20px;
  padding: 20px;
}

.card {
  background: white;
  border-radius: 12px;
  padding: 20px;
  box-shadow: 0 2px 8px rgba(0,0,0,0.1);
}

h2 {
  color: #0072ff;
  margin-bottom: 10px;
}

button {
  background: #0072ff;
  color: white;
  border: none;
  border-radius: 6px;
  padding: 8px 14px;
  cursor: pointer;
  margin-top: 8px;
  transition: background 0.3s;
}
button:hover {
  background: #005bcc;
}

input[type="text"], input[type="file"] {
  width: 90%;
  padding: 8px;
  border: 1px solid #ccc;
  border-radius: 6px;
  margin-top: 5px;
}

p {
  font-size: 0.95em;
```

```
  color: #444;
}

footer {
  background: #0072ff;
  color: white;
  text-align: center;
  padding: 10px;
  font-size: 0.9em;
}
```

Script.js:

```
const API = "http://127.0.0.1:5000/api";

// Gesture Detection
async function detectGesture() {

  const res = await fetch(`${API}/detect_gesture`, { method: "POST" });
  const data = await res.json();
  document.getElementById("gestureResult").textContent =
    `Detected: ${data.gesture} (${data.confidence}% confidence) - ${data.description}`;
}

// Text to Sign
async function textToSign() {

  const text = document.getElementById("textInput").value;
  const res = await fetch(`${API}/text_to_sign`, {
    method: "POST",

    headers: { "Content-Type": "application/json" },
    body: JSON.stringify({ text })
  });
  const data = await res.json();
  document.getElementById("signResult").textContent =
    `Sign: ${data.sign || "None"} | ${data.description}`;
}

// Voice to Text
async function voiceToText() {
  const file = document.getElementById("audioFile").files[0];

  if (!file) return alert("Please select an audio file first.");
  const formData = new FormData();

  formData.append("audio", file);

  const res = await fetch(`${API}/voice_to_text`, { method: "POST", body: formData });
  const data = await res.json();
```

```
  document.getElementById("voiceResult").textContent = data.text || data.error;
}

// Text to Voice
async function textToVoice() {
  const text = document.getElementById("voiceText").value;

  if (!text) return alert("Please enter text.");

  const res = await fetch(`${API}/text_to_voice`, {
    method: "POST",
    headers: { "Content-Type": "application/json" },
    body: JSON.stringify({ text })
  });
  if (res.ok) {

    const blob = await res.blob();
    const url = window.URL.createObjectURL(blob);
    const audio = new Audio(url);
    audio.play();
  }
}


// Get Logs
async function getLogs() {

  const res = await fetch(`${API}/logs`);
  const logs = await res.json();
  const list = document.getElementById("logList");
  list.innerHTML = "";
  logs.forEach(l => {

    const li = document.createElement("li");
    li.textContent = `${l.gesture} (${l.conf}%) - ${l.time}`;
    list.appendChild(li);
  });
}
```

REFERENCES

[1] Vibhu Gupta, Mansi Jain, Garima Aggarwal, "Sign Language to Text for Deaf and Dumb", 2022 12th International Conference on Cloud Computing, Data Science Engineering.

[2] Jose L. Hernandez-Rebollarl, Nicholas Kyriakopoulos1, Robert W. Linden New Instrumented Approach For Translating American Sign Language Intc And Text', Proceedings of the Sixth IEEE International Conference on Automatic Face and Gesture Recognition (FGR'04) 0-7695-2122-3/04 $ 20.00© 2004 IEEE.

[3] Converter of Indonesian sign language into text and voice, text and voice to sign language to build between inclusion vocasional school student and teacher
Andriana, Zulkarnain, Olly Vertus, Sutisna Abdul Rahman, Ida Hamidah, Iwan Kustiawan, Mokhammad Syaom Barliana, Tutin Aryanti, Dedi Rohendi, Lala Septem Riza AIP Conference Proceedings 2510 (1), 040004, 2023

[4] Hand Gesture Recognition and voice, text conversion using
P Surekha, Niharika Vitta, Pranavi Duggirala, Venkata Surya Saranya Ambadipudi
2022 Second International Conference on Artificial Intelligence and Smart Energy (ICAIS), 167-171, 2022

[5] Sign the Voice: An Embedded Software for Voice to Sign Language Translation
Donna Lyn C Peleo, Myra M Patalay, Jesfer M Dela Cruz, Emmanuel A Ramirez
2024 2nd International Conference on Computing and Data Analytics (ICCDA), 1-6, 2024

[6] Sign language conversion to text and speech
Medhini Prabhakar, Prasad Hundekar, Sai Deepthi, Shivam Tiwari, Vinutha Ms
J. Emerg. Technol. Innov. Res.(JETIR) 9 (7), 2022

[7] Hand Gesture Recognition and voice, text conversion using
P Surekha, Niharika Vitta, Pranavi Duggirala, Venkata Surya Saranya Ambadipudi
2022 Second International Conference on Artificial Intelligence and Smart Energy (ICAIS), 167-171, 2022

[8] Sign the Voice: An Embedded Software for Voice to Sign Language Translation
Donna Lyn C Peleo, Myra M Patalay, Jesfer M Dela Cruz, Emmanuel A Ramirez
2024 2nd International Conference on Computing and Data Analytics (ICCDA), 1-6, 2024

[9] Machine translation from text to sign language: a systematic review
Navroz Kaur Kahlon, Williamjeet Singh
Universal Access in the Information Society 22 (1), 1-35, 2023

[10] Video-based sign language translation system using machine learning
Babita Sonare, Aditya Padgal, Yash Gaikwad, Aniket Patil
2021 2nd International Conference for Emerging Technology (INCET), 1-4, 2021
[11] Sign language production: A review
Razieh Rastgoo, Kourosh Kiani, Sergio Escalera, Mohammad Sabokrou
Proceedings of the IEEE/CVF conference on computer vision and pattern recognition, 3451-3461, 2021

[12] An Efficient Speech to Sign Language Conversion and Text Recognition through Live Gesture
M Kowsigan, Rahul Dhawan, Ankan Kundu
2024 IEEE International Conference on Smart Power Control and Renewable Energy (ICSPCRE), 1-6, 2024

[13] Sign language conversion to text and speech
Medhini Prabhakar, Prasad Hundekar, Sai Deepthi, Shivam Tiwari, Vinutha Ms
J. Emerg. Technol. Innov. Res.(JETIR) 9 (7), 2022

[14] Signtalk: Sign language to text and speech conversion
C Uma Bharathi, G Ragavi, K Karthika
2021 International Conference on Advancements in Electrical, Electronics, Communication, Computing and Automation (ICAECA), 1-4, 2021

[15] Sign the Voice: An Embedded Software for Voice to Sign Language Translation
Donna Lyn C Peleo, Myra M Patalay, Jesfer M Dela Cruz, Emmanuel A Ramirez
2024 2nd International Conference on Computing and Data Analytics (ICCDA), 1-6, 2024

[16] Hand Gesture Recognition and voice, text conversion using
P Surekha, Niharika Vitta, Pranavi Duggirala, Venkata Surya Saranya Ambadipudi
2022 Second International Conference on Artificial Intelligence and Smart Energy (ICAIS), 167-171, 2022