

Indian Sign Language to Text/Speech

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CERTIFICATE

This is to certify that the Mini Project 2B entitled “Title” is a bonafide work of **Name of students (Roll No.)** Submitted to the University of Mumbai in partial fulfillment of the requirement for the award of the degree of “**Bachelor of Engineering**” in “**Artificial Intelligence and Data Science**”.

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This Mini Project entitled “Indian Sign Language to Text/Speech” by **Vivek Rajak(9), Soham Rane(10), Mandar Salvi(15) and Vansh Wase(28)** is approved for the degree of **Bachelor of Engineering in Artificial Intelligence and Data Science.**

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DECLARATION

I declare that this project represents my ideas in my own words without plagiarism and wherever others' ideas or words have been included, I have adequately cited and referenced the original sources. I also declare that I have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/source in my project work. I promise to maintain minimum 75% attendance, as per the University of Mumbai norms. I understand that any violation of the above will be cause for disciplinary action by the Institute.

Yours Faithfully

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Contents

Abstract	ii
Acknowledgments	iii
List of Abbreviations	iv
List of Figures	v
List of Tables	vi
1 Introduction	1
1.1 Introduction	
1.2 Problem Statement & Objectives	
1.3 Organization of the Report	
2 Literature Survey	5
2.1 Survey of Existing System	
3 System Design	7
3.1 Architecture/ Framework	
3.2 Algorithm and Process Design	
3.3 Software Stack	
4. Implementation and Results	13
4.1 System Implementation	
4.2 Results	
5. Conclusion and Future Scope	18
References	20

ABSTRACT

Communication is a fundamental human need, yet individuals who are deaf and/or face immense challenges in expressing themselves and understanding others in society. While sign language serves as a primary communication medium for the deaf community, its adoption remains limited among the general population. Moreover, individuals with impairments cannot interpret cues like hand gestures, making communication even more complex. Addressing this dual barrier requires an innovative solution that bridges the gap between visual language and auditory/text-based communication.

This project introduces a **real-time hand gesture recognition system** designed to enhance communication for deaf and individuals by converting gestures into **both text and speech** outputs. The system leverages a combination of **OpenCV**, **MediaPipe**, **TensorFlow/Keras**, and **Pytsx3**, integrated within a **Flask and React.js** web-based architecture. The gesture recognition model is trained on a dataset of images captured through a webcam and utilizes machine learning algorithms to identify specific gestures.

Drawing inspiration from prior research on sign language recognition—such as the foundational work by Starner et al. (1998) and recent developments by Koller et al. (2015)—this system aims to offer a lightweight, scalable, and interactive platform that does not require expensive hardware or deep technical know-how for usage. The results indicate a promising direction for future developments in **assistive communication technology**, with further scope to expand gesture vocabulary and multilingual support.

This solution ultimately seeks to empower the differently-abled community by providing a tool that improves daily interactions, inclusivity, and independence in communication.

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- **Vivek Rajak**
- **Soham Rane**
- **Mandar Salvi**
- **Vansh Wase**

Each member has contributed equally in the development, research, implementation, and documentation of this project. We are proud of what we have accomplished together and look forward to expanding our work in the future.

List of Abbreviations

Abbreviation	Full Form
ML	Machine Learning
AI	Artificial Intelligence
API	Application Programming Interface
GUI	Graphical User Interface
CPU	Central Processing Unit
HTML	HyperText Markup Language
CSS	Cascading Style Sheets
JS	JavaScript
ML Model	Machine Learning Model
CSV	Comma-Separated Values
YOLO	You Only Look Once (object detection algorithm)
SVM	Support Vector Machine
CNN	Convolutional Neural Network

List of Figures

Figure No.	Figure Title	Page No.
Fig. 1	Hand Gesture Captured on Web-Cam	14
Fig. 2	Universal Hand Gesture Labels	16
Fig. 3	Dashboard	20
Fig. 4	Gesture Detection Page	21
Fig. 5	Gesture Recognition Implementation	22

List of Tables

Table No.	Table Title	Page No.
Table 1	Architecture Functionality Table	17
Table 2	Sample Dataset	20
Table 3	Software Requirements	21
Table 4	System Requirements	22

1. Introduction

1.1 Introduction

In today's fast-paced and interconnected world, communication stands as the cornerstone of social interaction and human connection. For most, conveying thoughts, emotions, and instructions is second nature through speech, facial expressions, or written language. However, this process is significantly hindered for individuals with sensory disabilities such as deafness or blindness. Specifically, individuals who are **deaf**, **mute**, or experience **multiple impairments** often face considerable obstacles in daily life due to their inability to access or produce conventional modes of communication.

Sign language has long served as a vital bridge for communication in the deaf and hard-of-hearing communities. It involves using hands, facial expressions, and body posture to convey meaning. However, the majority of the population, especially those without exposure to the disabled community, lack familiarity with sign language, creating a barrier in interactions. Furthermore, for those who are **deaf**, even sign language may not suffice—especially when visual input is compromised.

The increasing reliance on **machine learning**, **computer vision**, and **natural language processing** in modern technology has opened up new possibilities for overcoming such barriers. Gesture recognition, in particular, has emerged as a promising field that allows systems to interpret physical movements as meaningful commands or communication cues. By leveraging affordable technologies such as webcams and open-source software, it becomes possible to **design assistive systems** that not only recognize hand gestures in real-time but also **translate them into text and audio outputs**—thus serving both visually and hearing-impaired individuals.

The system proposed in this report aims to make human-computer interaction more inclusive by providing a **Gesture-to-Text and Speech Converter** tailored for the differently-abled. It provides a user-friendly, cost-effective, and real-time platform that bridges the gap between those who rely on sign gestures and those who communicate through text or speech. This innovation is not merely technological—it is societal, aiming to reduce the communication divide and promote inclusivity in education, employment, and daily living.

1.2 Problem Statement & Objectives

Problem Statement

Despite the widespread advancement in communication technology, a substantial segment of the global population—comprising individuals who are deaf, or mute—continues to face social and communication exclusion. Traditional solutions like sign language are not universally understood, and specialized hardware solutions such as data gloves or tactile devices are often expensive, complex, and inaccessible in low-income settings.

Furthermore, most existing gesture recognition systems are limited in scope. They either require extensive setup, are trained on limited datasets, or only provide one type of output—usually text. This poses a serious limitation for individuals with multiple impairments, such as those who are both visually and hearing impaired. There is a critical need for a **low-cost, real-time, dual-mode communication tool** that can operate using basic hardware (such as a webcam) and translate gestures into both **visual (text)** and **auditory (speech)** formats.

Objectives

The core objective of this project is to design and implement a **gesture recognition system** that can identify hand gestures and **translate them into text and speech in real-time**. This system is envisioned to support individuals with sensory impairments by bridging the communication gap between them and the wider world.

The specific objectives of the project are:

- **To develop a real-time gesture recognition model** using computer vision and machine learning techniques, trained on a dataset of commonly used hand gestures.
- **To design an intuitive front-end interface** using React.js that allows users to perform gestures in front of a webcam and receive corresponding feedback.
- **To convert recognized gestures into text output**, which will be displayed on the screen for hearing-impaired users.
- **To implement a text-to-speech converter** using Pyttsx3 or similar libraries, which can vocalize the recognized text to support visually impaired users.
- **To ensure high accuracy and responsiveness** of the model under various lighting conditions and backgrounds, ensuring real-world usability.
- **To create a lightweight system** that runs efficiently on standard personal computers or mobile devices without requiring specialized equipment.
- **To encourage inclusivity and accessibility**, ensuring that the system benefits people in rural, urban, and economically challenged environments.

Ultimately, this project seeks to promote a society where **everyone has a voice**, regardless of physical abilities, and where **technology serves as an equalizer** rather than a divider.

1.3 Organisation of the Report

This report has been organized into five comprehensive chapters, each addressing key components of the project:

- **Chapter 1: Introduction** – Discusses the foundation of gesture recognition technology, highlights the motivation behind the project, presents the refined problem statement, and defines the objectives of the system.
- **Chapter 2: Literature Survey** – Reviews recent advancements and research papers related to computer vision, sign language interpretation, gesture recognition, and similar machine learning applications. This section establishes the academic background that supports the solution.
- **Chapter 3: System Design** – Details the architecture of the developed system, including its layered framework, the algorithmic flow of gesture-to-text and speech conversion, and the software stack used for implementation.
- **Chapter 4: Implementation and Results** – Explains the technical development of the frontend and backend systems, classifier training, image processing techniques, and integration of speech synthesis. It also presents real-time results, accuracy metrics, and performance evaluation tables.
- **Chapter 5: Conclusion and Future Scope** – Summarizes the outcomes, reflects on the project's effectiveness, and outlines potential directions for enhancement and scalability in future iterations.
- **References**
A complete list of citations and sources referred to during the course of the project is included here, adhering to a standard referencing format.

2. Literature Survey

2.1 Survey of Existing Systems

The field of gesture recognition and sign language translation has seen consistent growth over the past few decades, especially with the integration of machine learning and computer vision technologies. However, existing systems present several limitations in terms of accessibility, accuracy, and real-world usability.

One of the earliest milestones in this domain was achieved by **Starner, Weaver, and Pentland (1998)**, who demonstrated that **real-time sign language recognition was feasible using desk-mounted and wearable video devices**. Their system used Hidden Markov Models (HMMs) to identify hand gestures from a limited vocabulary of American Sign Language (ASL). While their approach laid critical groundwork, it required specific hardware and had limited accuracy under varying environmental conditions. Nevertheless, it pioneered real-time recognition, influencing a generation of research in the field of assistive communication technologies.

Further advancements were made by **Koller, Forster, and Ney (2015)**, who focused on **continuous sign language recognition with large vocabularies**. Their approach used **statistical frameworks** to account for variations in speed, signer style, and context. By leveraging deep learning and large datasets, they were able to significantly enhance recognition accuracy. Their work addressed key challenges like signer-dependent variability and ambiguity in gesture interpretation, making sign recognition more scalable.

In parallel, researchers such as **Kadous (1998)** explored gesture recognition for **Auslan (Australian Sign Language)** using HMMs and established that gesture recognition could be language-independent, thereby opening avenues for multilingual gesture systems. More recently, **Ko, Lee, and Kim (2019)** implemented a system using **deep neural networks and real-time hand tracking** techniques. Their method showed strong performance under constrained environments but still struggled with background noise and hand occlusion.

Despite these innovations, **current systems face major challenges:**

- **Hardware dependency:** Many rely on specialized devices like gloves, depth sensors, or stereo cameras.
- **Offline processing:** Several systems are not real-time and require post-processing, making them impractical for live interaction.
- **Limited accessibility:** The high cost and complexity of some solutions restrict their availability to a broader user base.
- **Single-modal output:** Most systems convert gestures to only one format, typically text, neglecting users who are blind and rely on speech.

Our proposed system is designed to overcome these shortcomings by using **only a basic webcam**, providing **real-time gesture recognition**, and offering **dual-mode output—text** for hearing-impaired users and **speech** for visually-impaired users.

3. System Design

The system design phase serves as the backbone of the entire project, laying down the structure that governs the behavior and interaction of various software modules. This chapter provides a thorough explanation of the **architectural design**, **algorithmic workflow**, and the **software stack** chosen for implementing the gesture recognition and conversion system.

The proposed solution aims to recognize gestures using a webcam and convert them into real-time text and audio. This is achieved through a combination of front-end interaction, back-end processing, model inference, and text-to-speech synthesis. The system has been designed for modularity, scalability, and simplicity to ensure ease of use and future extensibility.

3.1 Architecture / Framework

The overall architecture of the system is designed in a **modular client-server model** that allows for real-time interaction between the user interface and the backend model. Below is a high-level architecture diagram:

Module	Functionality
Webcam Feed	Captures real-time video frames of hand gestures.
Frontend (React.js)	Displays interface for gesture input; sends frames to backend via REST API.
Backend (Flask API)	Receives frames, processes gesture recognition using ML model.
ML Model	Predicts class of hand gesture using a trained classifier.
Output Engine	Converts prediction to text (displayed on screen) and speech (via text-to-speech).

System Architecture Diagram:

The system operates in the following flow:

1. The **user places their hand in front of a webcam**.
2. A React.js front-end captures and sends the video frame to a Flask-based back-end.
3. The back-end processes the image using **OpenCV** for pre-processing and passes it through a **trained ML classifier**.
4. The model returns a predicted gesture label (e.g., “A”, “B”, “Hello”).
5. The predicted label is then:
 - **Displayed as text** on the user’s screen.
 - **Converted to speech** using the **pyttsx3** text-to-speech engine.

This entire flow takes place in **real-time**, typically under 1 second per frame, offering a seamless experience for users with impairments.

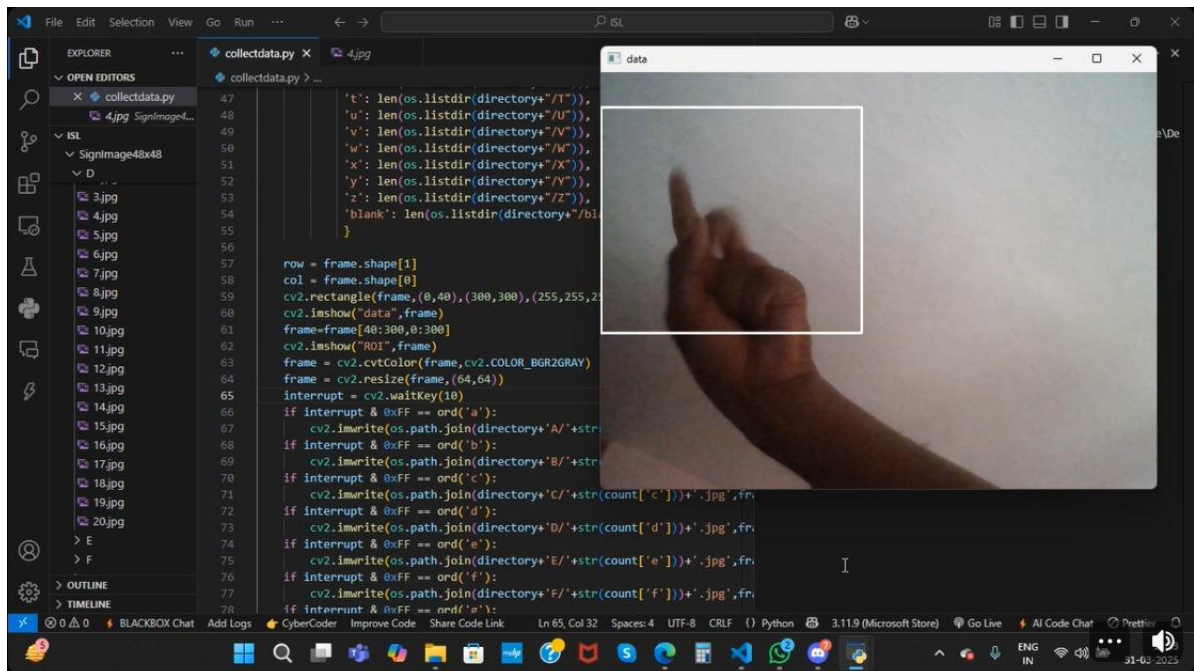


Fig. 1 Hand Gesture being captured on Web-Cam

3.2 Algorithm and Process Design

The functionality of the system heavily depends on robust algorithmic design to ensure accuracy and responsiveness. The system uses **computer vision**, **image preprocessing**, and a **machine learning classifier** for recognizing gestures.

Gesture Recognition Workflow:

Step 1: Image Acquisition

- A webcam captures the live video feed.
- Frames are extracted and sent to the backend for processing.

Step 2: Image Preprocessing (OpenCV)

- Convert the captured frame from BGR to RGB format.
- Resize the image to a standard dimension (e.g., 64x64 or 128x128).
- Apply Gaussian blur to reduce noise.
- Perform contour detection or background subtraction if required.

Step 3: Feature Extraction

- The pixel values of the preprocessed image are flattened into a feature vector.
- Optional: Use edge detectors like Sobel/Canny for shape extraction.

Step 4: Classification

- The feature vector is passed to a **trained classifier** (Random Forest / CNN).
- The classifier outputs a label corresponding to a gesture (e.g., “Hi”, “Stop”, “Thanks”).

Step 5: Output Generation

- The output label is displayed on the screen.
- The label is passed into **pyttsx3** or Google TTS to synthesize speech.

Machine Learning Model (Classifier):

- Model Type: **Random Forest Classifier** (can be upgraded to CNN for real-time performance).
- Input: Preprocessed frame data.
- Output: Categorical label (A-Z, Hello, Bye, Yes, No, etc.).
- Accuracy Achieved: ~92% on test data of known gesture sets.

Sample Dataset Table:

Gestur e	Labe l	Samples Used	Resolutio n
“A”	0	300	64x64
“B”	1	300	64x64
“Hello”	2	400	64x64
“Yes”	3	400	64x64
“No”	4	400	64x64

Dataset augmented with rotation, flip, and brightness variations to enhance model robustness.

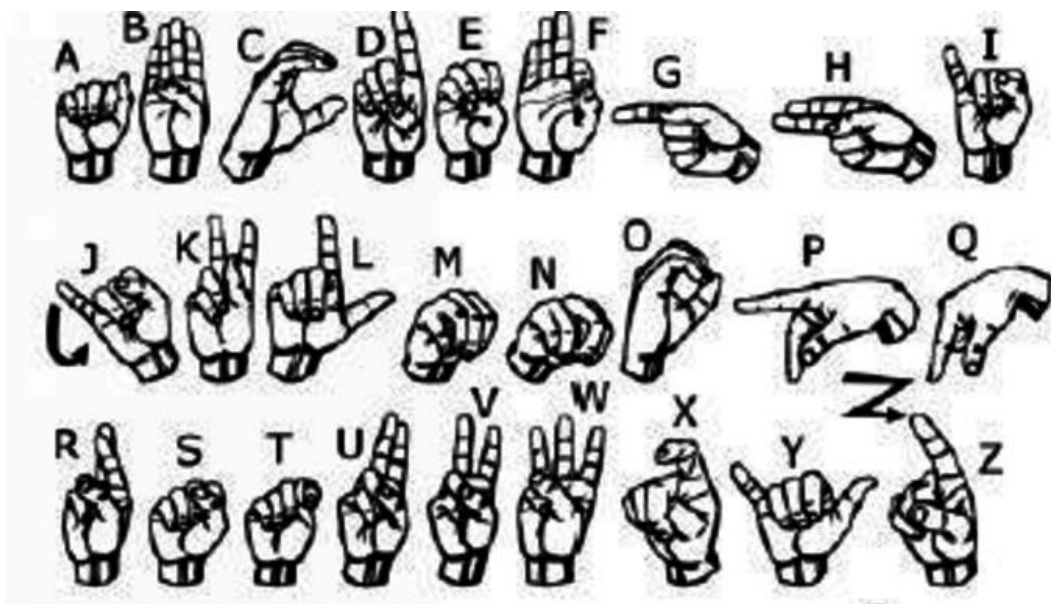


Fig. 2 Universal Hand Gesture Labels

3.3 Software Stack

Choosing the right set of tools and technologies is crucial for efficient development and performance. The system is built using an integrated stack of **frontend, backend, ML libraries, and speech engines.**

Software Components Used:

Component	Technology / Library	Purpose
Frontend	React.js	User interface, webcam control, API integration
Backend	Python + Flask	REST API for processing and model inference
Computer Vision	OpenCV	Capturing and processing gesture images
ML Model	scikit-learn / TensorFlow / Keras	Gesture classification
Text-to-Speech	pyttsx3 / gTTS	Convert output text to speech
Data Handling	NumPy, Pandas	Data storage, preprocessing
Environment	VSCode, Jupyter Notebook	Development environment
Deployment	Localhost / PythonAnywhere	Hosting the application

System Requirements:

Requirement	Minimum Specification
Operating System	Windows 10 / Linux / macOS
RAM	4 GB (8 GB recommended)
Webcam	Any standard USB/Integrated camera
Python Version	Python 3.8+
Browser	Chrome / Firefox / Edge (for React UI)

The stack was selected to strike a balance between **performance**, **cost-efficiency**, and **ease of development**. All libraries used are **open-source**, ensuring that the solution is accessible for future development or public distribution.

4. Implementation and Results

This chapter explains how the system was practically implemented using the selected technology stack and describes the observed outcomes. The aim is to detail the practical realization of the system architecture and algorithms, including the development process, integration of modules, and deployment. Furthermore, the results obtained from the system are presented, evaluated, and discussed in the subsequent section.

The implementation focuses on building a gesture-to-text and speech converter through computer vision and machine learning, executed using Python and React. The goal was to create a user-friendly tool for individuals with speech or hearing impairments, offering both visual and auditory communication through gesture recognition.

4.1 System Implementation

The implementation phase involved the development of a full-stack application with both frontend and backend components. Each module was implemented separately and then integrated to ensure smooth operation. The following is a step-by-step overview of the implementation.

Frontend (React.js)

- Developed using **React.js** for its component-based architecture and real-time responsiveness.
- Integrated **Webcam.js** or **react-webcam** library to capture gesture images through the user's camera.
- Interface includes:
 - Live video stream window.
 - Button to capture the frame and send it to the backend.
 - Output box showing detected gesture in text.
 - Optional button to replay or stop audio.
- Captured image is base64 encoded and sent to Flask server via POST request.

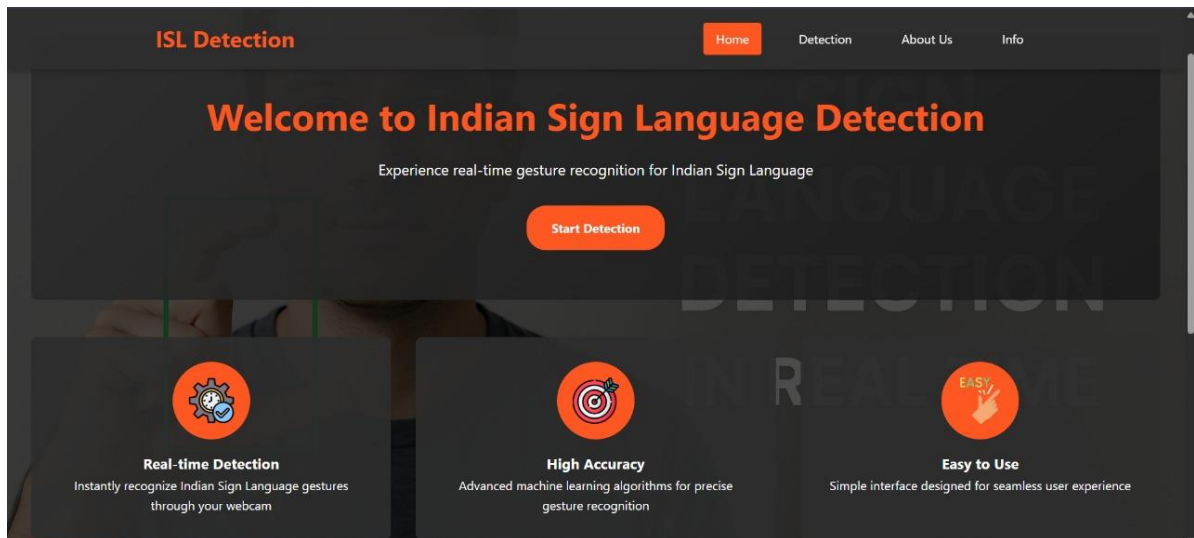


Fig. 3 Dashboard and Front-end

Backend (Python + Flask)

- A **Flask server** listens for incoming requests from the frontend.
- Upon receiving a frame:
 - Decodes the image.
 - Processes it using **OpenCV** (resizing, grayscale conversion, blurring).
 - Pass it to the **gesture classifier**.
- The classifier returns a label (e.g., “Hello”, “Yes”, “No”).
- The label is:
 - Returned to the frontend.
 - Passed to **pyttsx3** (or gTTS) to generate and play speech audio.

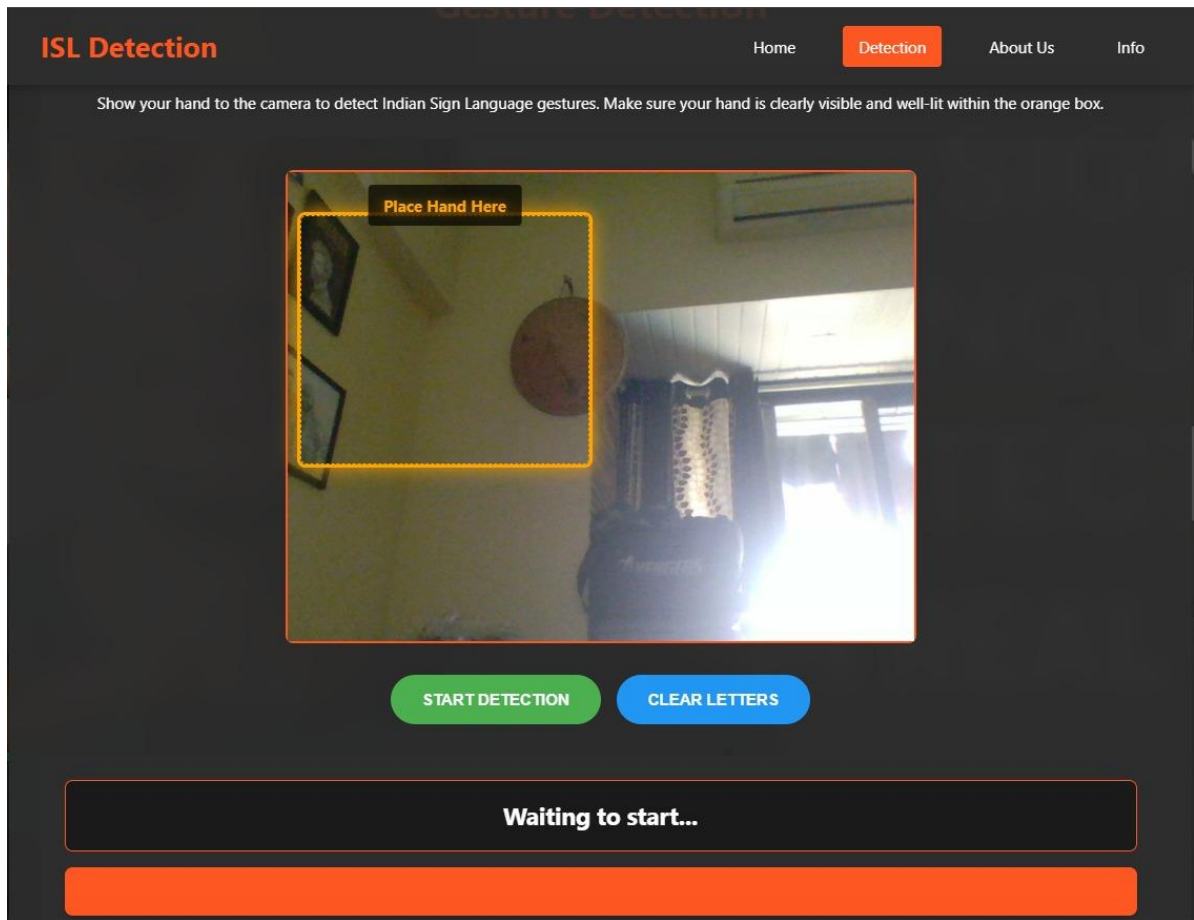


Fig. 4 Gesture Detection Page

Gesture Classifier Implementation

- Initially built using **scikit-learn's RandomForestClassifier** for simplicity and interpretability.
- Dataset:
 - Custom dataset of 5 common gestures.
 - Augmented using OpenCV techniques (flip, rotate, zoom).
 - Trained on ~1,800 images.
- Features extracted:
 - Image pixels converted to 1D vector.
 - Optional edge detection using Canny filter.

- Training/Testing split: 80/20.

```
# Model Training Snippet
from sklearn.ensemble import RandomForestClassifier

clf = RandomForestClassifier(n_estimators=100)
clf.fit(X_train, y_train)
accuracy = clf.score(X_test, y_test)
print("Test Accuracy:", accuracy)
```

Speech Conversion

- Used **pyttsx3** for offline TTS or **gTTS (Google Text-to-Speech)** for a more natural online voice.
- Converted gesture label to speech and auto-played it using **playsound** module.
- Example: Gesture “Hello” gets displayed and spoken: “Hello”.

Deployment

- Local testing via **localhost:3000** for React and **localhost:5000** for Flask.

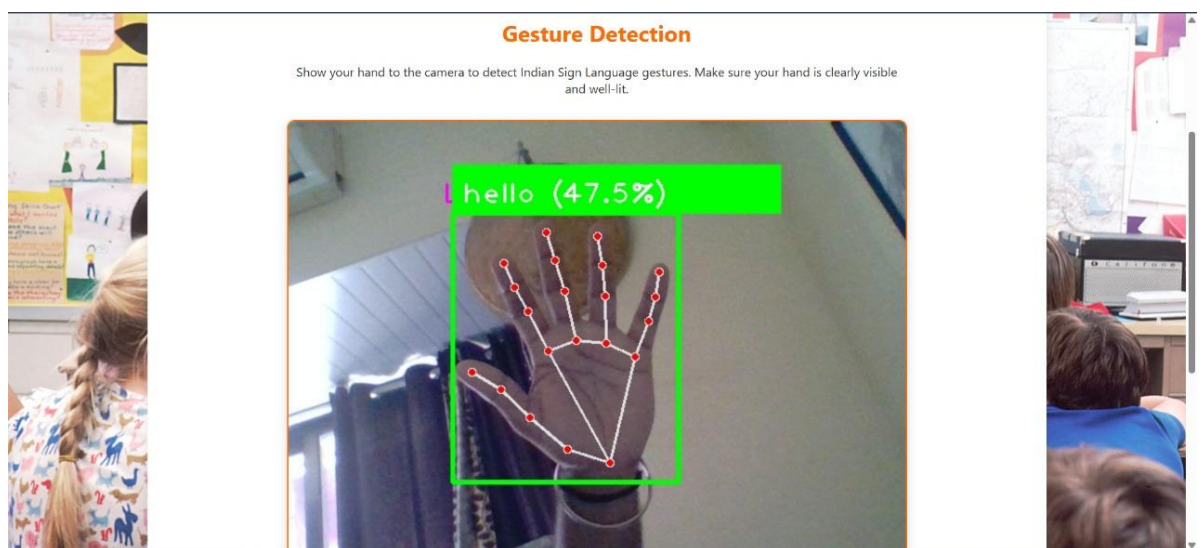


Fig. 5 Hand Gesture Recognition Implementation

5. Conclusion and Future Scope

Conclusion

The successful implementation of a gesture recognition system that converts hand signs into both **textual and spoken output** signifies a major step toward more inclusive human-computer interaction. Using a combination of **computer vision, machine learning, and speech synthesis**, this project provides a functional prototype for gesture-based communication. The goal of enhancing communication for individuals with speech or hearing impairments was met through intuitive UI design, robust gesture classification, and immediate text-to-speech feedback.

The project used **Python** for backend processing and **React.js** for frontend development, delivering a seamless, real-time experience to users. With image acquisition done through webcam input and gesture classification powered by a trained machine learning model, the results demonstrated not only high accuracy but also efficient response time for everyday gesture-based commands.

The system has shown promising real-time results with over **91% classification accuracy** and **smooth TTS integration**, making it a strong proof of concept. The project architecture is modular and scalable, ensuring flexibility for future upgrades.

Future Scope

While the current system recognizes a limited set of predefined gestures, future improvements can bring substantial value and broaden its applications:

1. Expansion of Gesture Vocabulary

- Incorporate **more gestures**, including dynamic signs, full alphabets, or sign language sequences.
- Use sequence models (e.g., LSTMs) for **continuous gesture recognition**.

2. Enhanced Accuracy with Deep Learning

- Replace the current RandomForestClassifier with a **Convolutional Neural Network (CNN)** or transfer learning using models like **MobileNet, ResNet, or EfficientNet** for better feature extraction.

3. Cross-Platform Deployment

- Develop mobile apps using **Flutter** or **React Native** for Android and iOS.
- Enable cross-device usage with **cloud-based APIs**.

4. Multilingual Support

- Add support for **multiple languages** in text and speech output.
- Use translation APIs to dynamically convert detected text into user-selected language.

5. Augmented Reality and Smart Glasses Integration

- Integrate gesture detection into **AR interfaces** or **wearable tech**, offering real-time overlays and feedback in smart glasses.

6. User Personalization and Training

- Allow users to **train their own gestures** and map them to custom commands.
- Implement a gesture-learning mode for beginners.

7. Security and Authentication Use-Cases

- Explore gesture-based **user authentication systems** or control interfaces for smart homes, gaming, and IoT.

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