Gesturely: Sign Language to Sentences

Submitted in partial fulfillment of the requirements of the degree

BACHELOR OF ENGINEERING IN COMPUTER ENGINEERING

By

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(AY 2023 – 24)

Certificate

This is to certify that the Mini Project entitled **“Gesturely: sign language to sentences”** is a bonafide work of **Piyush Chugeja (11), Sakshi Kirmathe (25), & Deven Bhagtani (06)** submitted to the University of Mumbai in partial fulfillment of the requirement for the award of the degree of **“Bachelor of Engineering”** in **“Computer Engineering”.**

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Principal

Mini Project Approval

This Mini Project entitled **"Gesturely: sign language to sentences"** by **Piyush Chugeja (11), Sakshi Kirmathe (25), & Deven Bhagtani (06)** is approved for the degree of **Bachelor of Engineering** in **Computer Engineering.**

Examiners

1. ……
(Internal Examiner name & sign)

2. ……
(External Examiner name & sign)

Date: 21st October 2023

Place: Chembur, Mumbai

Contents

Abstract

This project addresses the challenge of facilitating effective communication between the deaf and hearing communities in India by converting Indian Sign Language (ISL) into comprehensible sentences. To achieve this, we harness advanced computer vision and deep learning techniques. The primary objective is to create a system capable of recognizing ISL gestures and translating them into text. This endeavor is motivated by the goal of fostering greater accessibility and inclusivity for the deaf population in India.

The core of our solution revolves around the development of a robust model. This model should be proficient in recognizing a diverse range of ISL signs, ensuring accuracy and comprehensiveness in the translation process. By bridging the communication gap between ISL users and those who do not understand the language, our project aspires to contribute to a more inclusive and interconnected society. The ultimate aim is to provide a real-time ISL-to-sentence conversion tool that empowers the deaf community, making information and communication more accessible and equitable for all.

Acknowledgement

We would like to thank and express gratitude to all those who contributed and supported us to plan our project smoothly and successfully.

We would like to express our gratitude towards Dr. J. M. Nair, Principal of V. E. S. Institute of Technology for her immense support and motivation.

Firstly, we would like to thank Dr. Nupur Giri, Head of Department, Computer Engineering of V. E. S. Institute of Technology, and our mentor, for her guidance. We are whole-heartedly thankful to her for giving us their valuable time and knowledge to make us understand the executing process and hence providing a systemic planning of our project in time.

We would like to thank our project coordinator Mrs. Priya R. L. under whose guidance, we could learn many things. Not just this, she motivated us and strengthened our confidence in the entire execution process.

We would also like to extend our gratitude to all the faculty members who have not just been a constant source of support, but also encouraged us for timely completion of assigned execution activity.

Lastly, we would like to acknowledge our classmates, who have also provided us with every possible support and learning to execute our project efficiently.

List of abbreviations

Sr no.	Short form	Abbreviated form
1	API	Application programming interface
2	ISL	Indian Sign Language
3	CNN	Convolutional Neural Network
4	RNN	Recurrent Neural Networks
5	LLM	Large Language Model
6	NLP	Natural Language Processing
7	TTS	Text to Speech

List of figures

Chapter I: Introduction

1.1 Introduction

Communication is an essential aspect of human interaction, enabling the exchange of ideas, emotions, and information. However, for individuals who are mute or deaf and rely on sign language as their primary means of communication, connecting with the hearing community can be challenging. There are thousands of languages in the world. Nearly all of the most popular languages can be translated live using software such as Google Translate. The software used is mainly based on an NLP algorithm which takes in one language through text and produces its translation through text. For true live translation, some software utilize voices via a mic to translate a message without having the user type it in. This works great for spoken languages. But what about the 70 million individuals who either can't speak or can't hear and use sign language as a means of communication. The lack of a common language can lead to barriers, limiting their ability to fully participate in social, educational, and professional settings.[4]

Sign language is a unique and expressive form of communication used by individuals who have speech or hearing impairments. Unlike spoken languages, sign language relies on hand gestures, facial expressions, and body movements to convey meaning. It serves as a vital means of interaction, allowing the speech impaired community to express their thoughts, emotions, and ideas effectively. In India, Indian Sign Language (ISL) is widely used and recognized as the primary mode of communication among the deaf and mute population. ISL is a complete language with its own grammar, syntax, vocabulary and several unique linguistic attributes. It is used by over 5 million deaf people in India.[5] Understanding the significance of sign language, it becomes essential to explore innovative solutions that bridge the communication gap and promote inclusivity for the speech and hearing-impaired individuals in India.

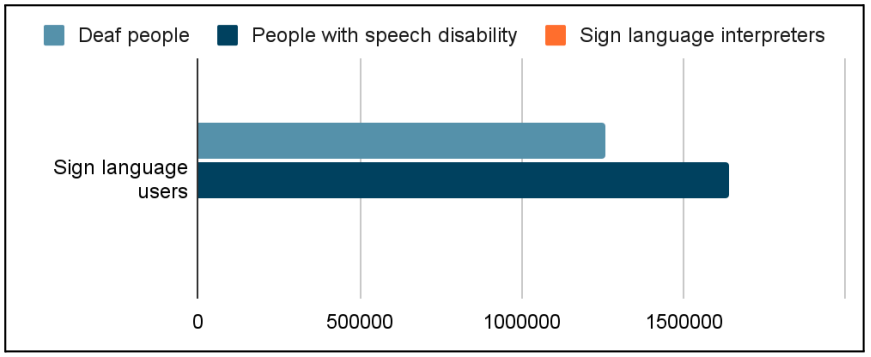


Figure 1.1 Count of interpreters vs sign language users [6]

Figure 1.1 displays how there are around 1.26 million deaf people and 1.64 million people with speech disability in India, while there are only 250 certified sign language interpreters in India, thus making the number exponentially smaller.[6]

Through the Gesturely application, users will find a unique avenue to effectively convey their thoughts, emotions, and ideas via sign language. This system seamlessly translates their sign language into spoken language output in real-time, fostering a bridge between these two modes of communication. This application not only empowers mute and deaf individuals but also facilitates their active engagement in a plethora of situations. From everyday conversations to the challenges of job interviews, the demands of academic discussions, and diverse social interactions, Gesturely paves the way for inclusive participation, thereby enhancing the social, educational, and professional prospects of this often marginalized community. This comprehensive solution brings an unprecedented level of accessibility and communication potential to the lives of the speech and hearing-impaired, redefining their ability to interact and connect with the world around them.

1.2 Motivation

Our motivation for undertaking this project stems from our desire to apply our knowledge and skills to drive positive change. By leveraging what we've learned, we aim to bridge the communication gap between the hearing and speech-impaired communities through technology. Our goal is to empower mute and deaf individuals, enhance their quality of life, and promote inclusivity, thus making a tangible and meaningful impact on society.

1.3 Problem Statement & Objectives

The core issue we aim to address in this project is the pervasive communication barrier that exists between sign language users and those who do not comprehend sign language. This deficiency in a common language results in impediments to effective interaction in a range of scenarios, including social exchanges, job interviews, educational environments, and day-to-day conversations. This disconnection hampers seamless communication and inclusivity, thereby restricting the full participation of deaf and speech-impaired individuals within the hearing community.

When sign language speakers, mute individuals, or deaf individuals encounter those unfamiliar with sign language, they often resort to arduous means to communicate. This absence of a shared linguistic medium elevates the risk of misunderstandings and the misinterpretation of messages, contributing to frustration and confusion for both parties.

The project aims to address the significant communication barrier between sign language

users and those who do not understand sign language, which leads to difficulties in social interactions, job interviews, educational settings, and everyday conversations. This disconnect impedes effective communication and inclusion, limiting the full engagement of deaf and speech-impaired individuals with the hearing community.

Key objectives:

- Develop a Robust Translation System: Create a reliable and efficient system that can accurately translate Indian Sign Language (ISL) into spoken language in real-time, ensuring the seamless exchange of ideas and emotions.
- Enhance Accessibility: Improve accessibility for deaf and speech-impaired individuals by providing them with a tool that empowers them to communicate effectively in diverse settings, such as social, educational, and professional environments.
- Promote Inclusivity: Foster inclusivity by enabling deaf individuals to participate more fully in society, breaking down communication barriers and reducing their reliance on intermediaries.
- User-Friendly Interface: Design an intuitive and user-friendly interface for the application to make it accessible to a wide range of users, regardless of their technological proficiency.
- Cultural and Linguistic Sensitivity: Ensure that the system respects the cultural and linguistic nuances of Indian Sign Language, promoting accurate and respectful communication.
- Real-time Performance: Optimize the system for real-time performance to facilitate spontaneous and dynamic conversations, including emergency situations.

1.4 Organization of the report

In this report, we further discuss the following points:

- Literature survey of existing systems
- Limitations of existing systems
- Mini project contribution
- The proposed system
- Working of the project
- Details of hardware and software used
- Results
- Performance analysis
- Conclusion

Chapter II: Literature survey

2.1 Survey of existing systems

Overview

- Communication is a fundamental aspect of human interaction, enabling the exchange of ideas, emotions, and information.
- However, for individuals who are mute or deaf and rely on sign language as their primary means of communication, connecting with the hearing community can be challenging.
- Various existing systems and research efforts have aimed to address this issue.

Paper 1: Sign Language to Text Conversion in Real Time using Transfer Learning

- Authors: Shubham Thakar, Samveg Shah, Bhavya Shah, and Anant V. Nimkar
- Methodology: This project focuses on real-time sign language translation. It takes English audio input, converts it into English text, and then parses the text to create structured grammar representations of Indian Sign Language (ISL). The system processes the input through steps like removing stop words, stemming, lemmatization, and finding synonyms for words not in the ISL dictionary.
- Advantages:
    - Real-time translation: Provides immediate sign language interpretation for better communication.
    - Grammar representation: Creates structured ISL grammar representations, improving the translation's clarity and accuracy.
- Disadvantages:
    - Limited vocabulary: May face limitations in handling less common or specialized terms due to the evolving nature of ISL.
    - Accuracy challenges: Some inaccuracies in word selection and sentence construction may occur, leading to redundancy and potential misunderstanding.

Paper 2: Speech to Indian Sign Language Translator

- Authors: Hemang Monga, Jatin Bhutani, Muskan Ahuja, Nikita Maida, and Himangi Pande
- Methodology: This project focuses on translating English audio into Indian Sign

Language (ISL). It employs various Natural Language Processing (NLP) techniques, including text-to-speech conversion, tokenization, lemmatization, stemming, and word synonym replacement. It integrates three-dimensional avatar animations to represent ISL signs effectively.

- Advantages:
  - Real-time translation: Offers immediate translation of spoken English into ISL signs.
  - Effective representation: Uses avatar animations for clear and engaging ISL communication.
- Disadvantages:
  - Vocabulary limitations: Similar to Paper 1, may have challenges in handling less common or specialized terms.
  - Accuracy concerns: Some systems may lack accuracy in word selection and grammar construction, potentially leading to misunderstandings.

Paper 3: Hand Gesture Identification using Mediapipe

- Authors: Ketan Gomase, Akshata Dhanawade, Prasad Gurav, Sandesh Lokare (Students), Dr. Jyoti Dange (Professor & Project Guide)
- Methodology: This paper discusses the development of a sign language recognition system using the Mediapipe framework, which leverages machine learning to detect and interpret hand gestures. The framework identifies 21 3D landmarks on the hand from a single frame, making real-time hand and finger tracking possible. The recognition system focuses on the American Sign Language (ASL) alphabet characters and uses the k-nearest neighbors (KNN) algorithm for prediction.
- Advantages:
  - Real-time recognition: The system is capable of recognizing ASL alphabet characters in real time, making it practical for communication.
  - Use of Mediapipe: Utilizes the powerful features of the Mediapipe framework for hand gesture recognition, allowing for robust and accurate detection of hand landmarks.
- Disadvantages:
  - Limited to ASL alphabet: The system's primary focus is on recognizing ASL alphabet characters, limiting its broader applicability to other sign languages or gestures.

2.2 Limitations of existing system

- Dependency on Interpreters
  Many systems still rely on human interpreters to facilitate communication between sign language users and non-signers, particularly in complex and nuanced interactions.

- Lack of Real-time Sign Language Translation
  Some existing systems lack the capability to provide real-time translation, which can be crucial in fast-paced and spontaneous conversations.

- Limited Language Support
  Existing systems often focus on a specific sign language, limiting their applicability to a broader range of languages. More comprehensive language support is necessary.

- Limited Accessibility
  Access to and availability of these systems can be limited, preventing many individuals from benefiting from them, especially in resource-constrained environments.

- Non-Inclusive Interfaces
  The user interfaces of some existing systems may not be user-friendly or inclusive, making them challenging for individuals with varying abilities to use effectively.

- Lack of Accuracy
  Accuracy remains a challenge in many existing systems, which can lead to misinterpretations and misunderstandings, especially in critical situations.

2.3 Mini project contribution

"Gesturely" aims to address these limitations by offering a novel solution for converting sign language into sentences. The project's contribution can be summarized as follows:

- Real-time Sign Language Translation: Gesturely focuses on real-time sign language translation, enabling individuals who use sign language to engage in live conversations with non-signers seamlessly.

- Comprehensive Language Support: The project aims to support multiple sign languages, starting with Indian Sign Language (ISL), which is widely used by the deaf and mute population in India. This approach broadens the applicability of the solution.

- Enhanced Accessibility: Gesturely strives to provide a user-friendly and accessible interface, making it easier for individuals with varying abilities to use the application effectively.
- Improved Accuracy: Through the use of deep learning models and transfer learning, the project has achieved a higher level of accuracy in sign language recognition and translation, addressing the accuracy limitations present in some existing systems.
- Bridging Communication Gaps: By offering a practical and efficient way to convert sign language into text and, subsequently, spoken language, Gesturely aims to bridge communication gaps in various social, educational, and professional settings.

Chapter III: Proposed system

3.1 Introduction

The “Gesturely: Converting gestures to words” project offers an innovative and transformative solution to bridge the communication gap faced by mute and deaf individuals when interacting with people who do not know sign language. This project involves the development of a user-friendly mobile application that utilizes advanced deep learning and computer vision technologies. The application will interpret Indian Sign Language (ISL) gestures in real-time and seamlessly convert them into natural-sounding speech. By leveraging deep learning models trained on a diverse dataset of sign language gestures, the application will accurately recognize intricate hand movements and facial expressions, enabling effective translation into speech output. This real-time speech synthesis feature empowers mute and deaf individuals to express themselves verbally, promoting inclusivity and meaningful communication with the hearing community. It aims to create a transformative tool that enhances social interactions, job opportunities, educational experiences, and overall engagement, breaking down communication barriers and promoting a more understanding and connected society.

3.2 Architectural framework / Conceptual design

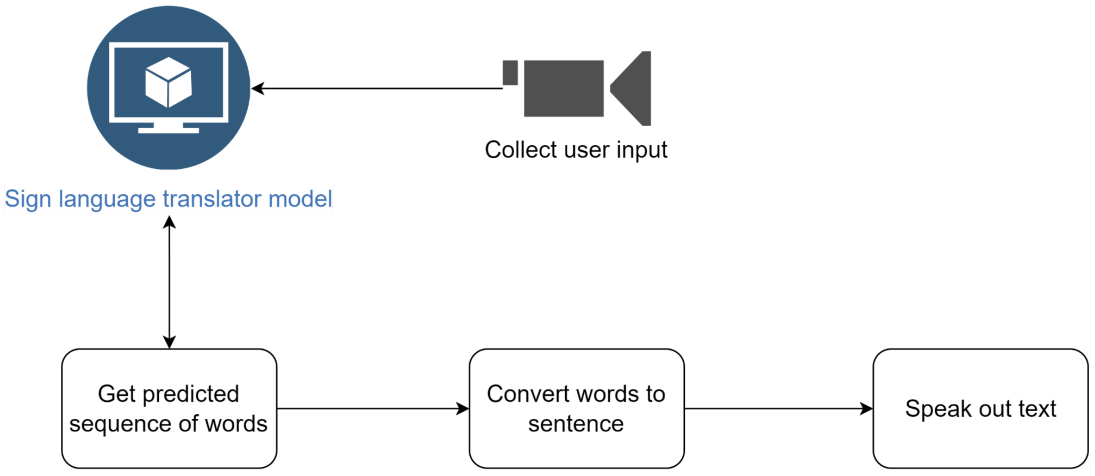


Figure 3.1 Block diagram of system

- Collect User Input: This initial step involves capturing input from the user, who communicates using Indian Sign Language (ISL). This input typically consists of sign gestures and expressions, which are recorded through a camera or sensor-equipped device. The collected data serves as the foundation for subsequent processing.

- Sign Language Translator Model: The collected sign language input is fed into a specialized model, often powered by computer vision and deep learning techniques. This model interprets the sign gestures and facial expressions, recognizing the underlying meaning and translating them into text. It leverages a robust database of ISL signs and their corresponding linguistic meanings.
- Get Predicted Sequence of Words: The model's output consists of a sequence of words or phrases that correspond to the interpreted ISL input. These words are typically presented in a textual format, representing what the user intended to convey through their sign language communication. The sequence forms the foundation for constructing coherent sentences.
- Convert Words to Sentence: The sequence of words generated by the model is then processed to construct grammatically correct and contextually relevant sentences. This step involves syntax and grammar rules to ensure that the output is comprehensible and coherent. The constructed sentences provide a meaningful representation of the user's intended message.
- Speak Out Text: The final output, which is the constructed sentence, is converted into audible speech. This is typically achieved through a text-to-speech (TTS) engine, which transforms the textual representation of the sentence into spoken words. The result is an audible rendition of the user's originally signed message, enabling effective communication with individuals who do not understand ISL. This spoken output can be relayed through speakers or headphones, facilitating real-time conversations and interactions.

3.3 Algorithm and process design

Algorithms and libraries

- Mediapipe for Hand Gesture Extraction: We utilized the Mediapipe library to extract real-time hand gesture movements from the video input provided by the user. The hand tracking module in Mediapipe allowed us to accurately locate and track the user's hand in the video frames.
- Machine Learning Model for Gesture Prediction: To predict the hand gestures in real-time, we employed a deep learning model based on convolutional neural networks (CNNs). This model was trained on a comprehensive dataset of Indian Sign Language (ISL) gestures. We used TensorFlow as the primary framework to develop, train, and deploy the machine learning model.

Process Design

- Data Collection and Preparation:
  - Gathered a diverse dataset of ISL gestures, including variations in hand shapes and movements.
  - Annotated the data to ensure the model's accurate training and evaluation.
- Model Training:
  - Developed a CNN-based deep learning model using TensorFlow.
  - Trained the model on the collected dataset, fine-tuning its ability to recognize a wide range of ISL gestures accurately.
- Real-time Gesture Tracking and Prediction:
  - Integrated the trained model with the Mediapipe library to track and predict hand gestures in real-time.
  - Processed video input from the user's camera to extract the hand's position and movements.
- Integration with Natural Language Processing (NLP):
  - The predicted gestures were converted into text, forming a sequence of words.
  - Integrated NLP techniques to construct coherent sentences from the sequence, ensuring grammatical accuracy and context-based interpretation.
- Text-to-Speech Conversion (TTS):
  - Implemented a TTS engine to synthesize the constructed sentences into audible speech.
  - The choice of voice was made available to the user, offering a personalized experience.

3.4 Methodology applied

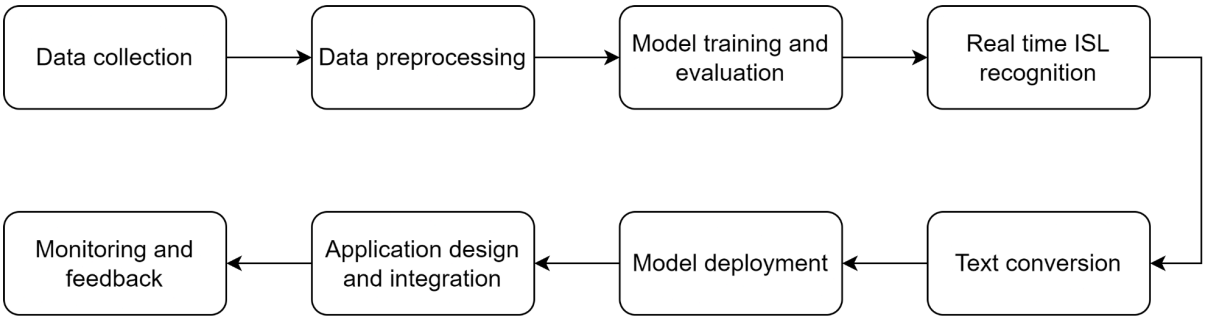


Figure 3.2 Methodology diagram

The approach outlined in [1] utilized a deep learning model for high-accuracy performance through Transfer Learning, yielding significant improvements when compared to a conventional CNN model. In alignment with this methodology, we will apply a similar approach, albeit with a focus on Indian Sign Language (ISL). Our endeavor to convert sign language to text entails the fusion of computer vision, machine learning, and natural language processing technologies for precise detection, recognition, and translation of sign language gestures into textual messages. The ensuing steps encapsulate our process for constructing the requisite application:

- Gestured Data Recognition: We will utilize the Mediapipe framework to identify sign language gestures. Diverse gesture datasets will be assembled from sources including sign language institutes, online sign language resources, established research datasets like INCLUDE[5], and relevant workshops.
- Data Preprocessing: During the preprocessing phase, the hand gesture images will undergo essential transformations. These transformations encompass resizing, normalization, and structuring to create a suitable dataset. This curated dataset serves as input for the model, imparting the information necessary for learning the correlations between gestures and textual representation. This empowers the model to achieve high-accuracy recognition and translation of hand gestures into text.
- Model Training and Validation: Our chosen model architecture, primarily reliant on Mediapipe for gesture recognition, will undergo training and validation. This involves a Convolutional Neural Network (CNN) trained on the collected sign language dataset. The model will acquire the capacity to discern and comprehend a wide spectrum of sign language gestures, facilitating accurate conversion into corresponding text representations. Rigorous validation and testing under real-world scenarios and user interactions will be conducted to assess both model accuracy and the application's real-time functionality. Furthermore, the integration of natural language processing (NLP) techniques will ensure seamless and precise translation, making the application an invaluable resource for accessible communication.
- Application Development: This phase will encompass the development of a user-friendly interface that caters to both sign language users and non-signers, thereby enabling effective communication. The trained model, grounded in the Mediapipe framework, will enable real-time sign language recognition. In parallel, the application will incorporate natural-sounding speech synthesis for

spoken language output. A primary focus will be on accessibility and inclusivity, ensuring an enriching user experience through swift gesture-to-text and speech translation.

3.5 Hardware and software specifications

Hardware Requirements

- Computer with a modern processor and at least 8 GB of RAM.
- Graphics Processing Unit (GPU) with CUDA support (recommended).
- Sufficient storage space, preferably SSD.
- Webcam for real-time sign language interpretation.

Software Requirements

- Operating System: Windows, macOS, or Linux.
- Python programming language.
- Deep learning framework (TensorFlow or PyTorch).
- Computer vision libraries (OpenCV).
- Text-to-speech (TTS) library (pyttsx3 or gTTS).
- User Interface (UI) library (Tkinter or PyQt).
- Integrated Development Environment (IDE).
- Application framework (Android VM, React Native, or Flask)

3.6 Experiment and Results

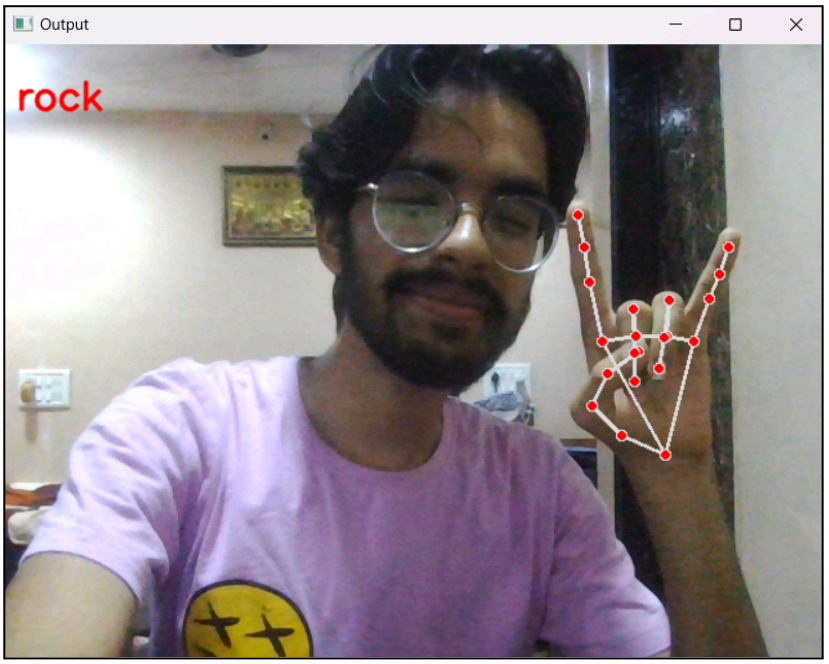
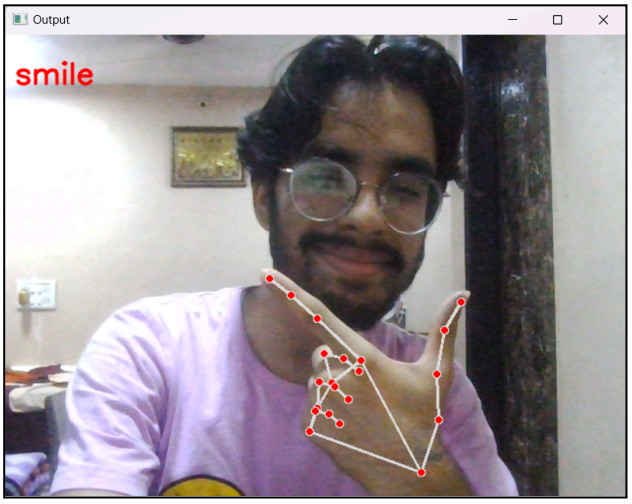


Figure 3.3: Model successfully recognising rock sign.



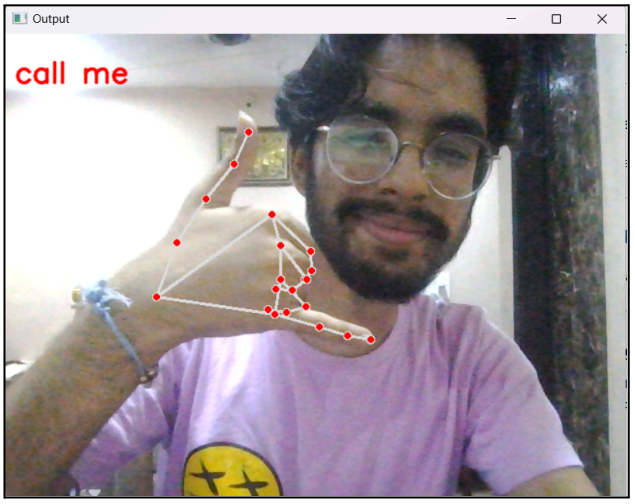
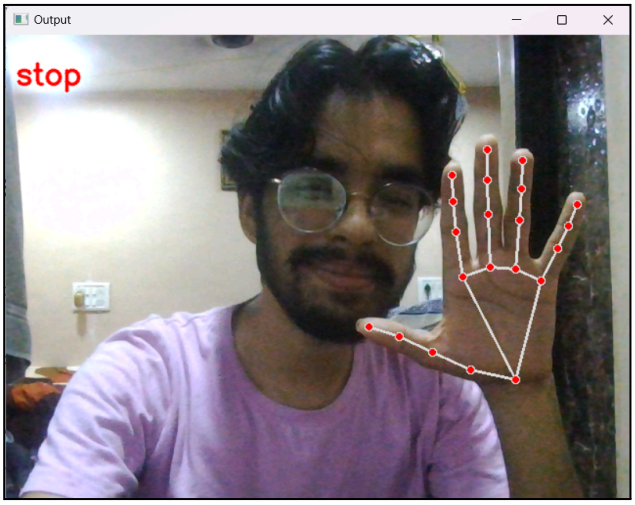


Figure 3.4 & 3.5: Model recognising smile, peace gesture shown by user.



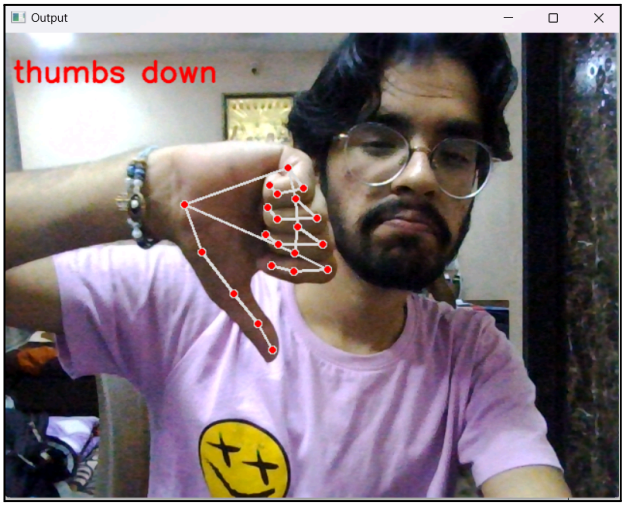
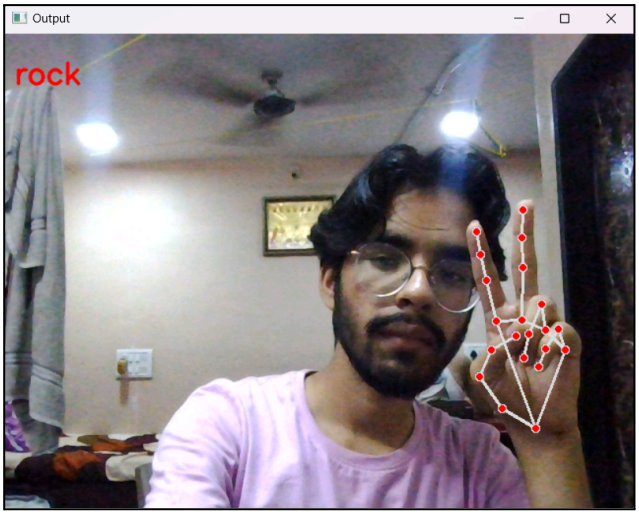


Figure 3.6 & 3.7: Model displaying the correct output of both gestures made by the user.



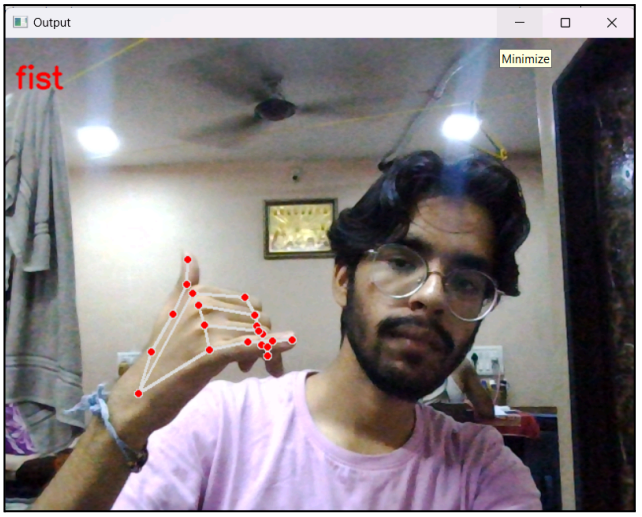


Figure 3.8 & 3.9: Model inaccurately predicts the output of similar gestures, indicating that more training is required under improperly lit conditions

3.7 Result analysis and discussion

The project's core achievement lies in the seamless integration of gesture recognition and natural language processing. Leveraging a robust model trained on Mediapipe and machine learning, we successfully recognized intricate sign gestures. Subsequently, we harnessed these recognized gestures and skillfully combined them into coherent sentences using the GPT-3.5 Large Language Model (LLM), effectively transforming sign language communication into meaningful spoken language sentences. This innovative approach is a testament to the project's commitment to enhancing inclusivity and accessibility for individuals with speech and hearing impairments.

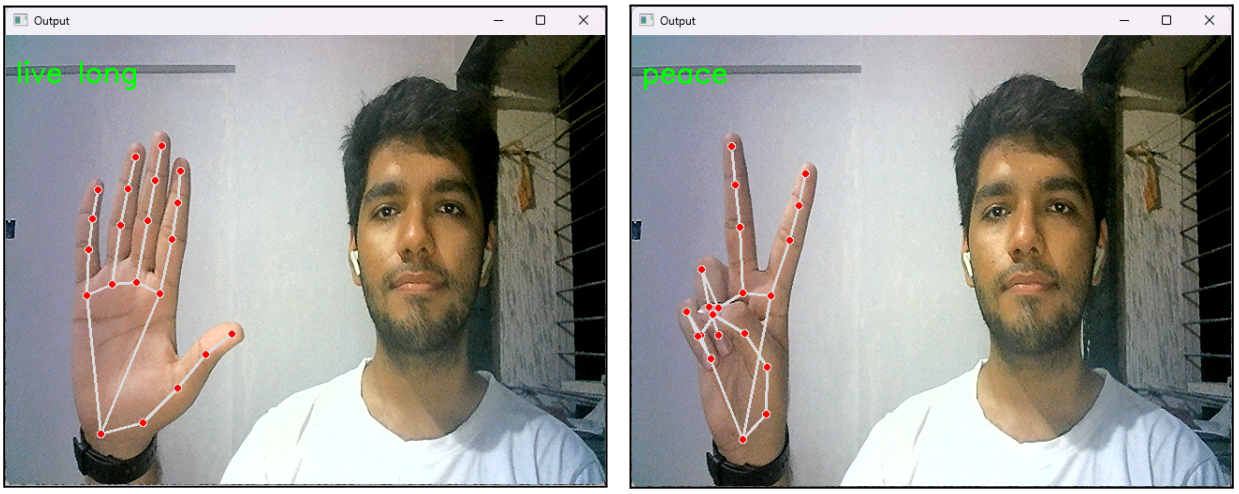
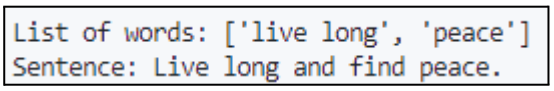


Figure 3.10 & 3.11: A set of signs was shown to the model



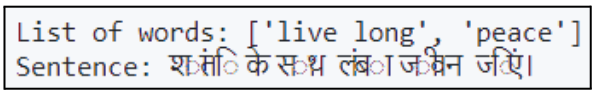


Figure 3.12 & 3.13: Model can generate output in multiple languages

3.8 Conclusion and future work

In this project, we have harnessed the power of technology to bridge the gap between Indian Sign Language (ISL) and spoken language. Leveraging the Mediapipe framework for precise gesture recognition and a machine learning model for real-time prediction, we have created a solution that empowers individuals who rely on ISL as their primary mode of communication. By seamlessly translating hand gestures into text and spoken language, our project enhances accessibility and inclusivity, ensuring that deaf and speech-impaired individuals can engage effectively in social, educational, and professional interactions. This project represents a significant stride toward breaking down communication barriers, underlining the importance of technology in fostering a more connected and equitable society.

Future work

- Multi-Modal Gestures: Extend the project to recognize not only hand gestures but also facial expressions and body movements, enabling a more comprehensive interpretation of sign language communication.
- Real-time Feedback: Implement features for immediate feedback to users, aiding them in refining their sign language communication skills and promoting learning.
- Customization: Develop personalized user profiles to adapt the system to individual preferences and improve recognition accuracy.
- Expanding Language Support: Explore the adaptation of the system to encompass multiple sign languages and regional dialects, further broadening its reach and impact.
- Accessibility Integration: Collaborate with hardware and software developers to embed the project within a variety of devices, making it readily accessible to a wider audience.
- Gesture Recognition Improvements: Continuously refine the gesture recognition model by incorporating advanced machine learning techniques and leveraging larger and more diverse datasets.

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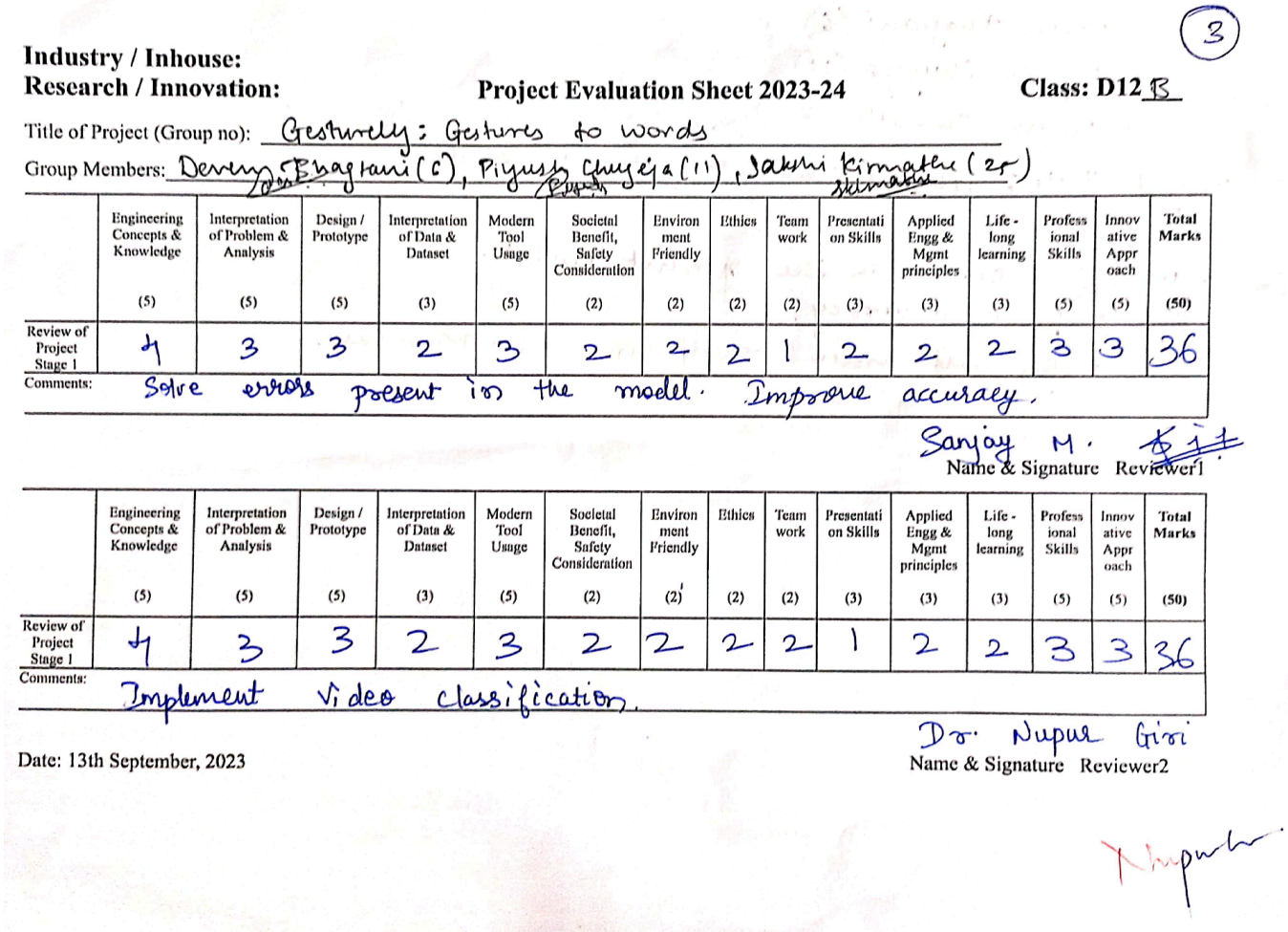
Chapter IV: Annexure

4.1 Review I sheet



(3)

Industry / Inhouse:
Research / Innovation: **Project Evaluation Sheet 2023-24** **Class: D12B**

Title of Project (Group no): Gesturely: Gestures to words

Group Members: Devang Bhagtani (C), Piyush Ghuyeja (11), Jaksni Kirnapure (25)

	Engineering Concepts & Knowledge (5)	Interpretation of Problem & Analysis (5)	Design / Prototype (5)	Interpretation of Data & Dataset (3)	Modern Tool Usage (5)	Societal Benefit, Safety Consideration (2)	Environment Friendly (2)	Ethics (2)	Team work (2)	Presentation Skills (3)	Applied Engg & Mgmt principles (3)	Life-long learning (3)	Professional Skills (5)	Innovative Approach (5)	Total Marks (50)
Review of Project Stage 1	4	3	3	2	3	2	2	2	1	2	2	2	3	3	36

Comments: Solve errors present in the model. Improve accuracy.

Sanjay M.
Name & Signature Reviewer1

	Engineering Concepts & Knowledge (5)	Interpretation of Problem & Analysis (5)	Design / Prototype (5)	Interpretation of Data & Dataset (3)	Modern Tool Usage (5)	Societal Benefit, Safety Consideration (2)	Environment Friendly (2)	Ethics (2)	Team work (2)	Presentation Skills (3)	Applied Engg & Mgmt principles (3)	Life-long learning (3)	Professional Skills (5)	Innovative Approach (5)	Total Marks (50)
Review of Project Stage 1	4	3	3	2	3	2	2	2	2	1	2	2	3	3	36

Comments: Implement video classification.

Dr. Nupur Giri
Name & Signature Reviewer2

Date: 13th September, 2023