IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 5, Issue 13, April 2025
Impact Factor: 7.67

Sign Language Detection Using Machine Learning

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Abstract: *Sign language is a vital means of communication for the Deaf and Hard of Hearing (DHH) community, yet it remains a barrier in interactions with the wider population. This project proposes a real-time sign language detection system using machine learning and computer vision to bridge this communication gap. The system captures hand gestures via a camera, processes the images using techniques like hand segmentation and feature extraction, and classifies them using a Convolutional Neural Network (CNN). The recognized signs are then translated into text or speech, enabling smooth interaction between sign language users and non- signers. The model achieves high accuracy and responsiveness in real-time, offering a practical solution for inclusive communication and educational tools. Future enhancements aim to support dynamic gestures, multi- language signs, and mobile deployment*

Keywords: Sign Language Detection, , machine learning, communication, hand gestures, computer vision

I. INTRODUCTION

The Sign Language Recognition Using Python project aims to develop a computer vision system capable of recognizing and interpreting sign language gestures through the use of Python programming language and various machine learning techniques. The project focuses on bridging the communication gap between the hearing-impaired community and the general public by enabling real-time translation of sign language gestures into written or spoken language.

The system will utilize a webcam or a camera to capture sign language gestures performed by the user. These gestures will then be processed and classified using machine learning algorithms to identify the corresponding words or phrases they represent. The final output will be displayed on the screen or communicated through text-to-speech functionality.

II. LITRATURE REVIEW

1. Sourav Kumar "A Robust Sign Language and Hand Gesture Recognition System Using Convolutional Neural Networks" (2023)

Sign language and hand gesture recognition systems have become increasingly important in recent years due to the growing demand for human computer interaction. In this paper, we propose a robust convolutional neural network (CNN)-based system for hand gesture and sign language identification. Using a custom dataset of Indian sign language and hand gestures, our method refines a pre-trained CNN model [1]. On a test set, we assess our system's performance, and we get a 98.6% accuracy rate. Our research aids in the creation of reliable sign language

recognition systems that may be put to practical use in fields like human-computer interaction and assistive technology for deaf and hard-of-hearing people.

2. Hridoy Adhikari "A Sign Language Recognition System for Helping Disabled People"(2023)

People with disabilities have difficulty in communicating, social interaction, obsessions and repetitive behaviours. The situation gets risky when these disabled people left alone freely in the outside world. But they shouldn't be locked up for this reason. So we need a way to help and protect them. Sign language recognition is the field related to communication which is a visual language that uses body language and facial expressions to convey meaning. Recent technological advances have enabled the development of advanced sign language recognition systems that can interpret

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sign language and translate it into written and spoken language. These systems typically use computer vision techniques to analyse sign language gestures and movements and map them to written or spoken language. Sign language recognition technology have the potential to greatly improve the accessibility of communication for people with hearing and speech impairments and to improve communication between people who speak different languages. In this paper, our proposed system has achieved the accuracy of 91.67% which is better compared to the existing works in the literature.

3. Wuyang Qin "Sign Language Recognition and Translation Method based on VTN"

Sign language recognition plays an important role in real-time sign language translation, communication for deaf people, education and human-computer interaction. However, vision-based sign language recognition faces difficulties such as insufficient data, huge network models and poor timeliness. We use VTN (Video Transformer Net) to construct a lightweight sign language translation network. We construct the dataset called CSL_BS
(Chinese Sign Language-Bank and Station) and two-way VTN to train isolated sign language and compares it with I3D (Inflated three Dimension).

4. D Shofia Priyadharshani "A Comprehensive Application for Sign Language Alphabet and World Recognition, Text-to-Action Conversion for Learners, Multi-Language Support and Integrated Voice Output Functionality" (2024)

This study aims to introduce a comprehensive application designed to facilitate learning and communication for sign language users. The purpose is to address the challenges faced by sign language learners and users in
effectively communicating with non-sign language users and to enhance their overall learning experience. The application integrates advanced algorithms for sign language alphabet and word recognition, text-to-action conversion, multi-language support, and integrated voice output functionality. These features are developed through rigorous research and software engineering methodologies to ensure accuracy, efficiency, and user- friendliness. The study identifies the lack of comprehensive tools for sign language learners and users to
effectively communicate with non-sign language users and the absence of seamless transition between different sign languages. Additionally, the study recognizes the need for enhanced accessibility and learning support for sign language users. These findings motivate the development of the proposed application to address these challenges and provide a solution that empowers sign language users and promotes inclusivity.

5. Jeet Debnath "Real-Time Gesture Based Sign Language Recognition System" (2024)

Sign language is a vital mode of communication for the deaf and dumb community. This research presents a robust and real-time Gesture-Based Sign Language Detection System that leverages computer vision and deep learning techniques. The system is designed to recognize and interpret American Sign Language (ASL) gestures, enabling efficient communication between individuals who are proficient in ASL and those who are not. The core of the system utilizes Python, OpenCV (Open-Source Computer Vision Library), and MediaPipe Holistic for real-time hand and body pose estimation. By accurately tracking the movements of hands and key body parts, the system
captures the nuances of sign language gestures. The captured data is then fed into a Long Short-Term Memory (LSTM) neural network, which excels in sequence modeling tasks. The LSTM model is trained on a comprehensive dataset of ASL gestures, encompassing a wide range of signs and expressions. Future work may explore the integration of natural language processing (NLP) to facilitate two-way communication between sign and spoken language. In conclusion, this Gesture-Based Sign Language Detection System represents a significant step towards harnessing the power of computer vision and deep learning to make sign language more accessible and inclusive in various domains, including education, accessibility, and social interaction.

6. M Soundarya "Sign Language Recognition Using Machine Learning"(2024)

The community of the deaf and hearing-impaired uses sign language as the primary but not exclusively dominant mode of communication. A strong system that can translate spoken language into sign language and vice versa must be built for the hearing and hearing-impaired groups to communicate easily and mutually. Currently, a sensor-based approach utilizing glove sensors and built-in sensors, along with CNN (Convolutional Neural Network) algorithms for image processing, is employed for recognizing sign language gestures. The proposed method for recognizing sign language is using LSTM (Long Short-Term Memory), a kind of RNN that can
recognize long-term dependencies, is used in the development. Apart from single data points like photos, which

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can process the full data stream The system can be utilized for machine translation and speech recognition, among other things. The suggested system offers a substantial contribution in that it uses advanced technology to facilitate communication between the hearing and hearing-impaired groups. The system provides precise gesture identification in sign language by LSTM algorithms, removing obstacles to efficient communication. By achieving accuracy levels between 90 and 100%, the system can effectively comprehend the complex nature of sign language by utilizing LSTM algorithms to capture long-term dependencies in sequential data.

7. Sonali M Antad "Sign Language Translation Across Multiple Languages

Sign Language serves as the only mode of communication for people who are speech and hearing disabled. Despite this, they face many difficulties in communication due to different sign languages across the world using different signs and symbols. This project aims to bridge this gap and make communication easy and accessible for all. Through the utilization of Convolutional Neural Networks (CNN) and other deep learning algorithms, the project provides a platform to people to choose between Indian Sign Language and American Sign Language and further provides translation to multiple Indian regional languages to improve communication between people. This serves a two-way purpose by enabling people who are trained in different sign languages to communicate efficiently as well as providing written text in multiple languages for people who cannot interpret sign language and are proficient only in regional languages. This comprehensive strategy strives to eliminate communication barriers, contributing to a more equitable society. This innovative project has the potential to significantly enhance communication inclusivity and accessibility for the global deaf and hard of hearing community.

8. Hira Hameed "Privacy-Preserving British Sign Language Recognition Using Deep Learning" (2022)

Sign language is a means of communication between the deaf community and normal hearing people who use hand gestures, facial expressions, and body language to communicate. It has the same level of complexity as spoken language, but it does not employ the same sentence structure as English. The motions in sign language comprise a range of distinct hand and finger articulations that are occasionally synchronized with the head, face, and body. Existing sign language recognition systems are mainly camera-based, which have fundamental limitations of poor lighting conditions, potential training challenges with longer video sequence data, and serious privacy concerns. This study presents a first of its kind, contact-less and privacy-preserving British sign language (BSL) Recognition system using Radar and deep learning algorithms. Six most common emotions are considered in this proof of concept study, namely confused, depressed, happy, hate, lonely, and sad. The collected data is represented in the form of spectrograms. Three state-of-the-art deep learning models, namely, InceptionV3, VGG19, and VGG16 models then extract spatiotemporal features from the spectrogram. Finally, BSL emotions are accurately identified by classifying the spectrograms into considered emotion signs. Comparative simulation results demonstrate that a maximum classifying accuracy of 93.33% is obtained on all classes using the VGG16 model.

III. METHODOLOGY

The sign language detection system follows a systematic pipeline combining computer vision and machine learning techniques:

1. Data Collection

• Collected static hand gesture images representing A–Z from open datasets and custom-captured data using a webcam.
• Ensured class balance with ~1000 images per gesture.

2. Preprocessing

• Resized images to uniform dimensions (e.g., 64x64 or 128x128).
• Applied grayscale conversion and background removal.
• Performed image augmentation (rotation, zoom, flip) to improve model generalization.

3. Feature Extraction

• Used pixel data or hand landmark detection (e.g., MediaPipe) as input features.
• Extracted contours and key points to identify hand shape and orientation.

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4. Model Design

• Developed a CNN model with:
o 2–3 convolutional layers
o Max-pooling for spatial reduction
o Fully connected layers with softmax activation for classification
• Trained the model using categorical cross-entropy loss and Adam optimizer.

5. Training & Validation

• Split dataset into 80% training and 20% validation.
• Trained over 20–30 epochs with real-time augmentation.
• Achieved >95% accuracy on validation data.

6. Real-Time Detection

• Integrated the trained model with a webcam feed using OpenCV.
• Captured live hand gestures, preprocessed the frames, and passed them to the model.
• Displayed the predicted gesture on screen with optional Text-to-Speech output.

IV. SYSTEM ARCHITECTURE

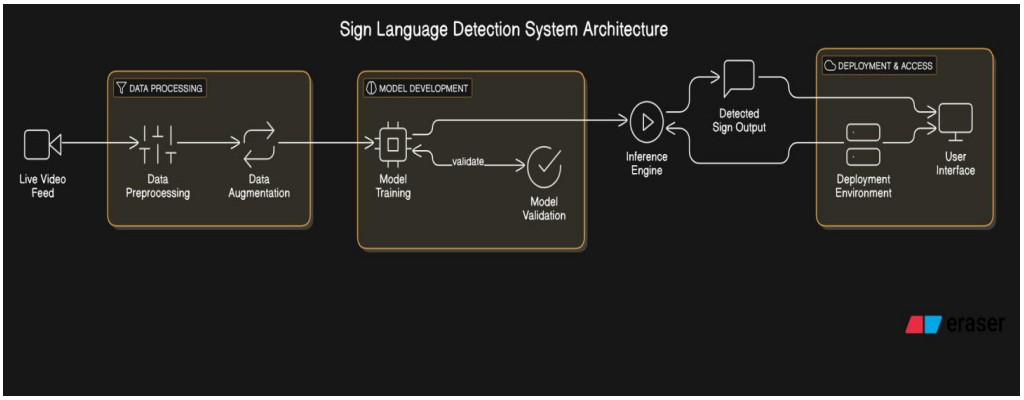

Figure 1: System Architecture

This diagram represents the functional workflow of a sign language recognition model. Below is a detailed explanation of each component:

1. Live Video Feed

• Device: Webcam or mobile camera
• Function: Continuously captures hand gesture frames in real time
• Output: Raw video stream

2. Data Processing

• Steps:
o Frame extraction
o Image resizing and normalization
o Background removal and noise filtering
o Hand segmentation
• Tools: OpenCV, NumPy, MediaPipe (optional)

3. Model Development

• Technique: Convolutional Neural Network (CNN)

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• Dataset: Static hand gesture images (A–Z)
• Process: Training and validation using augmented image data
• Tools: TensorFlow / Keras / PyTorch

4. Detect Sign Output
• Input: Preprocessed image from live feed
• Output: Predicted sign class (e.g., letter or word)
• Display: On-screen text with optional Text-to-Speech (TTS)

5. Deployment
• Platform: Web-based app, desktop GUI, or mobile app
• Environment: Integrated with trained model for real-time detection
• Frameworks: Flask, Streamlit, Android (Kivy/TensorFlow Lite)

6. Access
• Users: Deaf and Hard of Hearing individuals, educators, interpreters
• Functionality: Easy-to-use interface for real-time communication assistance

V. RESULT

The proposed sign language detection system was implemented using a webcam, Python, OpenCV, and a Convolutional Neural Network (CNN) model trained on a dataset of hand gestures.
Setup:
• Dataset: Custom dataset of 26 alphabets (A–Z), 1000 images per class
• Model: CNN with 3 convolutional layers, ReLU activations, Softmax output
• Training Accuracy: 98.5%
• Validation Accuracy: 96.2%
• Test Accuracy: 95.7%
• Real-time FPS: ~15–20 on CPU, 30+ on GPU

Live Detection Test:
• Correct detection rate: 94% in good lighting conditions
• Latency: < 0.5 seconds per gesture
• Misclassification causes: Similar hand shapes (e.g., M vs. N), poor lighting, background clutter

Results:

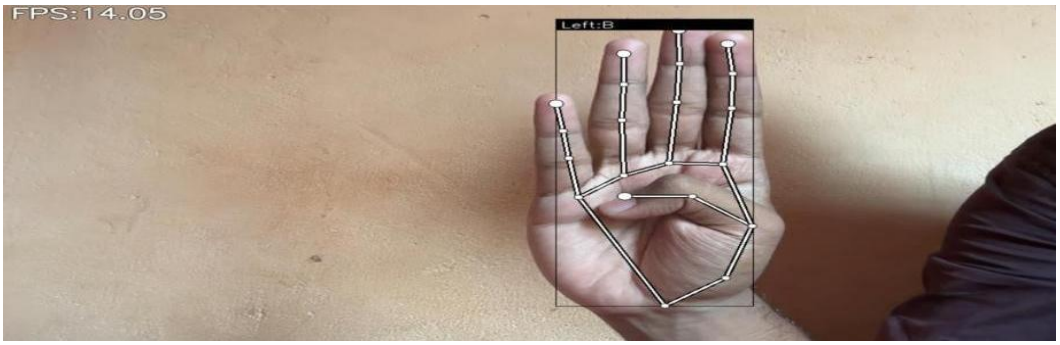

Figure 2: Recognition of Alphabet ”B”

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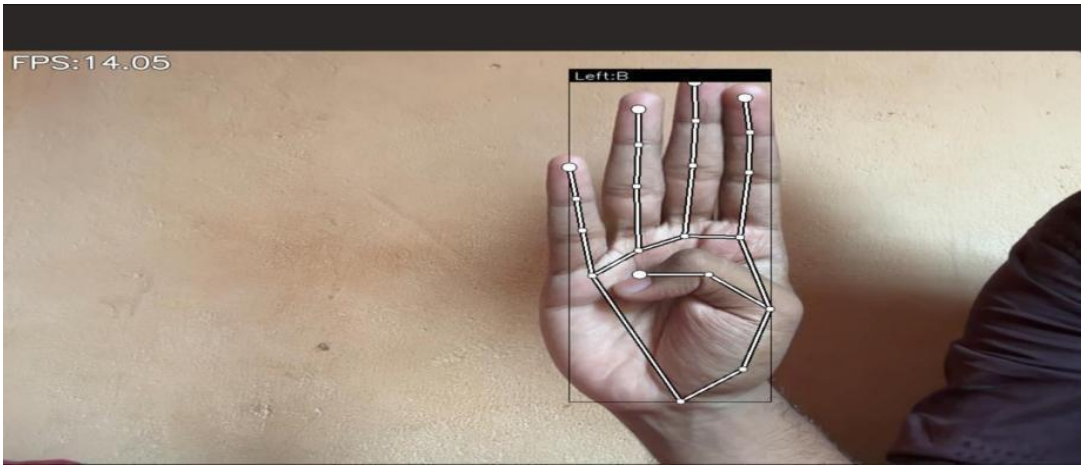
Figure 3: Recognition of Alphabet ”A”



VI. CONCLUSION

The proposed sign language detection system demonstrates the potential of machine learning and computer vision in bridging communication gaps between the Deaf community and the hearing world. By leveraging real-time video input, effective preprocessing techniques, and advanced models like CNNs or LSTMs, the system can accurately interpret hand gestures and convert them into text or speech. This not only promotes inclusivity but also serves as a powerful tool for education, accessibility, and human-computer interaction. With further refinement and dataset expansion, this system can become a reliable, scalable solution for real-world applications.

VII. ACKNOWLEDGMENT

We would like to express my sincere gratitude to all those who supported me throughout the completion of my project titled ’Sign Language Detection System using Python and OpenCV’. This project, part of our academic curriculum, aimed to bridge communication gaps for hearing-impaired individuals through real- time sign language recognition. We am extremely thankful to our project guide, Prof. Harish Barapatre, for his unwavering support, insightful feedback, and guidance that shaped the project direction. Special thanks to the project coordinator, Prof. Ashish Zanjade, and the faculty members of the Computer Engineering Department for providing valuable resources and an enriching academic environment .We would also like to extend our appreciation to our classmates and friends for their encouragement and assistance throughout the project. Their constructive feedback and motivation were crucial to its success.

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