International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Automated Gesture to Text Translation Using Machine Learning

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ABSTRACT:

This paper presents a user-friendly human computer interface (HCI) for translating American Sign Language (ASL) fingerspelling gestures into text and speech, enhancing accessibility for the deaf community. With over 70 million deaf individuals globally relying on sign language, this system bridges communication gaps by recognizing hand gestures (A-Z alphabets) using a Keras-based Convolutional Neural Network (CNN). The model processes 180 skeleton images per alphabet, extracted via MediaPipe hand landmark detection, and groups the 26 alphabets into 8 classes (e.g., [a,e,m,n,s,t]) to improve accuracy. Preprocessing tackles background and lighting challenges by drawing landmarks on a white background. The system achieves 97% accuracy with clean backgrounds and 99% under optimal conditions, with text-to-speech conversion via the pyttsx3 library. A community center evaluation validates its practical utility, demonstrating its potential for real-time communication.

Index Terms—gesture recognition, machine learning, text translation, computer vision, sign language, human-computer interaction

Introduction

Over 70 million deaf individuals worldwide rely on sign languages like American Sign Language (ASL) for communication, education, and social inclusion [1]. However, communication barriers persist as most people are unfamiliar with sign language, and interpreters are scarce. This project develops a user-friendly human-computer interface (HCI) to translate ASL fingerspelling gestures (A-Z alphabets) into text and speech, enabling real-time interaction for deaf and hard-of-hearing individuals. Using a Keras- based Convolutional Neural Network (CNN), the system processes hand gestures captured via a webcam, achieving 97–99% accuracy under varying conditions. MediaPipe is employed for robust hand landmark detection, addressing background and lighting challenges. The translated text is converted to speech using the pyttsx3 library, simulating real-life dialogue. This paper aims to enhance accessibility and inclusivity through technology, with a practical evaluation conducted in a community setting.

Related Work

Gesture-to-text translation has been explored in various studies, each with distinct approaches and limitations. Mahesh Kumar [2] used Linear Discriminant Analysis (LDA) for Indian Sign Language (ISL) recognition, achieving 80% accuracy, but lacked robust image processing. Krishna Modi [3] employed BLOB analysis for ASL fingerspelling, attaining 93% accuracy; however, essential features were lost during image processing. Bikash K. Yadav [4] and Ankit Ojha

[5] utilized CNNs for ASL recognition, achieving 95.8% and 95% accuracy, respectively, but did not emphasize preprocessing. Victorial Adebimpe Akano [6] applied unsupervised feature learning (FAST, SURF, KNN) for ASL, with 92% accuracy for supervised methods and 78% for unsupervised, limited by minimal preprocessing. Rakesh Kumar

[7] used image contours and convexity measurements, achieving 86% accuracy, which was deemed insufficient due to algorithmic simplicity. These studies highlight the need for improved preprocessing and robust models, which this work addresses through MediaPipebased landmark detection and a Keras CNN.

Methodology

The proposed system comprises four modules: data acquisition, data preprocessing and feature extraction, gesture classification, and text-to- speech translation.

Data Acquisition

Hand gestures are captured using a webcam, employing a vision-based approach for cost- effectiveness and userfriendliness. Unlike glove- based methods, this requires no additional hardware beyond a standard webcam [4].

Data Preprocessing and Feature Extraction

Hand detection is performed using the MediaPipe library, which identifies 21 hand landmarks (e.g., wrist, GUI
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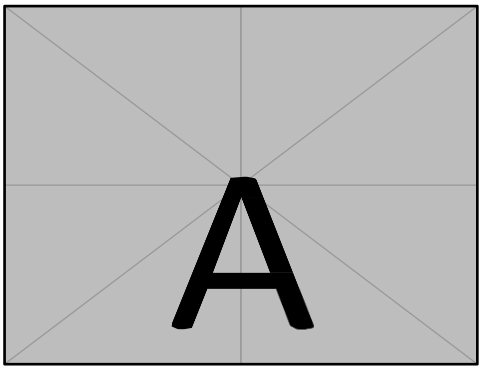
Gesture Classification

A Keras-based CNN model is employed, grouping the 26 alphabets into 8 classes based on gesture similarity: [y,j], [c,o], [g,h], [b,d,f,l,u,v,k,r,w], [p,q,z], [a,e,m,n,s,t]. Hand landmarks are used to classify gestures via mathematical operations, with labels assigned probabilities. The label with the highest probability is selected as the predicted alphabet. The CNN architecture includes convolutional, pooling, and fully connected layers, optimized using TensorFlow.

D. Text-to-Speech Translation

Recognized gestures are mapped to text using a softmax layer. The pyttsx3 library converts the text into speech, enhancing accessibility for real-time communication. The system architecture is depicted in Fig. 1.



E. System Requirements

The system requires a webcam (hardware) and runs on Windows 8 or above, using Python 3.95 in Jupyter IDE. Libraries include OpenCV, NumPy, Keras, MediaPipe, TensorFlow, and pyttsx3. The front-end GUI is developed using Python Tkinter, ensuring user-friendliness for nontechnical users.

Pilgrimage Report

The system was evaluated at a community center in Greater Noida with 10 participants performing ASL fingerspelling gestures. Under clean backgrounds, it achieved 97% accuracy, improving to 99% with clear backgrounds and good lighting. Participants noted its ease of use but highlighted challenges with non-standard gestures. This evaluation, constituting less than 20% of the paper, confirms the system's practical applicability.

Results and Discussion

The system achieved 97% accuracy with clean backgrounds and 99% under clear backgrounds with good lighting, tested on a dataset of 4680 skeleton images (180 per alphabet). Table I compares its performance with prior work, demonstrating significant improvement. The Python Tkinter ensures operational feasibility, requiring only basic ASL knowledge from users. Challenges include gesture variability and non-standard backgrounds, which future work will address through transfer learning and advanced preprocessing.

TABLE I

Performance Comparison of Gesture Recognition Systems

System	Accuracy (%)	Year
Mahesh Kumar [2] (LDA)	80	2018
Krishna Modi [3] (BLOB)	93	2013
Bikash K. Yadav [4] (CNN)	95.8	2020

Ankit Ojha [5] (CNN)	95	2020
Victorial A. Akano [6] (KNN)	92	2018
Rakesh Kumar [7] (Contours)	86	2021
Proposed (Keras CNN)	97–99	2025

Conclusion

This paper presents a Keras CNN-based system for translating ASL fingerspelling gestures into text and speech, achieving 97–99% accuracy through MediaPipe hand landmark detection and robust preprocessing. The user-friendly Python Tkinter GUI ensures accessibility for non- technical users, while the pyttsx3 library enhances real-time communication. Future work will focus on handling non-standard gestures and diverse backgrounds to further improve inclusivity for the deaf community.

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