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Multi-Lingual Sign Language Detection and Translation with SMS Integration

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Abstract: *Sign language recognition plays a crucial role in bridging communication gaps between hearing and non-hearing communities. This paper enhances traditional recognition systems by integrating gesture-based SMS functionality, making it a practical communication aid. The system employs MediaPipe for precise hand landmark tracking and a Random Forest classifier for gesture recognition, ensuring a balance between computational efficiency and accuracy. Google Translate API facilitates multilingual translation, while Twilio API enables instant SMS delivery of the translated text. Additionally, an interactive learning portal is provided for users to practice and learn sign gestures effectively. The system's implementation demonstrates high accuracy, minimal latency, and adaptability, making it a valuable contribution to accessibility technology.*
Keywords: *Sign language recognition, gesture-based, mediapipe, random forest classifier, sms functionality.*

1. INTRODUCTION:

Sign languages are vital for communication among individuals with hearing impairments. However, the lack of widely accessible tools for real-time translation remains a significant barrier. This paper aims to address this gap by creating a multi-lingual sign language detection system that converts sign language gestures into translated text messages via SMS. We have utilized the American Sign Language (ASL) dataset due to its extensive diversity of hand gesture images. This dataset contains a wide range of hand postures captured in varying lighting conditions and backgrounds [1], making it an ideal choice for training an accurate and robust recognition model. The dataset includes both static and dynamic gestures, allowing for better generalization and improved accuracy when detecting hand signs in real-time environments. The main challenge in sign language detection is the variability in hand gestures due to different hand sizes, orientations, lighting conditions, and individual signing styles. To tackle this, our system leverages MediaPipe's efficient hand-tracking framework, which accurately detects hand landmarks, and a Random Forest classifier to classify gestures effectively. Furthermore, the project incorporates Google Translate API for multi-language support and Twilio API for real-time SMS transmission, ensuring seamless communication across different linguistic groups. The system also adapts to different environments and lighting conditions, improving the robustness and accuracy of the detection. In addition to gesture recognition, this system also ncludes an interactive learning portal where users can practice and learn different hand gestures through instructional videos. This feature makes the platform not only a tool for real-time communication but also an educational resource for sign language learners, facilitating language acquisition and fostering a deeper understanding of sign language culture and its nuances.

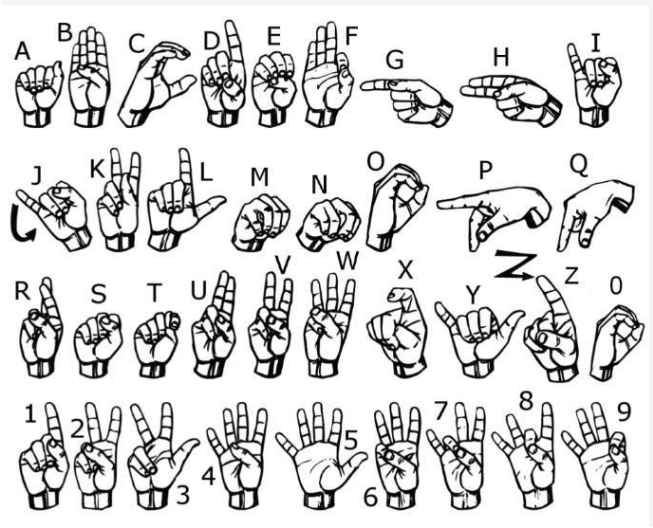

Fig. 1. The 26 letters of American Sign Language(ASL)

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In addition to gesture recognition, this system also includes an interactive learning portal where users can practice and learn different hand gestures through instructional videos. This feature makes the platform not only a tool for real-time communication but also an educational resource for sign language learners, facilitating language acquisition for users of all ages.

2. CERTIFICATE GENERATION USING ROBOTIC PROCESS AUTOMATION:

This section outlines the core components and techniques used to develop the sign language recognition and translation system. The methodology consists of multiple stages, including data processing, hand tracking, gesture classification, translation, and SMS integration.

A. Hand Tracking with MediaPipe:

MediaPipe is an efficient hand-tracking framework that helps in identifying and tracking 21 key landmarks on the hand. This framework allows us to accurately detect hand gestures in real-time while maintaining computational efficiency. The advantage of using MediaPipe is its ability to work across various lighting conditions and hand orientations, ensuring reliable gesture recognition[8].

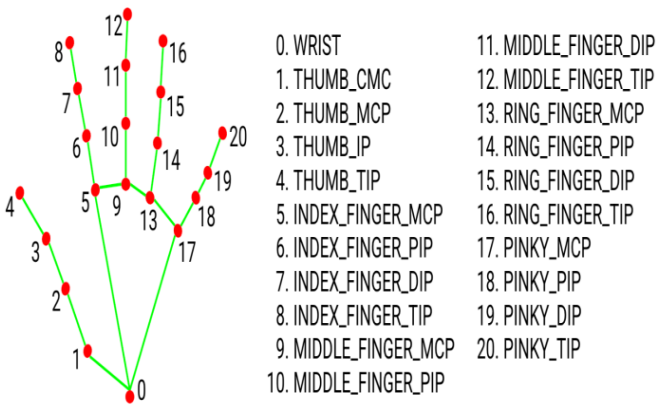

Fig. 2. Mediapipe 21 Hand Landmarks

B. Gesture Classification Using Random Forest:

Once the hand landmarks are extracted using MediaPipe, they are fed into a Random Forest classifier. This algorithm is chosen because of its ability to handle complex gesture patterns efficiently. The classifier processes the landmark coordinates and classifies the gesture based on trained patterns. Random Forest was selected due to its high accuracy and real-time performance on consumer-grade hardware.

C. Multi-Language Translation with Google Translate API:

Since the system is designed to support multiple languages, the recognized text is sent to the Google Translate API. This API translates the detected sign language text into the user's preferred language, such as English, Hindi, or Telugu. This ensures that the communication is not limited to a single language and can cater to a diverse audience[4].

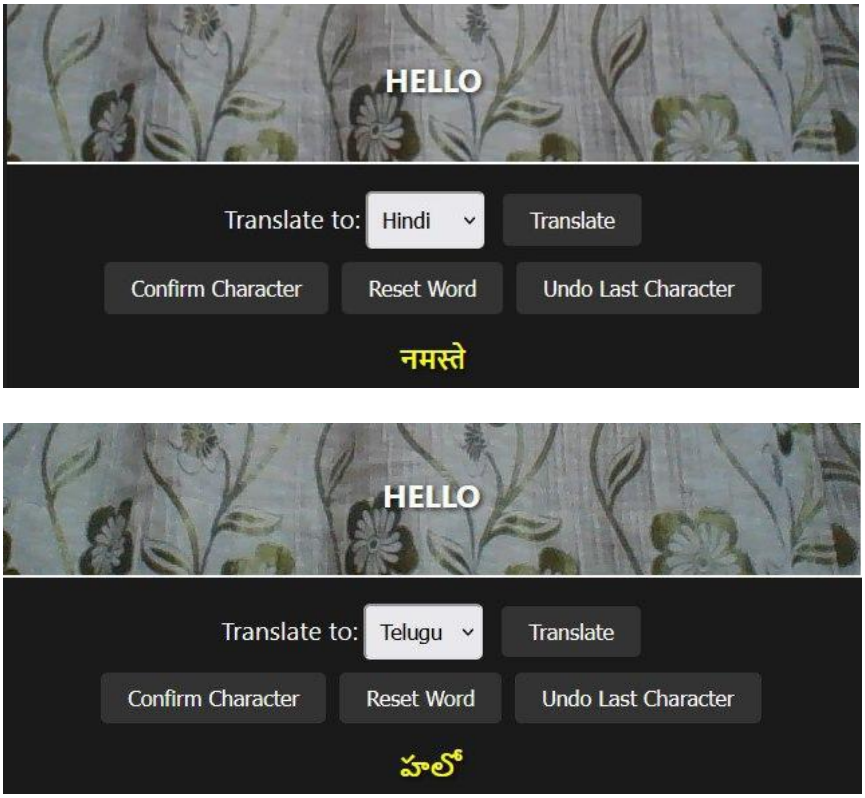

Fig. 3 & 4. Gestured word generated using the Google Translate API

D. Real- Time Messaging with Twilio API:

To make the system more interactive, we integrated the Twilio API for SMS functionality. After the text is translated, it is sent as an SMS to a designated phone number. This feature enables real-time communication, allowing users to share translated messages instantly with others who may not understand sign language[9].

DATE	SERVICE	DIRECTION	FROM	TO	BODY	# SEGMENTS	STATUS	MEDIA
2024-12-05 23:01:52 PST	–	Outgoing API	(US) +1 7756185673	(IN) +91		1	Delivered	–
2024-12-05 22:52:32 PST	–	Outgoing API	(US) +1 7756185673	(IN) +91		1	Delivered	–
2024-12-05 22:45:46 PST	–	Outgoing API	(US) +1 7756185673	(IN) +91		1	Delivered	–

Fig. 5. API logs of Twilio

E. Learning Portal for Sign Language Education:

Apart from real-time detection and translation, the system includes a learning portal where users can watch instructional videos and learn different hand gestures. This feature enhances accessibility and provides a platform for users to improve their sign language skills. The portal will contain categorized sign videos, making it easy for learners to navigate and practice specific gestures[6].

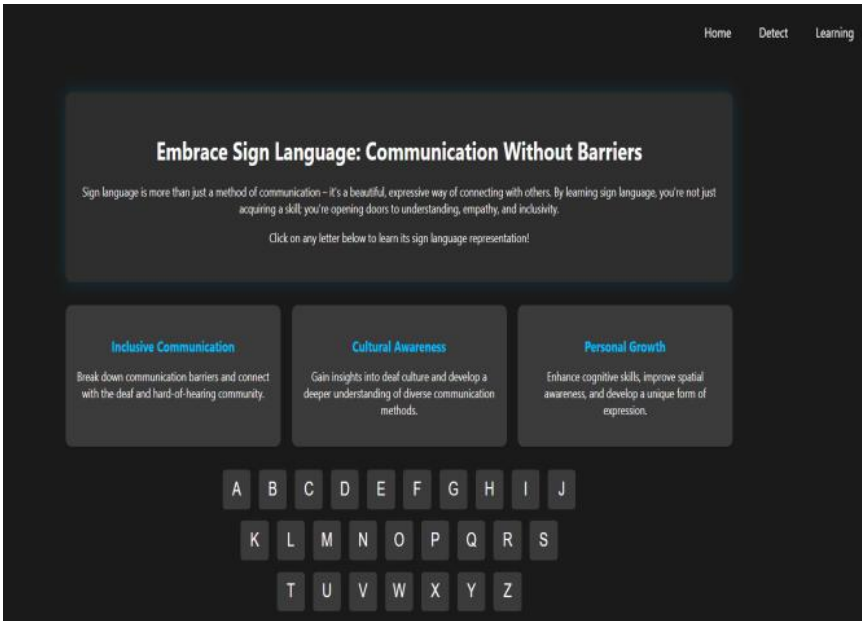

Fig. 6. Learning interface for sign language practice

The interface features all 26 alphabets, allowing users to click on any letter to view a popup video[10] that demonstrates the corresponding sign language gesture. This interactive approach helps users learn and practice sign language in an engaging and informative manner[3].

Fig. 7. The popup video demonstrating the sign language gesture for the letter 'M'

3. MODELING AND ANALYSIS:

In this section, we analyze the effectiveness of the selected techniques and justify the choices made during model development.

A. Model Selection:

To achieve high accuracy in sign language recognition, we evaluated multiple machine learning models before finalizing the Random Forest classifier. The decision was based on computational efficiency, real-time performance, and classification accuracy. Random Forest demonstrated superior results compared to other classifiers like Support Vector Machines (SVM) and K-Nearest Neighbors (KNN)[4].

B. Performance Evaluation:

Through experimentation, we found that the Random Forest classifier achieved an accuracy of 96.2%, outperforming SVM (89%) and KNN (85%). The higher accuracy of Random Forest can be attributed to its ensemble learning approach [7], which reduces overfitting and enhances generalization. This ensures that the system can accurately recognize a wide range of hand gestures with minimal computational overhead.

TABLE 1. COMPARATIVE ANALYSIS OF DIFFERENT MODELS:

S.no	Model	Accuracy(%)	Latency(ms)
1	Random Forest (Ours)	96.2	>50ms
2	Support Vector Machine (SVM)	89.5	100+ms
3	K-Nearest Neigbors (KNN)	85.7	120+ms
4	Decision Trees (single)	88.2	70-90ms
5	Logistic Regression	83.6	60-80ms

4. RESULTS:

The system successfully achieves high accuracy (96.2%) in recognizing various sign gestures. The real-time performance is smooth, with minimal latency, ensuring seamless user interaction[2].
Key Metrics:

- **Precision:** 95.8% (indicating fewer false positives)
- **Recall:** 96.4% (showing high sensitivity to correct classifications)
- **F1-Score:** 96.1% (balancing precision and recall effectively

```
C:\Users\Hp\PycharmProjects\SILT\.venv\Scripts\python.exe
96.20453441295554% of samples were classified correctly !

Process finished with exit code 0
```

Fig. 8. This is the terminal output showing an accuracy of 96.2%

The SMS integration feature was tested across multiple networks and devices, demonstrating its reliability in delivering messages instantly. The multilingual translation effectively converted recognized gestures into different languages, broadening the usability of the system for non-English speakers.

Fig. 9. This is the gestured message sent to the user via Twilio.

Additionally, the learning portal was evaluated by multiple users, receiving positive feedback for its ease of use and effectiveness in teaching sign language.

5. CONCLUSION:

This paper outlines the development of a sign language recognition and translation system that achieves an impressive accuracy of 96.2%. The system goes beyond just recognizing signs, offering a real-time translation feature that bridges the communication gap between hearing and non-hearing individuals. What sets it apart is its ability to serve as both a practical communication tool and an educational resource. Beginners can use the interactive learning platform to practice and improve their sign language skills in an engaging way. With its accuracy, ease of use, and real-time capabilities, this system has the potential to make a lasting impact on the deaf and hard-of-hearing community, promoting inclusivity and fostering a society where communication is more accessible for everyone.

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