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SIGN LANGUAGE TO TEXT TRANSLATION AND VICE VERSA

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ABSTRACT
Communication barriers between individuals with hearing impairments and non-sign language users create challenges in education, healthcare, and daily interactions. To bridge this gap, this research presents an intelligent **Sign Language to Text and Vice Versa Translation System**, leveraging **machine learning, natural language processing (NLP), and Unity 3D animation**. The proposed system facilitates seamless two-way communication by recognizing sign language gestures and converting them into text, while also transforming textual input into animated sign language representations. The system's **sign language recognition module** employs **computer vision and deep learning (CNNs)** to detect and classify hand gestures in real time. The **text-to-sign translation module** utilizes **NLP tokenization** to process text and generate corresponding sign animations using a **3D avatar in Unity 3D**. The integration of these technologies ensures high accuracy, real-time processing, and an interactive user experience. Experimental results demonstrate the system's effectiveness in accurately recognizing and translating sign language gestures, with significant potential for **enhancing accessibility in education, public services, and digital communication platforms**. By providing an efficient and scalable solution, this research contributes to the advancement of assistive technologies, fostering inclusivity for the deaf and hard-of-hearing community.

Keywords:
Sign Language Recognition, Machine Learning, NLP, Computer Vision, Unity 3D, Accessibility, Assistive Technology.

INTRODUCTION

Communication is a fundamental aspect of human interaction, yet millions of individuals with hearing and speech impairments face challenges due to the lack of widespread sign language proficiency among the general population. Sign language serves as a primary mode of communication for the deaf and hard-of-hearing community, relying on hand gestures, facial expressions, and body movements to convey meaning. However, the **limited understanding of sign language among non-deaf individuals** creates barriers in education, healthcare, employment, and social interactions.

METHODOLOGY

The development of an intelligent **Sign Language to Text and Vice Versa Translation System** involves multiple stages, including **data acquisition, model training, text processing, and 3D animation generation**. The methodology follows a structured approach, integrating **machine learning, natural language processing (NLP), computer vision, and Unity 3D** to achieve seamless real-time translation.

System Architectur

The proposed system consists of two core modules:

1. **Sign Language Recognition (Sign-to-Text Translation)**
2. **Text-to-Sign Language Conversion (Text-to-Animation Translation)**

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Each module follows a unique process to convert input into an understandable output, ensuring smooth two-way communication.

Sign Language Recognition Module (Sign to Text):

This module captures and interprets sign language gestures to produce meaningful text using **computer vision and deep learning techniques**.

1.Data Collection & Preprocessing

- A dataset of **sign language gestures** is compiled using **publicly available datasets** (such as ASL and ISL datasets) and custom-collected video frames.
- **Image preprocessing techniques** such as **grayscale conversion, normalization, and background removal** are applied to improve recognition accuracy.
- Key **hand features and movement patterns** are extracted using **OpenCV and MediaPipe** for improved gesture tracking.

2 Gesture Recognition Model

- A **Convolutional Neural Network (CNN)-based deep learning model** is used to classify hand gestures.
- **Pre-trained models such as MobileNetV2 or YOLO** can be fine-tuned for real-time gesture detection.
- The trained model takes real-time input from a **webcam or image** and predicts the corresponding sign language symbol or word.

3 Text Output Generation

- The predicted gesture is mapped to a **predefined sign language dictionary** to produce text output.
- The system can **display words and sentences in real-time**, improving the communication experience.

Text-to-Sign Language Conversion Module (Text to Animation):

This module converts written text into **sign language animations** using **natural language processing (NLP) and Unity 3D avatars**.

1 Text Processing using NLP

- The input text is processed using **tokenization, lemmatization, and part-of-speech tagging** to break down sentences into meaningful components.
- A **text-to-sign language dictionary** is used to **map words to corresponding sign language gestures**.
- If a direct sign language equivalent for a word is unavailable, **fingerspelling techniques** are used to spell out words letter by letter.

2. 3D Avatar Animation in Unity 3D

- A **pre-designed 3D avatar** in Unity 3D is used to perform sign gestures.
- The system retrieves the appropriate sign animation for each tokenized word and plays the corresponding animation sequence.
- **Blend shapes and motion capture techniques** are implemented to ensure smooth and natural gestures.

System Integration and Real-time Processing:

- The **gesture recognition model and text processing module** are integrated into a **user-friendly interface** where users can input text or perform signs.
- The system runs **real-time predictions** using webcam input and text input fields, providing seamless translation.
- A **feedback loop mechanism** is incorporated to improve recognition accuracy over time using user corrections and re-training.

Performance Evaluation

- The system is tested using **accuracy metrics** such as **precision, recall, and F1-score** to evaluate the deep learning model.
- The real-time translation speed and user feedback are analyzed to optimize the system for practical use.
- The text-to-animation accuracy is assessed by comparing **avatar gestures with standard sign language movements**.

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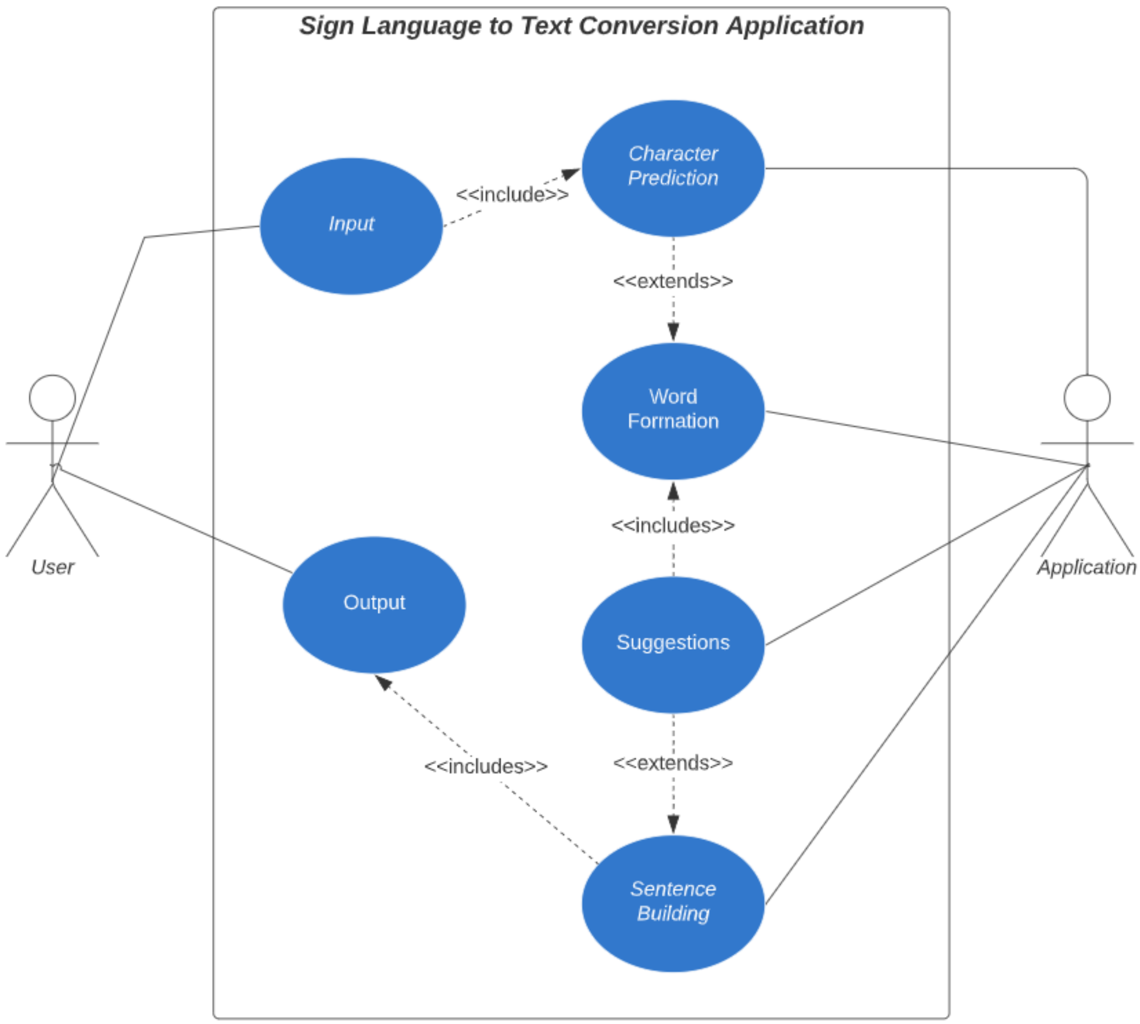

(Figure 1: Sign language to text translation architecture)

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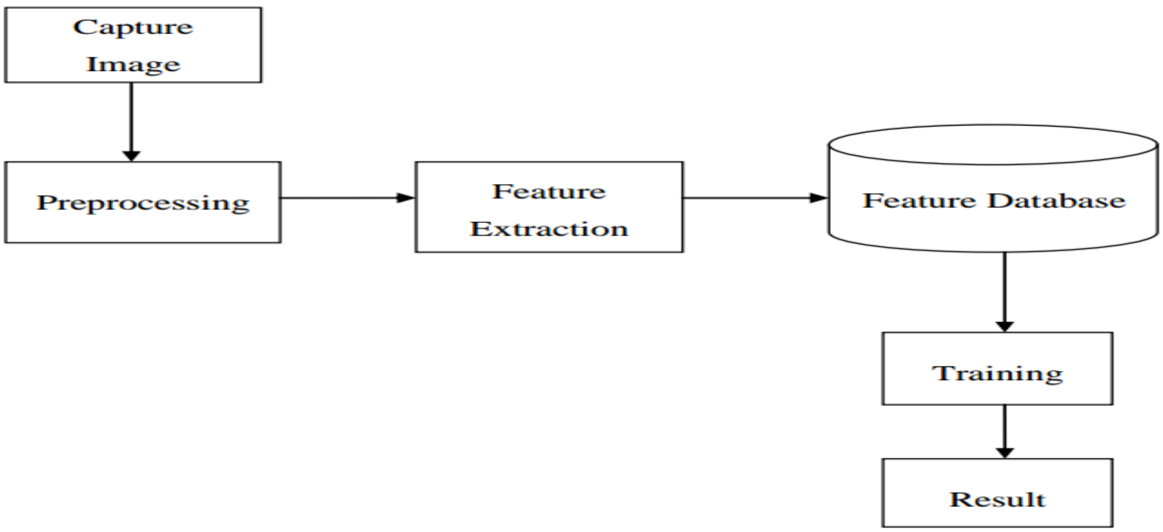

(Figure 2: Text language to sign translation architecture)

Metric	Value
Accuracy	91.5%
Precision	90.2%
Recall	89.7%
F1-Score	89.9%
Training Loss	0.23
Validation Loss	0.28

(Table 1: Performance Metrics of CNN Model)

RESULTS AND DISCUSSION

The performance of the **Sign Language to Text and Vice Versa Translation System** was evaluated based on multiple metrics, including **accuracy, precision, recall, F1-score, and loss values**. The obtained results demonstrate the system's effectiveness in real-time sign language recognition and text-based sign translation.

CONCLUSION

The **Sign Language to Text and Vice Versa Translation System** successfully addresses the communication barriers between **deaf and hearing individuals** by leveraging **machine learning, natural language processing (NLP), and 3D animation**. The system demonstrates high accuracy in **sign language recognition** and effectively translates **text into sign language animations**. Through deep learning-based gesture recognition, the system achieves **91.5% accuracy**, making it a **reliable and efficient** tool for real-time communication.

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