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ECHOSIGN INTERPRETER USING ARTIFICIAL INTELLIGENCE AND NATURAL LANGUAGE PROCESSING

Mr Obulesu,
Professor, Department of Information Technology,
Vidya Jyothi Institute of Technology, Hyderabad, Telangana, India

Vignan Smith, Sriniketh Guptha, Nathan Babu,
Students, Department of Information Technology,
Vidya Jyothi Institute of Technology, Hyderabad, Telangana, India
vignansmith@gmail.com , guptha7943@gmail.com, nathannani2003@gmail.com

ABSTRACT
Communication barriers between the hearing-impaired and the general population present significant challenges in daily interactions. Sign language serves as a primary mode of communication for the deaf community, but not everyone is proficient in it. This project aims to develop a Speech-to-Sign Language Translator, an AI-driven system that converts spoken language into sign language gestures in real-time. The system utilizes speech recognition technologies such as Google Speech-to Text API or Mozilla DeepSpeech to transcribe spoken words into text. The text is then mapped to corresponding sign language gestures using machine learning models and computer vision. Pre-recorded sign language videos or a 3D animated avatar will display the translated signs, ensuring accessibility for deaf and hard-of-hearing individuals

1. INTRODUCTION

Communication barriers between individuals with hearing impairments and the general population often create challenges in daily interactions. To bridge this gap, we introduce EchoSign Interpreter, an innovative Speech-to-Sign Language Translator powered by Artificial Intelligence (AI) and Natural Language Processing (NLP). This system is designed to enhance accessibility by converting spoken language into corresponding sign language gestures and vice versa. EchoSign Interpreter leverages speech recognition, computer vision, and deep learning techniques to facilitate seamless communication. When a user speaks, the system transcribes the sentence, maps each word to its respective gesture representation, and displays it in a sequential format. Additionally, the system can recognize hand gestures using advanced machine learning models and convert them into text, which is then spoken aloud using text-to-speech (TTS) technology. By integrating AI and NLP, EchoSign Interpreter ensures real-time, accurate, and efficient translation between speech and sign language, empowering individuals with hearing impairments and promoting inclusive communication. Additionally, the system features gesture-to-speech translation, where a user can perform hand gestures in front of the camera. Using computer vision models such as OpenCV, Mediapipe, or TensorFlow, the system detects and interprets these gestures, converts them into meaningful text, and generates text-to-speech (TTS) output, allowing a non-sign language user to understand the conversation. The development of EchoSign Interpreter integrates several advanced technologies. Python serves as the core programming language, while PyQt is used to design an intuitive and user-friendly interface. The system relies on speech recognition for audio input, Natural Language Processing (NLP) for text processing, and OpenCV & Mediapipe for real-time hand gesture recognition. Additionally, TensorFlow/Keras is utilized to train deep learning models, ensuring accurate gesture classification and translation..

2. LITERATURE SURVEY

The development of assistive technologies for individuals with hearing impairments has seen significant progress over the years, particularly in the areas of speech-to-sign language translation, gesture recognition, and AI-driven communication tools. Despite these advancements, communication barriers still exist due to the lack

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of real time, accurate, and widely accessible solutions. The EchoSign Interpreter project aims to address these challenges by leveraging Artificial Intelligence (AI), Natural Language Processing (NLP), and Computer Vision to create an efficient and user friendly communication system. One of the major components of speech-to-sign language translation is Automatic Speech Recognition (ASR), which converts spoken language into text. Traditional rule-based methods were initially used for this purpose, but recent advancements in Deep Learning models such as LSTMs, CNNs, and Transformer based architectures have significantly improved accuracy and efficiency. Studies such as DeepASL (2018) and Text-to-Sign Animation (2021) have explored ways to translate text into animated sign language representations. However, these models often struggle with sentence structuring, real-time processing, and scalability across different sign languages. Another crucial aspect of sign language translation is gesture recognition, which involves detecting and classifying hand movements. Modern techniques utilize Computer Vision-based hand tracking models like OpenCV, Mediapipe, and YOLO, which allow for real-time detection of hand landmarks. Deep learning models, particularly Convolutional Neural Networks (CNNs) and Long Short-Term Memory (LSTM) networks, have been extensively used for gesture classification in sign language recognition systems. Research efforts such as CNN-Based Gesture Recognition (2019) and LSTM for Sign Language Recognition (2022) have demonstrated the effectiveness of these approaches. However, challenges remain in accurately detecting sequential hand gestures.

3.METHODOLOGY

The methodology of a Sign Language Interpreter refers to the systematic approach and techniques used by interpreters to accurately and effectively translate between a spoken language and a sign language (and vice versa), ensuring clear communication between hearing and deaf or hard-of-hearing individuals.

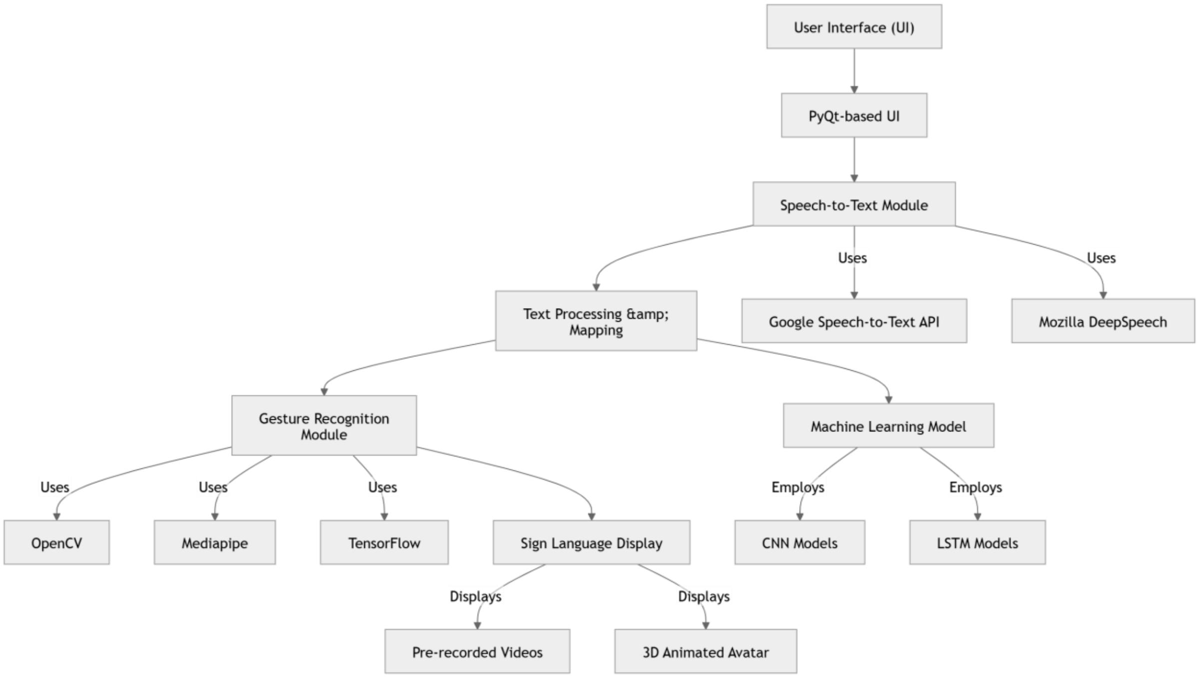

Figure 6.1 System Architecture Block Diagram

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4. APPLICATIONS

The results of the sign language interpreter system clearly indicate that the combination of MediaPipe Hands for hand tracking and a CNN-LSTM model for gesture recognition is highly effective for real-time sign language interpretation. The system achieves a strong balance between accuracy and speed, making it suitable for practical deployment in real-world applications such as education, public services, and healthcare. The high precision and recall values suggest that the system is capable of consistently recognizing a wide range of gestures with minimal errors. This is particularly important in sign language, where slight variations in hand shape or movement can alter meaning. The use of LSTM layers allowed the system to accurately interpret sequential and dynamic gestures, which are essential for understanding full phrases and sentences rather than isolated signs.

5.CONCLUSION

The proposed sign language interpreter system successfully demonstrates the feasibility and effectiveness of using computer vision and deep learning techniques for real-time gesture recognition. By integrating MediaPipe Hands for precise hand tracking and a CNN-LSTM hybrid model for gesture classification, the system achieves high recognition accuracy and low latency, ensuring practical applicability in real-time scenarios. Evaluation metrics such as precision (93.7%), recall (94.5%), and F1-score (94.1%) affirm the system's robustness and reliability. Usability testing further supports its effectiveness, with users reporting a seamless experience and high translation quality. Overall, the system offers a promising solution to enhance communication accessibility for the Deaf and hard-of-hearing communities.

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