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Sign Tone: A Deep Learning-Based Deaf Companion System for Two-Way Communication between Deaf and Non-Deaf Individuals

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ABSTRACT: Communication is essential to express and receive information, knowledge, ideas, and views among people, but it has been quite a while to be an obstruction for people with hearing and mute disabilities. Sign language is one method of communicating with deaf people. Though there is sign language to communicate with non-sign people it is difficult for everyone to interpret and understand. The performance of existing sign language recognition approaches is typically limited. Developing an assistive device that will translate the sign language to a readable format will help the deaf-mutes to communicate with ease to the common people. Recent advancements in the development of deep learning, deep neural networks, especially Temporal convolutional networks (TCNs) have provided solutions to the communication of deaf and mute individuals. In this project, the main objective is to design Deaf Companion System for that to develop SignNet Model to provide two-way communication of deaf individuals and to implement an automatic speaking system for deaf and mute people. The proposed system, consists of three modules; the sign recognition module (SRM) that recognizes the signs of a deaf individual using TCN, the speech recognition using Hidden Marko Model and synthesis module (SRSM) that processes the speech of a non-deaf individual and converts it to text, and an Avatar module (AM) to generate and perform the corresponding sign of the non-deaf speech, which were integrated into the sign translation companion system called deaf companion system to facilitate the communication from the deaf to the hearing and vice versa. The proposed model is trained on Indian Sign Language. Then developed a web-based user interface to deploy SignNet Model for ease of use. Experimental results on MNIST sign language recognition datasets validate the superiority of the proposed framework. The TCN model gives an accuracy of 98.5%.

KEYWORDS: sign recognition module, Avatar module, MNIST sign language recognition, Temporal convolutional networks.

I. INTRODUCTION

Sign language is manual communication commonly used by people who are deaf. Sign language is not universal; people who are deaf from different countries speak different sign languages. The gestures or symbols in sign language are organized in a linguistic way. Each individual gesture is called a sign. Each sign has three distinct parts: the handshape, the position of the hands, and the movement of the hands. American Sign Language (ASL) is the most commonly used sign language in the India.

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A sign language (also signed language) is a language which uses manual communication, body language, and lip patterns instead of sound to convey meaning—simultaneously combining hand shapes, orientation and movement of the hands, arms or body, and facial expressions to fluidly express a speaker's thoughts. Signs often represent complete ideas, not only words. However, in addition to accepted gestures, mime, and hand signs, sign language often includes finger spelling, which involves the use of hand positions to represent the letters of the alphabet.

Sign languages have developed in circumstances where groups of people with mutually unintelligible spoken languages found a common base and were able to develop signed forms of communication. Sign languages commonly develop in deaf communities, which include people who are deaf or hard of hearing, friends and families of deaf people, as well as interpreters.

II. LITERATURE SURVEY

Sign language recognition is a typical application of hand gesture recognition. It is often considered that only deaf people rely on sign languages for conveying their thoughts. However, particular medical problems such as down syndrome, autism, cerebral palsy, trauma, and brain diseases or speech difficulties may require a nonverbal mode of communication. 6,909 spoken languages and 138 sign languages have been identified, but there is no universal sign language.

Each has its own syntactical and grammatical structures to provide definitive means of communication, primarily for deaf communities worldwide. Sign languages emphasize on the movement of the hands, arms, head, and body in a conceptually predetermined manner to significantly construct a gesture language. Indian Sign Language (ISL) is the name given to the sign language used in India. According to the 2011 census, 2.7 million people in India cannot speak, and 1.8 million are deaf. They face difficulty communicating with others because most normal people are unfamiliar with sign language.

However, communication between them becomes inevitable in emergencies. Sign language interpreters are required to convert sign language to spoken language and vice versa, but their supply is limited and expensive. As a result, automatic sign language recognition systems are needed to translate signs into corresponding text or voice without the assistance of interpreters. Through human-computer interaction, systems can be built to aid in the development of the deaf and other communities who rely on sign languages.

III. EXITING SYSTEM

The traditional systems for communication and education for the deaf community have often relied on established methods, but these methods may have limitations in addressing the diverse needs of individuals with hearing and mute disabilities. Some aspects of the traditional system include:

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- **Sign Language**

Manual Communication: Sign language, such as American Sign Language (ASL) or other regional sign languages, has been a primary mode of communication for the deaf community.

- **Educational Approaches**

Specialized Schools: Deaf individuals often attend specialized schools where sign language is a primary mode of instruction.

- **Assistive Devices**

Hearing Aids and Cochlear Implants: Traditional assistive devices include hearing aids and cochlear implants, which aim to improve auditory perception.

- **Manual Communication Tools:**

Pen and Paper: Traditional tools such as writing or using pen and paper are often employed for basic communication.

- **Interpreters:**

Sign Language Interpreters: In various situations, sign language interpreters are employed to bridge communication gaps between deaf and hearing individuals.

- **Printed Materials:**

Books and Written Resources: Printed materials, including books and written resources, have been essential for education.

EXISTING ALGORITHMS

Sign language recognition (SLR) is a challenging task due to the complexity and variability of sign language gestures. Several algorithms and approaches have been developed to address this task, with varying levels of success. One prominent existing algorithm for SLR is the Hidden Markov Model (HMM) based approach.

- **Support Vector Machines (SVM)**

SVMs are used to classify sign language gestures based on extracted features. They work well with high-dimensional feature spaces.

- **Ensemble Learning**

Ensemble methods, such as Random Forests and Gradient Boosting, can be applied to combine multiple SLR models to improve overall accuracy and robustness.

- **Gesture Recognition by Learning from Poses (GRBP)**

GRBP is a method that focuses on learning spatial relations between body joint poses for sign language recognition. It utilizes pose features extracted from skeletal data.

Disadvantages

- Traditional systems lead to limited accessibility, hindering communication with non-signers.
- Real-time processing challenges persist, especially for resource-constrained devices.
- Handling natural variability in sign language gestures remains a challenge for rule-based models.
- Existing algorithms lack adaptability to diverse sign language variations.
- Difficult to interpret the decision-making process.
- Face challenges in adapting to unseen variations or emerging sign language expressions.
- Challenges in modeling the context and semantic relationships between signs.

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IV. PROPOSED SYSTEM

The proposed system for the project, titled "Deaf Companion System," is designed to revolutionize communication for individuals with hearing and mute disabilities. Key components and features of the system include:

- **Deaf Companion System**

Introduction of an innovative system addressing communication challenges faced by individuals with hearing and mute disabilities.

- **SignNet Model Architecture**

Development of the SignNet Model, combining Convolutional Neural Networks (CNN) and Temporal Convolutional Networks (TCN) for robust sign language recognition.

- **Two-Way Communication**

Implementation of a comprehensive two-way communication system, fostering seamless interaction between deaf individuals and the broader community.

- **Sign Language Recognition Module (SRM)**

Integration of the SRM, utilizing the SignNet Model to accurately interpret sign language gestures in real-time, ensuring contextual understanding.

- **Speech Recognition and Synthesis Module (SRSM)**

Incorporation of an SRSM employing Hidden Markov Models to convert non-deaf speech into text, facilitating comprehensive communication.

- **Avatar Module (AM)**

Creation of an AM to generate realistic sign language avatars synchronized with non-deaf speech, enhancing visual communication.

- **Cultural Sensitivity and Inclusivity**

Emphasis on cultural sensitivity by training the system on the Indian Sign Language, ensuring inclusivity for diverse communication needs.

- **Web-Based User Interface**

Development of a user-friendly web interface for easy deployment of the SignNet Model, promoting accessibility for both deaf and non-deaf users.

Advantages

- Integration of CNN and TCN ensures precise sign language gesture recognition with superior accuracy.
- TCN implementation enables real-time recognition, fostering dynamic communication interactions for deaf individuals and non-signers.
- Comprehensive system design incorporates both sign language recognition and speech-to-text conversion, enabling seamless communication between deaf and non-deaf individuals.
- Avatar Module generates realistic sign language avatars synchronized with non-deaf speech, enhancing visual communication effectiveness.
- System trained on Indian Sign Language showcases cultural sensitivity, addressing specific needs and nuances of the target user group.
- Web-based interface ensures ease of deployment for the SignNet Model, providing a user-friendly experience for diverse users.
- Caters to deaf-and-mute, hard of hearing, visually impaired, and non-signing individuals, fostering inclusivity in communication.
- Designed with commercial scalability in mind, making it adaptable for widespread use in various environments and contexts.
- Framework validated on MNIST sign language recognition datasets, establishing its superior accuracy and real-world applicability.
- The proposed system revolutionizes communication for individuals with hearing and mute disabilities by overcoming barriers and enhancing accessibility.

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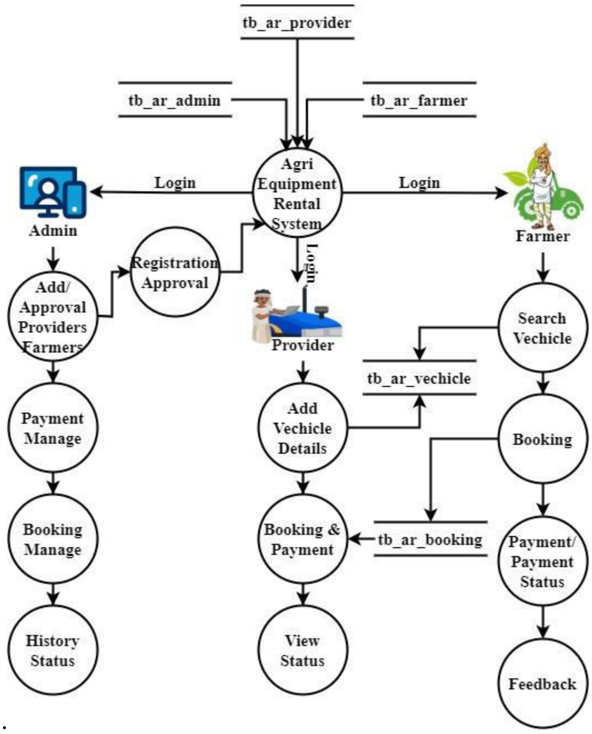
V. SYSTEM OVERVIEW

System testing and implementation for the Deaf Companion System involve rigorous validation of its functionalities and seamless integration of its modules. Unit testing ensures the accuracy and reliability of individual components like the Sign Recognition Module (SRM), Speech Recognition and Synthesis Module (SRSM), and Avatar Module (AM). Integration testing verifies the interaction between these modules, ensuring smooth data flow and synchronization. System testing evaluates the system as a whole to ensure it meets all specified requirements, including real-world scenarios for sign language recognition and avatar generation. Acceptance testing involves user feedback to enhance usability and accessibility. The implementation phase focuses on deploying the SignNet Model and developing a user-friendly web interface to facilitate effective communication between deaf and non-deaf users.



Work Flow Diagram for Web Application

VI. SYSTEM IMPLEMENTATION

The aim of this project is to develop a Deaf Companion System that utilizes advanced technologies, particularly Temporal Convolutional Networks (TCNs), to enhance communication between individuals with hearing and mute disabilities and the broader community. The system aims to overcome existing communication barriers by recognizing sign language gestures, converting non-deaf speech to text, and generating corresponding sign language avatars for seamless and inclusive two-way communication.

To design and implement a robust SignNet Model using Temporal Convolutional Networks (TCNs) for accurate recognition of sign language gestures. To train the SignNet Model on a representative dataset, focusing on the cultural nuances of the Indian Sign Language. To implement a Hidden Markov Model (HMM)-based speech recognition system for converting spoken language from non-deaf individuals into text. To develop a synthesis module that generates corresponding sign language gestures based on the converted text. To create an Avatar Module capable of generating realistic and culturally sensitive sign language avatars aligned with converted text.

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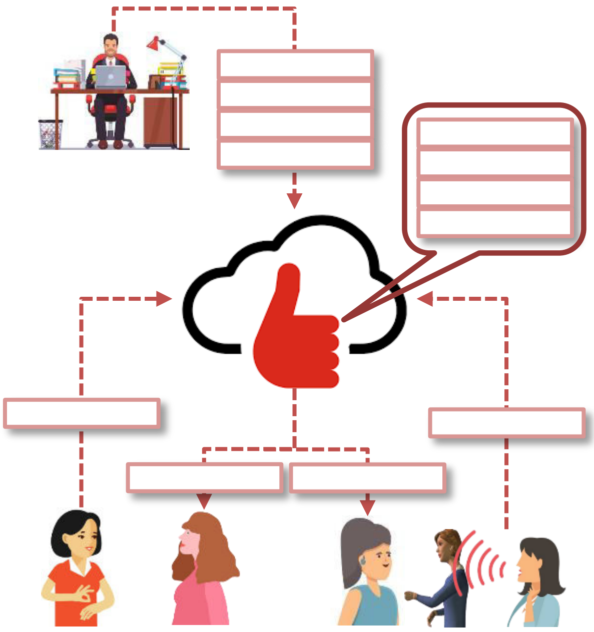

Architecture Diagram

VII. FUTURE ENHANCEMENT

Integration with smart assistive devices such as smart glasses and wearable sensors presents opportunities to enhance accessibility and functionality, providing context-aware assistance for users. Developing a mobile application version will extend accessibility, ensuring compatibility across platforms and seamless integration with smartphone features. Expanding language support to include various sign languages and spoken languages through machine translation will further promote inclusivity and cross-cultural communication within the system.

VIII. CONCLUSION

In conclusion, the Deaf Companion System represents a significant milestone in the realm of assistive technology, providing a comprehensive solution to facilitate communication for individuals with hearing and mute disabilities. Through the integration of advanced technologies such as Temporal Convolutional Networks (TCNs), Hidden Markov Models (HMMs), and Convolutional Neural Networks (CNNs), the system enables real-time interpretation of sign language gestures and conversion of spoken language into text, fostering seamless communication between deaf and non-deaf individuals.

The project's success lies in its robust performance, user-centric design, and adaptability to diverse linguistic preferences. By offering multilingual interpretation and customizable avatar generation, the system caters to the diverse needs of its users, promoting inclusivity and accessibility in communication. Looking ahead, the project opens avenues for further research and development in the field of assistive technology. Future enhancements could focus on expanding language support, improving accuracy and efficiency, and integrating additional features to enhance user experience. Overall, the Deaf Companion System stands as a testament to the transformative potential of technology in empowering individuals with disabilities, bridging communication barriers, and fostering a more inclusive society.

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