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Sign Language Recognition and Translation Systems: A Comprehensive Review with Special Focus on Malayalam Sign Language (MSL)

Dr. Ambili A.R

Assistant Professor, Senior Grade ECE, FISAT, Angamaly, India

Abstract: The main form of communication for those with speech and hearing problems is sign language. Recent developments in artificial intelligence, computer vision, and machine learning have greatly expedited the development of automated sign language detection and translation systems. These technologies use sign-to-text, sign-to-speech, speech-to-sign, and text-to-sign translation methods to close the communication gap between hearing-impaired people and the hearing community. Malayalam Sign Language (MSL), which was legally adopted in Kerala in 2021, has received comparatively less attention than American Sign Language (ASL), Arabic Sign Language, and other extensively used sign languages. With an emphasis on machine learning, deep learning, transfer learning, graph convolutional networks, and multimodal communication frameworks, this study offers a thorough analysis of current advancements in sign language identification and translation systems. The review highlights current issues and potential future research areas while analyzing present approaches, datasets, methodologies, and performance measures. This study gives special attention to Malayalam Sign Language detection and the necessity for effective, scalable, and real-time assistive communication technology.

Keywords: Sign Language Recognition, Malayalam Sign Language, American Sign Language, Deep Learning, Machine Learning, Assistive Technology

I. INTRODUCTION

In social contact, education, healthcare, and the workplace, communication is essential. Sign language is the main form of communication for those who are hard of hearing. However, because many hearing people are unfamiliar with sign language, communication hurdles frequently occur. These obstacles are especially noticeable in emergency circumstances, educational institutions, and healthcare settings where good communication is crucial.

The COVID-19 pandemic brought hearing-impaired people's communication difficulties to light even further. Lip reading and facial expressions, two crucial aspects of sign language communication, were hindered by the widespread usage of face masks. As a result, there has been an increase in interest in creating intelligent technologies that can help hearing and hearing-impaired people communicate. Developments in artificial intelligence, machine learning, and computer vision have made significant progress in automated sign language detection and translation systems possible. These systems can be divided into two general categories:

1) Translation from Speech to Sign Language
2) Recognition of Sign Language in Text and Speech

From conventional machine learning techniques to deep learning architectures like Convolutional Neural Networks (CNNs), Recurrent Neural Networks (RNNs), Long Short-Term Memory (LSTM) networks, attention mechanisms, and Graph Convolutional Networks (GCNs), researchers have investigated a wide range of approaches. Notwithstanding these developments, issues with dataset accessibility, computational complexity, real-time deployment, and support for regional sign languages still exist.

The introduction of Malayalam Sign Language (MSL) in Kerala in 2021 is a significant step toward giving deaf communities who speak Malayalam a standardized framework for sign language. Research activities on Malayalam Sign Language (MSL) are still scarce, especially in contrast to those for American Sign Language (ASL) and Indian Sign Language (ISL). Therefore, to determine research trends, obstacles, and prospects for future development, a thorough analysis of current sign language recognition and translation systems is required.

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II. MOTIVATION

According to estimates from the World Health Organization, hundreds of millions of people worldwide suffer from hearing loss and use sign language to communicate. Communication hurdles still have an impact on hearing-impaired people's quality of life despite advances in technology.

Research on sign language recognition and translation systems is necessary for several reasons:

- Sign language interpreters are few in public services and healthcare.
- Communication difficulties in learning settings.
- The hearing populace is unaware of sign language.
- Real-time assistive communication devices are necessary.
- Research on regional sign languages, like Malayalam Sign Language, is scarce.
- The need for bidirectional and multilingual communication solutions is growing.

These difficulties have prompted academics to investigate artificial intelligence-based solutions that can assist communication in an accurate, timely, and efficient manner.

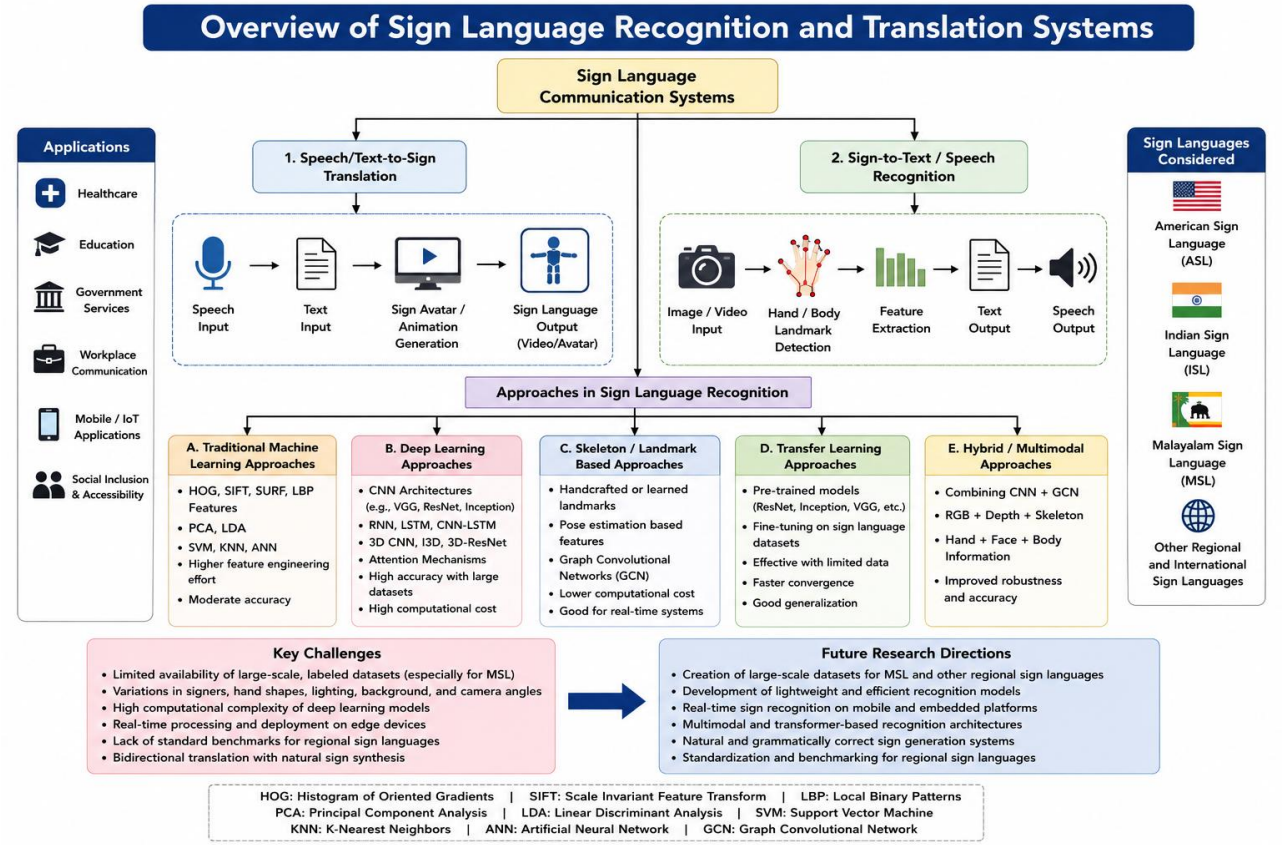

Figure 1. Overall architecture of the proposed Sign Language Recognition and Translation System

III. LITERATURE REVIEW

A. Speech/ Text-to-Sign Language Translation

The goal of speech-to-sign language systems is to translate written or spoken language into sign language representations. The Saudi Deaf Companion System (SDCS), an AI-powered bidirectional communication platform that combines speech recognition, sign language recognition, speech synthesis, and avatar-based sign production, was proposed by Faisal et al. [1]. The system achieved 97.25% accuracy using a 3D graph convolutional network.

Mosleh and Gumaei [2] created an Android-based bidirectional translation system for Yemeni Arabic Sign Language. The MobileNet, GoogleNet, ResNet152, DenseNet161, and VGG16 architectures were assessed using their framework. At 98.78%, ResNet152 had the best classification accuracy.

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The ability of avatar-based sign generation systems to visually convey information to those with hearing impairments has also drawn interest. Realistic facial expressions, grammatical accuracy, and genuine motions are still difficult to achieve, nevertheless.

B. Sign Language Recognition Systems

Conventional systems for recognizing sign language used classifiers like SVM and ANN in conjunction with manually created feature extraction techniques like HOG, SIFT, PCA, and form descriptors. In their analysis of advancements in Indian Sign Language identification, Viswanathan and Idicula [3] highlighted that methods created for ASL cannot be directly applied to ISL due to variations in gesture shapes and facial expressions.

A thorough analysis of deep learning-based systems for sign language recognition was carried out by Adaloglou et al. [4]. In their review, they examined CNN-LSTM, I3D, 3D-ResNet, and attention-based architectures. The study proved that deep learning techniques are better at learning temporal and spatial gesture information. Skeleton-based representations, graph convolution networks, and landmark-based techniques are being used more frequently in recent research to increase recognition accuracy while lowering computing complexity.

C. Malayalam Sign Language Recognition

Because MSL was only recently standardized, there is still a dearth of research on Malayalam Sign Language. A modified Inception-V4 architecture served as the foundation for a Malayalam Sign Language character recognition system created by Praneel et al. [5]. The study demonstrated the capabilities of specialized MSL recognition systems that concentrated on identifying nine Malayalam sign symbols. Salim [6] suggested a ResNet50-based system for recognizing Malayalam sign language using transfer learning. The model's validation accuracy was 92.35%, and its training accuracy was 97.62%.

Isaac et al. [7] introduced a deep learning-based real-time framework for recognizing Malayalam sign language using TensorFlow and transfer learning. Their research demonstrated that real-time gesture detection algorithms can effectively recognize Malayalam sign language. Figure 1 illustrates the overall architecture of the proposed Sign Language Recognition and Translation System, highlighting the major components and the flow of data from sign acquisition to text and speech generation

IV. RESEARCH GAP

Recognition systems for sign language have come to improve significantly, but they still have several limitations. The majority of studies concentrate on ASL, Arabic Sign Language, and other globally accepted sign languages.

- There is still a lack of research on Malayalam Sign Language.
- Large datasets and significant processing power are needed for current deep learning algorithms
- . • In environments with limited resources, real-time deployment is still difficult.
- There are still few bidirectional communication systems that combine sign production and recognition.
- There are few datasets in Malayalam Sign Language that are accessible to the public.

These difficulties highlight the need for efficient, scalable, and lightweight systems for recognizing sign language that cover both regional and worldwide sign languages.

V. CONCLUSION

Recent advancements in sign language recognition and translation systems, such as speech-to-sign translation, sign-to-text recognition, deep learning techniques, and research on Malayalam sign language, were reviewed in this paper. Sign language systems have made great strides, but there are still issues with computational complexity, dataset availability, real-time deployment, and regional language compatibility, according to the survey. Future studies should concentrate on creating effective multimodal systems, growing datasets in Malayalam sign language, and creating useful assistive technologies that enable two-way communication between the hearing and hearing communities.

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