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Machine Learning-based Sign Language Recognition and Translation System

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***Abstract*— These are the Indian Sign Language Recognition (SLR) systems, which are essential for bridging the communication gap between the population of people with hearing impairments and those who have lost their capacity to hear. Due to the quick developments in computer vision, deep learning, and machine learning, researchers are very interested in automated sign language gesture detection. These algorithms are able to convert facial expressions, hand gestures, and body language into readable text or speech. The various methods that are present have been mentioned in the review paper to identify sign language, including vision-based, sensor- based systems on upper wearables and techniques. It discusses mainstream machine learning procedures, data, issues, its flaws, and applications. The Indian Sign Language (ISL) is provided with special consideration as it implies the absence of standardised repositories of information and mobile-based real-time systems. Additionally, the research points out gaps in the literature and makes recommendations for future directions in the creation of reliable, long-lasting, multicultural, and mobile-friendly sign language recognition systems.**

***Index Terms*— Indian Sign Language, computer vision, deep learning, machine learning, assistive technology, and sign language recognition.**

I. INTRODUCTION

Sign language helps people who cannot hear to communicate using hand signs and facial expressions [1,2]. Hearing impairment is one of the most common sensory disabilities among individuals [6]. According to the World Health Organization, we need better ways for people with hearing problems to communicate, because more than 63 million people in India are affected [6]. ISL is used across different regions of India and is influenced by sign languages from the broader Asian region [2,7]. India lacks a traditional sign language as in America and Europe does [2]. Most of the portions of the ISL got their roots in the British Sign Language [2,5]. The use of the localized sign language in India is very ancient. Studies have shown that sign languages vary across regions, with similarities and differences observed among different communities [2]. The alphabet chart of ISL is illustrated in figure 1 [7]. The automatic conversion of gestures [3,4] to text or voice is especially useful when communicating with people who have disabilities and don't comprehend their language [3,4,8]. The study of sign language interpretation has been around for a while [1]. A recognizer algorithm is utilized to identify the markings in the sign conversion so that gestures can be automatically translated into human-readable text or voice [3,4,8].

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The data set helps condition the system to identify, anticipate, and evaluate the target [4,10,11]. These methods use cameras to detect and understand gestures, so the system gives more accurate and reliable results [5,8].

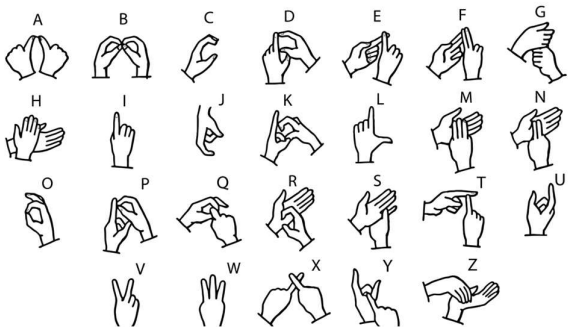

Figure 1: ISL Alphabets

A. Sign Language Recognition

In order to recognize, comprehend, and classify hand gestures and movements into logical written or spoken qualities, the SLR system employs systematic mathematical and computational procedures [3,4]. SLR systems help people interact with computers and machines, and they also help people who cannot hear. Gesture recognition is used in places like hospitals, banks, and stations. These technologies also facilitate learning materials for people with hearing impairments, special education, and inclusive communication for people with disabilities [1,3,4].

B. SLR process steps

A Sign Language Recognition (SLR) system looks at hand shape, movement, and position, along with facial expressions and body posture to understand signs [4,8,21]. Its main goal is to convert these signs into text or speech so that anyone can easily understand them [3,4,8]. The SLR process's primary steps are described in this section [1,3,4,8].

- Image/Video Capturing: The first step in an SLR system is to collect gesture data using cameras, mobile phones, or sensors [1,16,19]. The system captures real-time or captured images, video, which includes hand in image sequence, body language and facial expression[5,8,10]. The movement patterns are formed upon which the next processing is based through the collection of video frames of dynamic signs at regular intervals to explore movement patterns in the dynamically received video frames [8,11].
- Preprocessing: Preprocessing means the extraction of the video frames or the captured images in order to be analyzed further[5,8]. The main aim is to do away with noise, and to do away with unwanted background information. Some of the common image preprocessing methods used are image scaling, image normalization, background subtraction, and lighting correction as well as conversion to color space [5,8]. The processes assist in the enhancing of the recognition under low light especially under simple or complex backgrounds [8,10].
- Hand and Face Detection: In this step, the system finds and focuses on the important parts, mainly the hands and face [8,21]. Detection is achieved using various methods including color division of the skin, outlines separation, and deep learning models[8,21]. The facial detection techniques come in handy to identify facial points, which are required identifications of expressions[6,8,21].
- Segmentation: Segmentation is where the parts of the hands and face are separated to find those areas relative to the background[5,8]. In this step, the system separates objects by finding their edges or using simple methods or learning-based techniques [5,8].
- Feature Extraction: Feature extraction means changing images or videos into simple numbers that the system can understand [4, 8].
- Feature Fusion: To make the system more accurate, SLR uses learned patterns of hand and facial gestures [8,12,21].
- Classification: Machine learning methods like CNN, LSTM, and combined models are used in these systems [8,21,25].
- Post-Processing: These techniques are those that typically improve the outcome of the classification by removing false alarms and coping with transition interaction among gestures[8,21].
- Output Generation: Recognized gestures are inputted into written text or are read out[3,4,8,11].

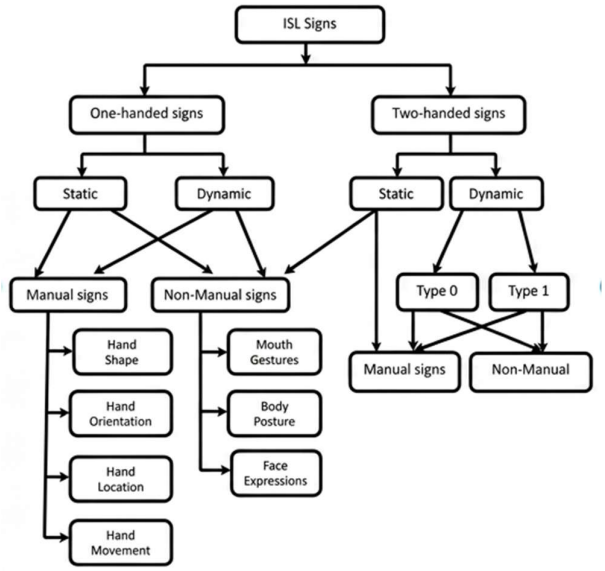

Figure 2: ISL categories

Figure 2 shows different types of Indian Sign Language, including alphabets, numbers, and gestures used for communication. These classification types aid in the comprehension of the manner in which signs are organized and understood by SLR systems.

II. Related Work

Numerous computer-based, machine learning, vision, and sensor-based studies have focused on Sign Language Recognition (SLR) [1,3,4,8,16,19]. Static sign recognition was the main focus of the early systems, particularly for alphabets and numerals that used pictures [3,4,9,14,15]. These systems used classifiers along with image processing methods [3,4]. Reasonable results were attained by these systems. controlled environments but was unable to deal with accuracy in uninterrupted movements and live action [17,18].

Convolutional Neural Networks (CNNs) are very popular today and are widely used. They help the system understand important details from hand gesture images. Researchers also used CNNs along with RNNs. RNNs help in understanding movement over time, and LSTM helps in remembering long patterns. When CNN and LSTM are used together, they give better results for understanding gesture sequences [8,21,22,23,24,25]. The requirement for numerous processing resources and annotations made this possible.

A few researchers proposed wearable glove systems that use gyroscopes, accelerometers, and flex sensors to record hand movements [16,19]. Even still, these technologies were expensive, awkward and cumbersome, inaccurate, and not a useful way to get information on a daily basis [16,19,26,27]. Over the recent years, some technologies have come up with two-way communication where the sign language is converted to speech or writing and vice versa. Most of these systems however, prefer disguised words over sentence flow particularly with regards to ISL and are also in support of American Sign Language (ASL). There has also been the use of mobile-based applications, yet they tend to have weak vocabulary, less accuracy when working in complicated backgrounds, and lack of facial expression, emotional context support.

In general, the available systems of ISL recognition experience several such issues as inadequate dataset availability, absence of poor real world robustness, continuous gesture recognition world conditions, lack of a two-way communication, and limited mobile implementation[7,11,28,29,30].

III. Challenges and Future Search

Although recognition of sign language has advanced significantly, there is still much room for improvement. Lack of experience with continuous sign recognition systems is one major drawback. The majority of current models lack natural communication because they hesitate between gestures. In the future, automatic gesture splitting and attention-based models can help improve recognition of full sentences in sign language.

Another problem is that many systems do not use things like head movement, facial expressions, and body posture [8,11,20]. These are important in Indian Sign Language because they show emotions and meaning. When all these features are used together, the system becomes more accurate and better at understanding [20, 21]. The lack of a general Indian Sign. Language datasets can be also of heavy concern. Future endeavors must seek to generate various datasets by considering a large number of individuals, geographical differences, light conditions and contexts across the world. These kinds of datasets would be useful in creating models that are more applicable outside of the lab.

In the future, these systems can translate signs into Indian languages like Tamil, Marathi, and Hindi. They can also be made to work on simple mobile and lightweight devices. It can be done with the help of frameworks such as TensorFlow Lite and ONNX to increase accessibility, particularly rural and social [12,13].

Communication between hearing and hearing-impaired people can be improved using systems that convert speech into sign language with animated characters. Future potential for clinical, educational, and general medical emergency services applications as well as emotion-aware recognition systems are also promising.

IV. CONCLUSIONS

This study gives a detailed explanation of the existing research and literature on Indian Sign Language Recognition systems. ISL stands for Indian Sign Language. various techniques, including mobile applications, wearable sensors, deep learning models, and vision-based systems [2,7,8]. The existing systems do not cope with two-way communication, real-time application, continuous recognition and coverage of the ISL, whereas they are effective when working on static and limited dynamic gestures.

The lack of ISL datasets, multimodal integration [11,21], robustness to real-world situations, and the absence of mobile-friendly solutions are some of the constraints identified by the article. Future research will focus on edge deployment, language support, facial expression integration, and continuous gesture detection to address these problems [8,11,21,25].

Finally, a mobile app that can understand and translate Indian Sign Language in real time can help reduce communication problems and make things easier for deaf and hearing-impaired people.

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