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Translation of Indian Sign Language to Text-A Comprehensive Review

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Abstract: Deaf and mute persons across the world uses gestures, non-manual features to interact with fellow persons. This way of communication is called Gesture language or Sign language. Gesture languages are local in nature because of their dependency on geographical area, syntax, pragmatics, and other attributes. The focus of this paper is to present a comprehensive review of conventional as well as contemporary Indian sign language translation system. The process of literature review has been carried out in accordance with Preferred Reporting Items for Systematic reviews and Meta Analysis (PRISMA) guidelines by searching in Scopus, google scholar, Science direct and Lensorg databases. Different articles were included between the years 2010 to 2023 for the purpose of literature review. The study was based on four themes-dataset, technique, result and previous literature reviews. This is the first detailed review conducted in the field of Indian sign language translation system which solely analyses literature related to ISL as per author's knowledge. The findings of this research article may contribute to gain insights and form a blueprint for future areas in the arena of Indian Sign Language translation/recognition system.

Keywords: *Comprehensive review, ISL Translation, ISL Recognition, Indian Sign Language, PRISMA*

1. Introduction

Nonverbal communication encompassing body language, gestures, facial emotions is a vital aspect of human interaction. However, people with special needs are solely reliant on this form of communication. Deaf and dumb persons across the world uses gestures, non-manual features to interact with fellow persons. This way of communication is called Gesture language or Sign language[1]. These languages have evolved over the years because of their natural existence. Due to lack of resources for these especially abled persons, they used sign language to communicate with their families. With technological advances, to aid these persons, schools, medical facilities came into existence. Gesture languages are local in nature because of their dependency on geographical area, syntax, pragmatics, and other attributes[2]. Indian Sign Language (ISL) came into existence in 2018, after a long battle by deaf and dumb community[3]. There are many popular sign languages used in India apart from ISL such as Bangla Sign Language (BSL), Tamil Sign Language (TSL), Panjabi Sign Language (PSL) and Malayalam Sign Language (MSL) etc. Currently, Sign language translation is most popular domain with the potential to provide automatic and effective communication tool for hearing disabled persons[4]. It translates the given input sign language gesture into corresponding text. Promptness and exactness are the important parameters for the decision makers to determine the efficacy of the proposed system[5].

Machine learning is an offshoot of artificial intelligence which aims to simulate human intelligence in machines using various algorithms. However, recently advanced form of machine learning is deep learning which relies on artificial neutral network to emulate human neurons for image processing tasks. Machine Learning (ML) and Deep learning (DL) paradigms can process huge amount of data in a reasonable time limit and build an efficient translation system. Consequently, ML and DL practices are getting immensely popular in the discipline of sign language processing [6].

Although a lot of literature reviews has already been conducted in the field of sign language but dearth of an exhaustive literature review in the field of ISL was one of the major motivation factors for this research article using standard Preferred Reporting Items for Systematic reviews and Meta Analysis (PRISMA) guidelines [7]. The contributions of this research paper are as follows.

- In this paper, we have studied the work done in the field of Indian Sign Language Translation for the vicennial period along with their shortcomings.
- Various datasets available in the domain of Indian Sign Language Translation System (ISLTS) has been explored with the focus on available open access dataset.
- Different levels of translation such as Alphabet level, word level and sentence level has been discussed.
- This paper examines current trends in ISLTS and

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provide suggestions to researchers for future works.

The rest of the research paper is organized as follows- Section II describes methodology followed by the authors to conduct this literature review. Section III describes the results followed by conclusion in future scope in Section IV.

2. Materials and Methods

We carried out a PRISMA comprehensive review to analyze technological advancements in the field of translation of Indian sign language into text. The research questions were formulated in the first step to initiate the process of conducting literature review.

- RQ1- What is the focus of study in previous literature review in the field of ISLTS?
- RQ2-What are various types of datasets available for researchers in the field of ISLTS?
- RQ3- What are the number of research paper published per year on ISLT/RS?
- RQ4- What are existing techniques for translating ISL gestures and their performance?

2.1 Search Query

Different research papers related to ISLTS/ Indian Sign Language Recognition System (ISLRS) were searched on four popular research databases such as Scopus, Google Scholar, Science Direct and Lensorg. The principal objective of this literature survey is to examine translation/recognition attempts made in the ISL sector. Open Access articles in English language has been selected for this review process from year 2010 to 2023 based on the search queries mentioned in Table 1.

Table 1. Search Query

Name of Dataset	*Query*
Scopus	TITLE-ABS-KEY ("INDIAN SIGN LANGUAGE TRANSLATION" OR "ISL TRANSLATION" OR "ISL RECOGNITION" OR "INDIAN SIGN LANGUAGE RECOGNITION") AND (LIMIT-TO (EXACTKEYWORD , "Indian Sign Languages") OR LIMIT-TO (EXACTKEYWORD , "Indian Sign Language"))
Science Direct LensOrg Google Scholar	"INDIAN SIGN LANGUAGE TRANSLATION" OR "ISL TRANSLATION" OR "ISL RECOGNITION" OR "INDIAN SIGN LANGUAGE RECOGNITION"

The workflow of the literature review process has been shown using **Error! Reference source not found.**. A total of 598 research articles were identified for the purpose of literature review using above mentioned queries from four major research databases. In the next stage, 47 articles were excluded from the study because of redundancy. Upon preliminary literature investigation, every research article's title and abstract were examined manually and then 414 pertinent papers were selected for further assessment criteria. Subsequently, 202 research articles were selected based on the criteria of availability of research paper or whether it is open access. Four eligibility criteria were adopted for this literature survey in the next phase.

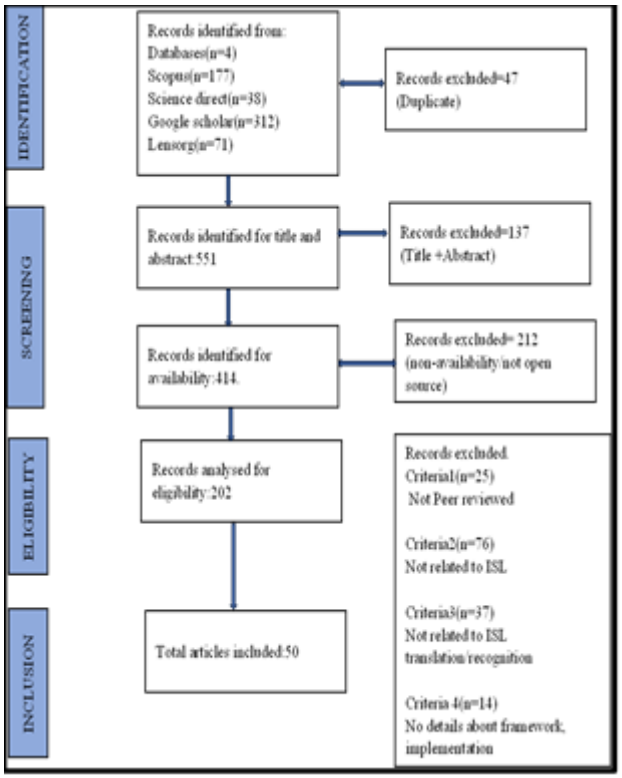


Fig. 1. Flowchart of comprehensive review process using PRISMA guidelines

- The article should be peer reviewed.
- The article should be related to Indian Sign Language.
- The theme of the article should be related to recognition/translation of ISL to text.
- The details about framework/implementation should have been mentioned in the research article.

After stringent eligibility criteria more than 50 articles has been selected for this literature review.

3. Results and Discussion

In this section, we will try to answer all the research questions on the basis of literature.

3.1 RQ1- What is the focus of study in previous literature review in the field of ISLTS?

To analyze previous literature surveys in this field and their focus areas on which review has been performed a list of review articles has been crafted in the field of ISLRS/ISLTS process. Table 2. shows various research articles published along with their year and focus of review from the period of 2010 to 2023.It has been observed that no literature review article has been published in the field of ISLTS/ISLRS using PRISMA guidelines as per the author's knowledge. It has been observed that most of the literature review articles [8]–[12] included less than 10 research articles for their analysis due to lack of standard research work in the domain of ISL. [13] contemplated 29 research articles related to dynamic recognition and compared different methodologies. However, [9], [13] reviewed various methodologies and [12], [14] discussed various feature extraction techniques in ISLTS/ISLRS. [15] examined different articles related to dataset acquisition techniques and concluded that area of non-manual features is yet to be explored in case of ISL. [16] studied few ISLR articles along with other sign languages to conclude there are limited work in alphanumeric recognition, dynamic sign recognition. It has been analyzed that 90% of review papers in ISL translation/recognition process considered less than 20-25.

Table 2. Prior literature reviews in ISL

Ref	*Type*	*Year*	*Criteria for Review*
[8]	J	2015	Gesture set and technique
[9]	J	2023	Methodology
[10]	J	2013	Input, segmentation, Feature vector, classification, recognition rate, platform
[11]	C	2015	Challenges
[12]	C	2021	Feature extraction
[13]	C	2021	Dynamic ISLRS with focus on methodology
[14]	C	2022	Feature Extraction
[15]	C	2022	Dataset acquisition techniques
[16]	C	2019	Input, dataset, segmentation, method, number of gestures, output, limitation, recognition percentage

3.2 RQ2- What are various types of datasets available for researchers in the field of ISLTS?

A standard well annotated dataset is very important for any sign language processing system. In case of ISLTS, lack of standard, open access datasets are few of the major challenges in translation/recognition process. Table 3. describes list of open access datasets available in the domain of ISLTS along with their characteristics. We have also included some dataset with limited access.

Table 3. List of open access datasets available in ISL

Ref	*Year*	*Dataset*	*Type*		
			Alphanumeric	*Word*	*Sentence*
[17]	2010	ISL		22	
[18]	2020	Include	-	15W	
[19]	2021	ISL-CSLTR	-	1036	100
[20]	2021	ISLAN	24 A	-	-
[21]	2021	Emergency	-	8W	-
[22]	2021	INSIGNVID	-	55W	15S
[23]	2022	IISL2020	-	11W	-

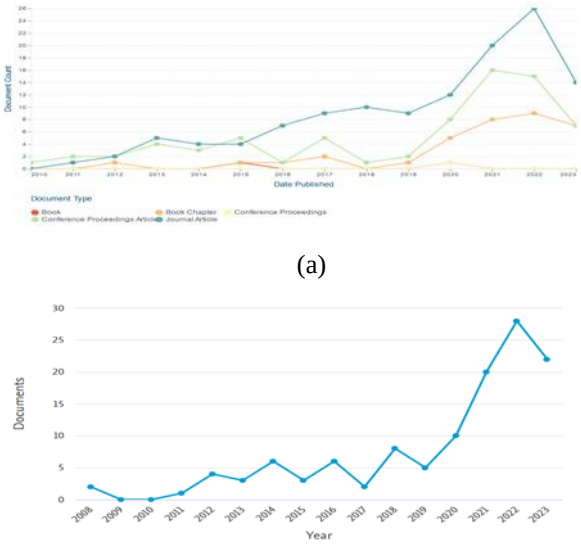
In 2010, [17], created RGB video dataset of 23 different ISL word gestures at 30 frames per second (fps) under various background and lightning conditions. The access of this dataset has been restricted and only given to educational institutions based on agreement through their website by the creators. In 2020, [18] presented Indian lexicon sign language dataset (INCLUDE) with the help of 7 experienced signers. This word level dataset consists of 263 classes of 15 categories, 4287 videos with 1920x1080 resolution and 25 fps. A subset of the above dataset having 50 signs across 15 categories was also proposed with same specifications called INCLUDE 50. Both the datasets include 15 words in total. In 2021, several other researchers came up with their own ISL datasets available freely like [19] Elakkiya et al developed first sentence level Indian sign language dataset for continuous Sign language translation and recognition i.e., ISL-CSLTR. The dataset contained 700 videos of 100 sentences made up with the help of 7 signers. Secondly, another ISL dataset for Alphanumeric (ISLAN) signs was developed by [20] comprising of 350 unique sign images and 12 unique videos compassing 24 alphabets of English language (except J, Z) and numbers totaling to 700 images and 24 videos by 6 signers. Another sign language dataset for emergency domain has been developed by [21]. It included 824 videos of 8 words by 12 males and 14 females. Indian Sign Language Video (INSIGNVID) dataset was developed by [22] for efficient recognition of 55 words of ISL. The dataset was created by 4 right-handed

persons and consists of videos with 30fps, 1920*1088 resolution and common background conditions. In 2022, Kothadiya et al [23] proposed a permission based Isolated ISL dataset (IISL2020) made up of 11 words from 16 persons and 1100 videos and average 28fps.

3.3 RQ3- What are the number of research paper published per year on ISLT/RS?

Error! Reference source not found.. elucidates an overview of ISLTS studies that are published annually from Lensorg and Scopus source in (a) and (b) parts. It has been observed from the figure that highest articles are published in the year 2023 till date i.e., maximum of 26 journal articles has already been published in the year 2023. The topic of ISLTS/ISLRS has garnered a lot of research attention in the last few years however, the work done in recent two years outshines the previous works quantitatively and qualitatively.

Three different categories of articles i.e., book chapter, conference articles and journal articles are contemplated for this research article as represented with figure 3(a) and 3(b). It has been observed that majority of articles published in the field of ISL recognition/translation domain are from journals i.e., 124 out of total 239 are research articles published in journals followed by numbers of articles in conference. This data has been taken from Lensorg website [24] with the constraint to include only selected articles related to the domain of ISLTS/ISLRS from the period 2010 to 2023.



(a)

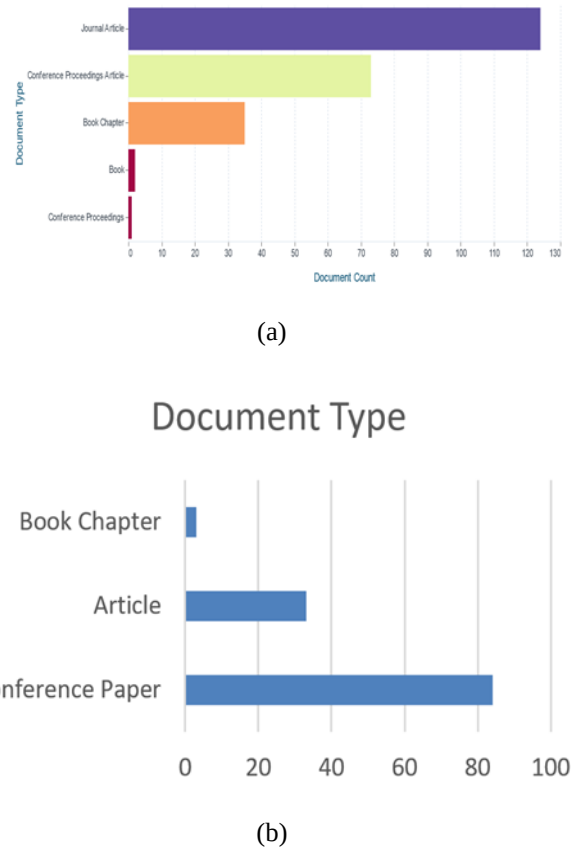
(b)

Fig. 2. Example of a Publications per year (a)LensOrg (b) Scopus

RQ4- What are existing techniques for translating ISL gestures and their performance?

Machine learning has garnered a lot of attention in the field of sign language processing over the last few years. Majumdar et al [25] in 2011 proposed Indian sign language recognition system with YCbCr segmentation, wavelet packet decomposition, principal curvature-based region as feature extraction, dynamic time warping (DTW) to classify alphabets with an accuracy of 91.3%. [26] concluded that Multi SVM classifier can classify static ISL gestures with recognition rate of 92.6 on a self-made dataset.[27]

proposed a ISL recognition system to classify 24 alphabet level gestures with 97 recognition accuracy using novel Eigen value weighted Euclidean distance. [28] proposed a framework for recognition of two-handed gestures of ISL by employing HOG feature extraction method and four popular pretrained models ALEXNET, VGG-16, VGG-19 and GoogleNet. The model attained highest accuracy of 99.11% with ALEXNET and VGG-19 pretrained transfer learning models to classify alphabets of ISL. [29] proposed model for recognizing alphabets of ISL using extreme learning with an average accuracy of 80.76% on self-made dataset. [30] developed a ISLRS for alphabets using CNN with



(a)

(b)

Fig. 3. Publication types (a) LensOrg (b) Scopus

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In numeric ISLTS, [33] in 2014, proposed ISL numeric digit (0-9) recognition system on a self-made ISL dataset using KNN classifier and an accuracy of 97.1%. However, [34] proposed Kinect sensor based ISLRS using scale, rotation, and background lightning invariant ORB feature extraction method and KNN machine learning algorithm to classify (0-9) digits of ISL on a self-made dataset with an accuracy of 93.26% outperforming standard feature extraction techniques like SIFT and SURF.

In the domain of alphanumeric level recognition, [35] proposed ISLRS framework using fingertip algorithm and PCA to obtain 94% accuracy. In 2013, [36] used Fourier descriptors, distance transform and artificial neural network with four layers to classify 36 alphanumeric gestures of ISL with an average accuracy of 91.11 %. [37] Geetha et al suggested alphanumeric ISL sign recognition system with B-spline approximation and SVM classification algorithm.[38] proposed novel fusion descriptor for classification of ISL numeric signs with Nearest Mean classifier and an accuracy of 100%. The novel fusion descriptor comprises of two contour (Boundary, Fourier descriptor) and one region based(7Hu) descriptors.[39] classified gestures of ISL using SVM machine learning algorithm.[40],[41],[42] used Kinect sensor to classify gestures at alphanumeric and word level along with popular classification algorithms such as PCA, SVM to attain remarkable accuracies.[43] suggested translation of word level ISL gestures by extensive training of humanoid robot HOAP-2 along with direction histogram feature extraction, Euclidean distance metric has been used to attain an average accuracy of 90%. [23] Kothadiya et al. in 2022 classified 11 words of ISL using sequential combination of LSTM and GRU with accuracy of 97% on their dataset IISL2020. [44] developed a model for classifying 24 dynamic word gestures of ISL using novel dynamic time warping recognition technique along with accuracy of around 90%. 20 different gestures were classified by [45] using 3D CNN and attaining 88% validation accuracy in 100 epochs. The model

comprises of 3 convolution layers, max pooling, dropout and softmax activation function. [46] Subramaniam suggested integrated model of Media pipe with optimized GRU model for recognition of 13 ISL gestures to attain average accuracy of 95%. The proposed system has been compared with RNN, LSTM, standard GRU, BiGRU, and BiLSTM models.

Hybrid ISLT paradigm comprising of combination of word and alphanumeric and sentence level. In this, [22] suggested transfer learning approach using MobileNetV2 to transcribe clips of ISL into English language. The proposed system was analyzed using other pretrained models such as MobileNet, VGG16 and ResNet50 using 25 epochs with 9 trainable layers to attain testing accuracy of 93.89%. Although proposed system achieves better accuracy but time to train the system was comparative high i.e., more than 12 hours.

[47] classified alphanumeric, word gestures of ISL using Fourier descriptor feature extractor and distance metric to attain overall accuracy of 92.91%. The proposed system [48] recognized 26 alphabets, 10 numbers and 10 distinct phrases on self-made skinpixel segmentation, Moment based feature extraction and SVM algorithm to classify dynamic gestures. The system obtained an accuracy of 97.5% recognition rate in classifying 4 signs (3 alphabet and one word). [49] presents a signer independent communication model for real time using YCbCr segmentation, Zernike moments feature vector and SVM as classifier.[50] Deshpande et al. classified 56 signs real time using CNN into text and audio with 98% accuracy with the constraint of plain background. The proposed model had 5 convolution layers, ReLU activation function, max pooling, dropout layer, single valued stride function and softmax layer to classify different signs. [51] recognized gestures of 7 days of week using Kinect sensor and random forest classifier algorithm to give an accuracy of 74.29% with focus on low cost and maximum efficiency.[52] Nareshkumar attained an accuracy of 98.77% in translating alphanumeric gestures of ISL and American Sign language using novel pretrained model for mobile MobileNetV2 consisting of pointwise convolution layers, separable depthwise convolution, ReLU activation function, swish

activation function, batch normalization, dropout layer and softmax as final classifier layer. [53] developed ISLRS using HSV segmentation, PCA with OH 18 and 36 bins feature extraction mechanism to classify 10 ISL sentences having 2,3 or 4 gestures using six different distance metrics. Euclidean distance topped the performance chart with 93% recognition rate (RR) on 36 bins of orientation histogram. [54] proposed a lightweight framework for translating sentence level ISL gestures into text and audio, LiST, and used pretrained model InceptionV3, two layered LSTM architecture on open access dataset with a translation accuracy of 91.2%. [55] proposed a framework for translation of 10 signs of ISL using HMM and DWT to achieve lowest accuracy of 80 and highest accuracy of 100%. [56] proposed a Leap motion sensor based ISLTS for 35 words and 942 sentences using four gated cell LSTM with 2 dimensional CNN to attain average accuracy of 89.5% and 72.3% respectively.[57] proposed gesture recognition mechanism for 42 signs of ISL using KNN and SVM machine learning classification techniques. HSV, Otsu thresholding for segmentation and novel MFCC feature extraction method has been used along with wavelet descriptor to translate 42 static and dynamic gestures of ISL. The authors concluded that SVM with MFCC feature extraction mechanism

Table 4. Work done in the domain of ISLTS

Ref	*Year*	*Type*	*Specifications*	*Features*	*Results*
[25]	2011	ALPHABET	26Alphabet	Support Vector Machine (SVM), K-Nearest Neighbour (KNN) and Dynamic Time Warping (DTW)	91.3 accuracy
[26]	2012		26Alphabet	Multi SVM classifier	92.6 Recognition Accuracy
[27]	2013		Alphabet (24)	Eigen value weighted Euclidean distance	97 Recognition Rate
[28]	2022		Alphabet	Histogram Oriented Gradient (HOG), AlexNet	99.11Accuracy
[29]	2020		-	Extreme learning	80.76Accuracy
[30]	2022		26 Alphabet	Convolution Neural Network (CNN) with diffGrad optimiser	99.64
[31]	2019		26 Alphabet	Neurofuzzy algorithm with correlation coefficient feature extractor	92.3
[32]	2022		26 Alphabet	VGG16	95
[33]	2014	NUMBER	10 Numbers	Neural network with KNN	97.1
[34]	2020		10 Numbers	Kinect and Bag of visual words with ORB, KNN	93.26
[35]	2012	ALPHANUMERIC	36Alphanumeric	Principal Component Analysis (PCA)	94 Recognition Accuracy
[36]	2013		36Alphanumeric	4-layer Artificial Neural Network (ANN)	91.11 Recognition Rate
[37]	2012		26Alphabet, 6Numbers	B-spline approximation	-
[38]	2016		36Alphanumeric	Novel fusion descriptor,	99.61
[39]	2022		Alphanumeric	Bag of Visual Words (BOVW), Speeded Up Robust Features (SURF), SVM, CNN	99.64Accuracy

[40]	2020		Alphanumeric	Kinect with SURF, HOG, Local binary pattern SVM	Average Accuracy-71.85
[23]	2022		11Words	Long short-Term Memory (LSTM), Gated Recurrent Unit (GRU)	97Accuracy
[41]	2015		37Words	Kinect with SVM	86.16%Validation Accuracy
[42]	2013	WORD	10Words	PCA with ALI, Microsoft Kinect (25 key points of each gesture)	Best-100A, Average-40, Worst-25
[43]	2010		22Words	Euclidean distance, KNN with 36 bins	Lowest-48.42, Highest-100Accuracy
[44]	2016		24Words	DTW	90Accuracy
[45]	2021		20Words	3D-CNN	88.24Average Accuracy
[46]	2022		13Words	MOPGRU with ELU activation and softsign activation function	99.92Accuracy, 0.21 Loss
[22]	2021		55Word, 15Sentences	MobileNetV2 pretrained model	93 Recognition Rate
[47]	2015		10Signs	Fourier Descriptor with Euclidean distance	Lowest-85, Highest-97Accuracy
[48]	2016		01Word, Alphabet	3SVM, Kinect sensor	97.5 Recognition Accuracy
[49]	2022		26Alphabet, 11Word	Co-articulation, Zernike moment, SVM	Alphabets-91A, W-89A
[50]	2023		36 Alphanumeric, 20Word	Region of Interest, CNN	98Accuracy
[51]	2022		7 Word	Kinect V2 sensor, Random Forest	74.28 Accuracy
[52]	2023		26Alphabet, 3Word	Transfer learning, Modified MobileNet V2	98.77 Accuracy
[53]	2015	HYBRID	10Sentences	PCA with OH	Lowest-85 , Highest -93 Accuracy
[54]	2023		15Sign	Inception v3 CNN with LSTM	95.90 Accuracy
[55]	2015		10Sign	DWT, Hidden Markov Model (HMM)	Lowest-80, Highest-100 Accuracy
[56]	2019		942Sentences, 35Word	CNN with LSTM and Leap motion sensor	Sentences-72.3Avg. Accuracy, Words-89.5 Avg. accuracy
[57]	2017		42Words	KNN, SVM with MFCC feature extraction	97 Accuracy
[58]	2019		80Word, 50Sentences	Fuzzy clustering algorithm	75 Accuracy
[59]	2018		33Alphanumeric, 12 signs	HMM, KNN	99.7 Static Sign

					97.23 Dynamic Sign
[60]	2012	80Words Sentences	andPCA feature vector, Fuzzy inference system		96 Accuracy

classified ISL gestures with better accuracy than KNN. [58] proposed Fuzzy c-means clustering algorithm for classifying 80 words and 50 sentences of ISL with an average accuracy of 75%. [59] proposed ISLTS for 45 sign (alphanumeric and word) using skin color segmentation, Hidden Markov Model, K-nearest neighbor recognition algorithm with an accuracy of 99.7% for static signs and 97.23% for dynamic signs. [60] proposed video gesture recognition of ISL using Gaussian filter, Canny edge detector, Fourier descriptor and Sugeno fuzzy inference system to attain higher accuracy of 100 and lowest accuracy of 60 among total signs. Although there are various researchers who have been working in the domain of Indian sign language translation/recognition to develop optimal framework but there is tradeoff between accuracy and time. The system is affected by so many parameters discussed in next section.

4 Conclusion and Future Scope

In this paper, we have conducted comprehensive literature review on Indian Sign Language Translation/Recognition System using PRISMA guidelines. After rigorous screening, more than 50 papers were selected for this review from four major research databases- Scopus, Google Scholar, Science Direct and LensOrg. There were four main criteria on which this survey was conducted- previous work done, datasets available, number of research articles published per year and summary of important work done. It has been concluded a lot of work has already been done in sign language processing systems, but ISLTS are still lagging in a lot of aspects.

- Lack of well annotated standard open access datasets
- Alphanumeric recognition
- Two-way communication system
- Domain specific translation system
- Lack of quality review papers
- Sensor based devices gives better accuracy but are not comfortable

As there are many challenges but exploitation of new emerging machine learning algorithms is need of the hour in ISLTS as compared to other sign language processing system. We hope that this research paper will help other future researchers in the field of ISL.

Author contributions

Seema Sabharwal: Conceptualization, Methodology, Software, Field study, Data curation, Writing-Original draft preparation, Software, Validation, Field study, Visualization **Priti Singla:** Investigation, Writing-Reviewing and Editing.

Conflicts of interest

The authors declare no conflicts of interest.

References

[1] A. Wadhawan and P. Kumar, “Sign Language Recognition Systems: A Decade Systematic Literature Review,” Arch. Comput. Methods Eng., vol. 28, no. 3, pp. 785–813, May 2021, doi: 10.1007/s11831-019-09384-2.

[2] S. M. Kamal, Y. Chen, S. Li, X. Shi, and J. Zheng, “Technical Approaches to Chinese Sign Language Processing: A Review,” IEEE Access, vol. 7, pp. 96926–96935, 2019, doi: 10.1109/ACCESS.2019.2929174.

[3] ISLRTC, “History | Indian Sign Language Research and Training Center (ISLRTC), Government of India,” Indian Sign Language Research and Training Center (ISLRTC). Accessed: Feb. 14, 2022. [Online]. Available: http://islrtc.nic.in/history-0

[4] S. Sabharwal and P. Singla, “Indian Sign Language Digit Translation Using CNN with Swish Activation Function,” in Key Digital Trends Shaping the Future of Information and Management Science, vol. 671, in Lecture Notes in Networks and Systems, vol. 671. , Cham: Springer International Publishing, 2023, pp. 245–253. doi: 10.1007/978-3-031-31153-6_21.

[5] I. A. Adeyanju, O. O. Bello, and M. A. Adegboye, “Machine learning methods for sign language recognition: A critical review and analysis,” Intell. Syst. Appl., vol. 12, p. 200056, Nov. 2021, doi: 10.1016/j.iswa.2021.200056.

[6] Seema and P. Singla, “A Comprehensive Review of CNN-Based Sign Language Translation System,” in Proceedings of Data Analytics and Management, vol. 572, A. Khanna, Z. Polkowski, and O. Castillo, Eds., in Lecture Notes in Networks and Systems, vol. 572. , Singapore: Springer Nature Singapore, 2023, pp. 347–362. doi: 10.1007/978-981-19-7615-5_31.

[7] A. Liberati et al., “The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate healthcare interventions: explanation and elaboration,” BMJ, vol. 339, no. jul21

1, pp. b2700–b2700, Dec. 2009, doi: 10.1136/bmj.b2700.

[8] Daleesha M Viswanathan and Sumam Mary Idicula, "Recent Developments in Indian Sign Language Recognition: An Analysis," International Journal of Computer Science and Information Technologies, vol. 6, no. 1, pp. 289–293, 2015.

[9] M. R. K, H. Kaur, S. K. Bedi, and M. A. Lekhana, "Image-based Indian Sign Language Recognition: A Practical Review using Deep Neural Networks." arXiv, Apr. 28, 2023. Accessed: Sep. 18, 2023. [Online]. Available: http://arxiv.org/abs/2304.14710

[10] Anuja V. Nair and Bindu V., "A Review on Indian Sign Language Recognition," ijca, vol. 73, no. 22, pp. 33–38, 2013.

[11] V. K. Verma, S. Srivastava, and N. Kumar, "A comprehensive review on automation of Indian sign language," International Conference on Advances in Computer Engineering and Applications, ICACEA 2015, 2015, pp. 138–142. doi: 10.1109/ICACEA.2015.7164682.

[12] A. Tyagi and S. Bansal, "Feature extraction technique for vision-based Indian sign language recognition system: A review," Advances in Intelligent Systems and Computing, 2021, pp. 39–53. doi: 10.1007/978-981-15-6876-3_4.

[13] B. Samal and M. Panda, "Integrative review on vision-based dynamic Indian sign language recognition systems," 1st Odisha International Conference on Electrical Power Engineering, Communication and Computing Technology, ODICON 2021, 2021. doi: 10.1109/ODICON50556.2021.9429002.

[14] S. Das, S. K. Biswas, M. Chakraborty, and B. Purkayastha, "Intelligent Indian Sign Language Recognition Systems: A Critical Review,"Lecture Notes in Networks and Systems, 2022, pp. 703–713. doi: 10.1007/978-981-16-5987-4_71.

[15] A. Singh, S. K. Singh, and A. Mittal, "A Review on Dataset Acquisition Techniques in Gesture Recognition from Indian Sign Language," in Lecture Notes on Data Engineering and Communications Technologies, vol. 106, 2022, pp. 305–313. doi: 10.1007/978-981-16-8403-6_27.

[16] Rakesh Savant and Dr. Jitendra Nasriwala, "INDIAN SIGN LANGUAGE RECOGNITION SYSTEM: APPROACHES AND CHALLENGES," International Journal of Advance and Innovative Research, vol. 6, no. 3(IV), pp. 76–84, 2019.

[17] A. Nandy, J. S. Prasad, S. Mondal, P. Chakraborty, and G. C. Nandi, "Recognition of Isolated Indian Sign Language Gesture in Real Time," in Information Processing and Management, vol. 70, V. V. Das, R. Vijayakumar, N. C. Debnath, J. Stephen, N. Meghanathan, S. Sankaranarayanan, P. M. Thankachan, F. L. Gaol, and N. Thankachan, Eds., in Communications in Computer and Information Science, vol. 70. , Berlin, Heidelberg: Springer Berlin Heidelberg, 2010, pp. 102–107. doi: 10.1007/978-3-642-12214-9_18.

[18] A. Sridhar, R. G. Ganesan, P. Kumar, and M. Khapra, "INCLUDE: A Large Scale Dataset for Indian Sign Language Recognition," in Proceedings of the 28th ACM International Conference on Multimedia, Seattle WA USA: ACM, Oct. 2020, pp. 1366–1375. doi: 10.1145/3394171.3413528.

[19] E. R, "ISL-CSLTR: Indian Sign Language Dataset for Continuous Sign Language Translation and Recognition." Mendeley, Jan. 22, 2021. doi: 10.17632/KCMPDXKY7P.

[20] E. R, "ISLAN." Mendeley, Jan. 08, 2021. doi: 10.17632/RC349J45M5.1.

[21] Adithya Venugopalan, "A Video Dataset of the Hand Gestures of Indian Sign Language Words used in Emergency Situations." Mendeley, Aug. 27, 2021. doi: 10.17632/2VFDM42337.1.

[22] K. Mistree, D. Thakor, and B. Bhatt, "Towards Indian Sign Language Sentence Recognition using INSIGNVID: Indian Sign Language Video Dataset," Int. J. Adv. Comput. Sci. Appl., vol. 12, no. 8, 2021, doi: 10.14569/IJACSA.2021.0120881.

[23] D. Kothadiya, C. Bhatt, K. Sapariya, K. Patel, A.-B. Gil-González, and J. M. Corchado, "Deepsign: Sign Language Detection and Recognition Using Deep Learning," Electronics, vol. 11, no. 11, p. 1780, Jun. 2022, doi: 10.3390/electronics11111780.

[24] "Results The Lens - Free & Open Patent and Scholarly Search," The Lens - Free & Open Patent and Scholarly Search. Accessed: Sep. 18, 2023. [Online]. Available: https://www.lens.org/lens

[25] J. Rekha, J. Bhattacharya, and S. Majumder, "Shape, texture and local movement hand gesture features for Indian Sign Language recognition," in 3rd International Conference on Trendz in Information Sciences & Computing (TISC2011), Chennai, India: IEEE, Dec. 2011, pp. 30–35. doi: 10.1109/TISC.2011.6169079.

[26] S. C. Agrawal, A. S. Jalal, and C. Bhatnagar, "Recognition of Indian Sign Language using feature fusion," in 2012 4th International Conference on Intelligent Human Computer Interaction (IHCI), Kharagpur, India: IEEE, Dec. 2012, pp. 1–5. doi:

10.1109/IHCI.2012.6481841.

[27] J. Singha and K. Das, "Indian Sign Language Recognition Using Eigen Value Weighted Euclidean Distance Based Classification Technique," Int. J. Adv. Comput. Sci. Appl., vol. 4, no. 2, 2013, doi: 10.14569/IJACSA.2013.040228.

[28] R. Sreemathy, M. Turuk, I. Kulkarni, and S. Khurana, "Sign language recognition using artificial intelligence," Educ. Inf. Technol., Nov. 2022, doi: 10.1007/s10639-022-11391-z.

[29] A. Kumar and R. Kumar, "A novel approach for ISL alphabet recognition using Extreme Learning Machine," Int. J. Inf. Technol. Singap., vol. 13, no. 1, pp. 349–357, 2021, doi: 10.1007/s41870-020-00525-6.

[30] U. Nandi, A. Ghorai, M. M. Singh, C. Changdar, S. Bhakta, and R. Kumar Pal, "Indian sign language alphabet recognition system using CNN with diffGrad optimizer and stochastic pooling," Multimed. Tools Appl., pp. 1–22, Jan. 2022, doi: 10.1007/s11042-021-11595-4.

[31] H. Bhavsar and Dr. J. Trivedi, "Indian Sign Language Alphabets Recognition from Static Images Using Correlation-Coefficient Algorithm with Neuro-Fuzzy Approach," SSRN Electron. J., 2019, doi: 10.2139/ssrn.3421685.

[32] T. S. Abraham, S. P. Sachin Raj, A. Yaamini, and B. Divya, "Transfer learning approaches in deep learning for Indian sign language classification," Journal of Physics: Conference Series, 2022. doi: 10.1088/1742-6596/2318/1/012041.

[33] A. K. Sahoo, M. Sharma, and R. Pal, "INDIAN SIGN LANGUAGE RECOGNITION USING NEURAL NETWORKS AND KNN CLASSIFIERS," ARPN, vol. 9, no. 8, pp. 1255–1259, Aug. 2014.

[34] J. Gangrade, J. Bharti, and A. Mulye, "Recognition of Indian Sign Language Using ORB with Bag of Visual Words by Kinect Sensor," IETE J. Res., vol. 68, no. 4, pp. 2953–2967, Jul. 2022, doi: 10.1080/03772063.2020.1739569.

[35] D. Deora and N. Bajaj, "Indian sign language recognition," in 2012 1st International Conference on Emerging Technology Trends in Electronics, Communication & Networking, Surat, Gujarat, India: IEEE, Dec. 2012, pp. 1–5. doi: 10.1109/ET2ECN.2012.6470093.

[36] V. Adithya, P. R. Vinod, and U. Gopalakrishnan, "Artificial neural network based method for Indian sign language recognition," in 2013 IEEE CONFERENCE ON INFORMATION AND COMMUNICATION TECHNOLOGIES, Thuckalay, Tamil Nadu, India: IEEE, Apr. 2013, pp. 1080–1085. doi: 10.1109/CICT.2013.6558259.

[37] Geetha M and Manjusha U C, "A Vision Based Recognition of Indian Sign Language Alphabets and Numerals Using B-Spline Approximation," International Journal on Computer Science and Engineering (IJCSE), vol. 4, no. 3, pp. 406–415, 2012.

[38] G. K. Kharate and A. S. Ghotkar, "Vision based multi-feature hand gesture recognition for indian sign language manual signs," Int. J. Smart Sens. Intell. Syst., vol. 9, no. 1, pp. 124–147, 2016, doi: 10.21307/ijssis-2017-863.

[39] S. Katoch, V. Singh, and U. S. Tiwary, "Indian Sign Language recognition system using SURF with SVM and CNN," Array, vol. 14, p. 100141, Jul. 2022, doi: 10.1016/j.array.2022.100141.

[40] T. Raghuveera, R. Deepthi, R. Mangalashri, and R. Akshaya, "A depth-based Indian Sign Language recognition using Microsoft Kinect," Sādhanā, vol. 45, no. 1, p. 34, Dec. 2020, doi: 10.1007/s12046-019-1250-6.

[41] K. Mehrotra, A. Godbole, and S. Belhe, "Indian Sign Language Recognition Using Kinect Sensor," in Image Analysis and Recognition, vol. 9164, M. Kamel and A. Campilho, Eds., in Lecture Notes in Computer Science, vol. 9164. , Cham: Springer International Publishing, 2015, pp. 528–535. doi: 10.1007/978-3-319-20801-5_59.

[42] Geetha M, Manjusha C, Unnikrishnan P, and Harikrishnan R, "A vision based dynamic gesture recognition of Indian Sign Language on Kinect based depth images," in 2013 International Conference on Emerging Trends in Communication, Control, Signal Processing and Computing Applications (C2SPCA), Bangalore, India: IEEE, Oct. 2013, pp. 1–7. doi: 10.1109/C2SPCA.2013.6749448.

[43] A. Nandy, S. Mondal, J. S. Prasad, P. Chakraborty, and G. C. Nandi, "Recognizing & interpreting Indian Sign Language gesture for Human Robot Interaction," in 2010 International Conference on Computer and Communication Technology (ICCCT), Allahabad, Uttar Pradesh, India: IEEE, Sep. 2010, pp. 712–717. doi: 10.1109/ICCCT.2010.5640434.

[44] W. Ahmed, K. Chanda, and S. Mitra, "Vision based Hand Gesture Recognition using Dynamic Time Warping for Indian Sign Language," in 2016 International Conference on Information Science (ICIS), Kochi, India: IEEE, Aug. 2016, pp. 120–125. doi: 10.1109/INFOSCI.2016.7845312.

[45] D. K. Singh, "3D-CNN based Dynamic Gesture

Recognition for Indian Sign Language Modeling," in Procedia Computer Science, 2021, pp. 76–83. doi: 10.1016/j.procs.2021.05.071.

[46] B. Subramanian, B. Olimov, S. M. Naik, S. Kim, K.-H. Park, and J. Kim, "An integrated mediapipe-optimized GRU model for Indian sign language recognition," Sci. Rep., vol. 12, no. 1, p. 11964, Jul. 2022, doi: 10.1038/s41598-022-15998-7.

[47] P. C. Badhe and V. Kulkarni, "Indian sign language translator using gesture recognition algorithm," in IEEE International Conference on Computer Graphics, Vision and Information Security (CGVIS), Bhubaneswar, India: IEEE, 2016, pp. 195–200. doi: 10.1109/CGVIS.2015.7449921.

[48] J. L. Raheja, A. Mishra, and A. Chaudhary, "Indian sign language recognition using SVM," Pattern Recognit. Image Anal., vol. 26, no. 2, pp. 434–441, Apr. 2016, doi: 10.1134/S1054661816020164.

[49] P. K. Athira, C. J. Sruthi, and A. Lijiya, "A Signer Independent Sign Language Recognition with Co-articulation Elimination from Live Videos: An Indian Scenario," J. King Saud Univ. - Comput. Inf. Sci., vol. 34, no. 3, pp. 771–781, Mar. 2022, doi: 10.1016/j.jksuci.2019.05.002.

[50] A. M. Deshpande, G. Inamdar, R. Kankaria, and S. Katage, "A Deep Learning Framework for Real-Time Indian Sign Language Gesture Recognition and Translation to Text and Audio," in Proceedings of the 6th International Conference on Advance Computing and Intelligent Engineering, vol. 428, B. Pati, C. R. Panigrahi, P. Mohapatra, and K.-C. Li, Eds., in Lecture Notes in Networks and Systems, vol. 428. , Singapore: Springer Nature Singapore, 2023, pp. 287–300. doi: 10.1007/978-981-19-2225-1_26.

[51] S. Paul, M. Jajoo, A. Raj, A. F. Mollah, M. Nasipuri, and S. Basu, "Dynamic Hand Gesture Recognition of the Days of a Week in Indian Sign Language Using Low-Cost Depth Device," in Intelligent Data Engineering and Analytics, vol. 266, S. C. Satapathy, P. Peer, J. Tang, V. Bhateja, and A. Ghosh, Eds., in Smart Innovation, Systems and Technologies, vol. 266. , Singapore: Springer Nature Singapore, 2022, pp. 141–149. doi: 10.1007/978-981-16-6624-7_15.

[52] M. Daniel Nareshkumar and B. Jaison, "A Light-Weight Deep Learning-Based Architecture for Sign Language Classification," Intell. Autom. Soft Comput., vol. 35, no. 3, pp. 3501–3515, 2023, doi: 10.32604/iasc.2023.027848.

[53] K. Tripathi and N. B. G. C. Nandi, "Continuous Indian Sign Language Gesture Recognition and Sentence Formation," Procedia Comput. Sci., vol. 54, pp. 523–531, 2015, doi: 10.1016/j.procs.2015.06.060.

[54] A. K, P. P, and R. C. Poonia, "LiST: A Lightweight Framework for Continuous Indian Sign Language Translation," Information, vol. 14, no. 2, p. 79, Jan. 2023, doi: 10.3390/info14020079.

[55] K. Tripathi, N. Baranwal, and G. C. Nandi, "Continuous dynamic Indian Sign Language gesture recognition with invariant backgrounds," in 2015 International Conference on Advances in Computing, Communications and Informatics (ICACCI), Kochi, India: IEEE, Aug. 2015, pp. 2211–2216. doi: 10.1109/ICACCI.2015.7275945.

[56] A. Mittal, P. Kumar, P. P. Roy, R. Balasubramanian, and B. B. Chaudhuri, "A Modified LSTM Model for Continuous Sign Language Recognition Using Leap Motion," IEEE Sens. J., vol. 19, no. 16, pp. 7056–7063, Aug. 2019, doi: 10.1109/JSEN.2019.2909837.

[57] N. Baranwal and G. C. Nandi, "An efficient gesture based humanoid learning using wavelet descriptor and MFCC techniques," Int. J. Mach. Learn. Cybern., vol. 8, no. 4, pp. 1369–1388, 2017, doi: 10.1007/s13042-016-0512-4.

[58] H. Muthu Mariappan and V. Gomathi, "Real-time recognition of Indian sign language," ICCIDS 2019 - 2nd International Conference on Computational Intelligence in Data Science, Proceedings, 2019. doi: 10.1109/ICCIDS.2019.8862125.

[59] K. Shenoy, T. Dastane, V. Rao, and D. Vyavaharkar, "Real-time Indian Sign Language (ISL) Recognition," 9th International Conference on Computing, Communication and Networking Technologies, ICCCNT 2018, 2018. doi: 10.1109/ICCCNT.2018.8493808.

[60] P. V. V. Kishore and P. Rajesh Kumar, "A Video Based Indian Sign Language Recognition System (INSLR) Using Wavelet Transform and Fuzzy Logic," Int. J. Eng. Technol., vol. 4, no. 5, pp. 537–542, 2012, doi: 10.7763/IJET.2012.V4.427.